epiSTEME 6

Focus Theme

Emerging Computational Media and Science Education

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PROCEEDINGS

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Foreword

EpiSTEME 6 is sixth in the series of biennial EpiSTEME conferences, which review research in science, technology and mathematics education. EpiSTEME 6 is organized by the Homi Bhabha Centre for Science Education (HBCSE), Tata Institute of Fundamental Research, Mumbai, India, and the Inter-Disciplinary program in Educational Technology, Indian Institute of Technology Bombay, Mumbai, India.

EpiSTEME focuses on three central research strands: Historical, Philosophical and Socio-cultural studies, Cognitive and Affective Studies, and Curriculum and Pedagogical Studies. This year's conference has an additional focus theme – the rapidly emerging field of novel computational media, and the way they are contributing to science learning.

The conference consists of review talks by invited speakers, paper and poster presentations, pre and post conference workshops, and a panel discussion. We received 84 paper submissions, of which 26 papers (31%) were accepted for oral presentation, and a further 29 papers (34%) were accepted for poster presentation.

Acknowledgements

We thank all HBCSE members who contributed to the organization of the conference. A special thanks to Prof. Chitra Natarajan, who passed away this year; she provided wonderful support and encouragement through the different stages of conference organization. We appreciate the program committee's inputs to quickly sort out the many organisational issues that came up.

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Editors
December 2015

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FROM TEST TUBES TO YOUTUBE: NATURE OF SCIENCE IN SOCIOSCIENTIFIC ISSUES AND HISTORY

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In preparing students to address socioscientific issues (SSIs), teachers must go beyond scientific content, and even beyond ordinary scientific reasoning. Citizens and consumers must understand the epistemic structure of science and its subsequent cultural communication (Kolstø, 2001; Raveendran & Chunawala, 2013; Ryder, 2001). Students must learn how scientific claims are grounded in observations in the lab or field, but also how they are transmitted and transformed in social contexts and the media—from the lab bench to the judicial bench, from test tubes to YouTube (Allchin, 2013, pp. 1–27). This knowledge guides non-experts in assessing the trustworthiness of scientific claims.

In this presentation, I describe the essential elements of this understanding—namely, how to conceive the nature of science (NOS), or how science works (Rai, 2011). Ironically, perhaps, this parallels a list of all the possible errors in science, or ways science can go wrong (Allchin, 2012a; Osborne, 2011).

The inventory of NOS concepts includes traditional internal (narrowly empirical, or evidential) concerns, as well as external (social and discoursive) contexts. It also includes both normative (philosophical) and descriptive (historical and sociological) dimensions (and their relationship to each other) (Allchin, 2013, pp. 107–120). This wide-ranging and inclusive "Whole Science" approach contrasts with the more limited focus and short lists proposed in recent years by some science educators (for example, by Lederman, Abd-el-Khalick, Bell & Schwartz, 2002; McComas & Olson, 1998).

Teaching this vast understanding of NOS seems challenging. What should teachers do? Science educators recognize three approaches as effective: student-led inquiry, contemporary cases, and historical cases. Each has benefits and deficits. Teachers must use and balance all three methods as complementary (Allchin, Andersen & Nielsen, 2014). However, the essential role of history is often overlooked. Educators need to appreciate the importance of studying scientific processes retrospectively, to understand fully how controversies and uncertainties are ultimately resolved. Teaching NOS should also be explicit and promote student reflection. Yet didactical lectures are not as effective as an inquiry style (Deng et al., 2011). Students should be actively involved in their own learning, for NOS as much as for science. Accordingly, for historical cases in particular, teachers must revive the historical perspective of science-in-the-making and pose open-ended NOS questions (Allchin, 2012b; 2013, pp. 28–45, 241–257; Hagen, Allchin & Singer, 1996). Educators thus benefit from collaborating with historians of science in producing valuable curriculum materials.

References

Allchin, D. (2012a). Teaching the nature of science through scientific error. *Science Education, 96,* 904–926.

Allchin, D. (2012b). The Minnesota case study collection: New historical inquiry cases for nature of science education. *Science & Education, 21*, 1263–1282.

Allchin, D. (2013). *Teaching the nature of science: Perspectives and resources.* St. Paul, MN: SHiPS Education Press.

Allchin, D., Andersen, H., & Nielsen, K. (2014). Complementary approaches to teaching nature of science: Integrating inquiry, historical cases and contemporary cases in classroom practice. *Science Education, 98,* 461-486.

Deng, F., Chen, D.-T., Tsai, C.-C., & Tsai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education, 95*, 961–999.

Hagen, J. B., Allchin, D., & Singer, F. (1996). *Doing biology.* Glenview, IL: Harper Collins.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85,* 291–310.

Lederman, N.G., Abd-el-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of nature of science questionnaire: Towards valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*, 497-52.

McComas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 41–52). Dordrecht, The Netherlands: Kluwer.

Osborne, J. (2011). Why knowing what's wrong matters as much as knowing what's right. In S. Chunawala & M. Kharatmal (Eds.), *Proceedings of epiSTEME 4 — International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 18–19). India: Macmillan.

Rai, A. K. (2013). Science education and nature of science: A review with reference to Indian context. In S. Chunawala & M. Kharatmal (Eds.), *Proceedings of epiSTEME 4 — International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 63–68). India: Macmillan.

Raveendran, A., & Chunawala, S. (2013). Towards an understanding of socioscientific issues as means to achieve critical scientific literacy. *Proceedings of epiSTEME 5 — International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 67–73). India: Cinnamonteal.

Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education, 36*, 1–44.

CTSIM: A COMPUTATIONAL THINKING ENVIRONMENT FOR LEARNING SCIENCE USING SIMULATION AND MODELING

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Science education in K-12 classrooms has been a topic of growing importance. The National Research Council framework for K-12 science education includes several core science and engineering practices: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, and constructing explanations and designing solutions. Several of these epistemic and representational practices central to the development of expertise in STEM disciplines are also primary components of Computational Thinking (CT). CT involves formulating and solving problems, designing systems, and understanding human behavior by drawing on the fundamental concepts of computer science. Specifically, CT promotes abstraction, problem representation, decomposition, simulation, and verification practices. Thus it is not surprising that CT is included as a key feature in NRC's K-12 science education framework. In fact, several researchers suggest that programming and computational modeling can serve as effective vehicles for learning challenging STEM concepts.

In spite of the observed synergies between CT and STEM education, empirical studies have shown that balancing and exploiting the trade-off between the domain-generality of CT and the domain specificity of scientific representations, presents an important educational design challenge. To address this gap in synergistic STEM and CT learning, we have developed a computer-based learning environment called CTSiM: Computational Thinking in Simulation and Modeling for K-12 science learning using a computational thinking approach. CTSiM provides an agent-based, visual programming interface for constructing executable computational models and allows students to execute their models as simulations and compare their models' behaviors with that of an expert model.

In this talk, I will first present key design principles and their translation to details of the CTSiM architecture. In an initial study with 6th-grade students in a middle Tennessee public school, students showed high pre-post learning gains and a good understanding of the basic science concepts. However, students also faced a number of challenges while working with CTSiM. We discuss the challenges that students faced while working on physics and ecology units using CTSiM.

Further, I will also present a framework for developing adaptive scaffolding to help students overcome their difficulties, while learning and building their models of science phenomena in the CTSiM environment. To interpret students' learning, modeling, and model verification behaviors as they work in CTSiM, we have developed a hierarchical task modeling and strategy modeling scheme that can be directly leveraged for online interpretation of students' activities in the learning environment. The strategy model complements the task model by describing how actions, or higher-level tasks and subtasks, can be combined to provide different approaches or strategies for accomplishing learning and problem-solving goals. The task and strategy modeling in combination with coherence and effectiveness metrics defines our approach to tracking and analyzing students' learning and problem solving behaviors in OELEs. We then describe an application of this framework in a Computational Thinking using Modeling and Simulation (CTSiM) environment -- an OELE that supports synergistic learning of science and computational thinking (CT) for middle school students. We discuss the learner modeling scheme for the CTSiM environment, and then describe how the learner model forms the basis for providing adaptive task and strategy based feedback to students using a contextualized, mixed initiative conversational dialog framework. A recent controlled study run in a 6th grade classroom showed that the experimental group that received adaptive feedback outperformed the control group (no feedback) in domain and CT learning gains, the ability to construct correct models, and in using strategies for effective learning and problem solving.

A THEORY OF ACTION FOR SUPPORTING IMPROVEMENTS IN THE QUALITY OF MATHEMATICS TEACHING ON A LARGE SCALE

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Research on the teaching and learning of mathematics has made significant progress in recent years. However, this work has had only limited impact on classroom instruction in many countries, including the U.S. For the past eight years, my colleagues and I have collaborated with mathematics teachers, school leaders, and educational system leaders in several large urban school systems in the U.S. to investigate what it takes to support large numbers of mathematics teachers in developing ambitious, inquiry-oriented instructional practices. We have conducted these partnerships as design research studies at the system level by enacting annual data collection, analysis, and feedback cycles in each school system. In doing so, we made empirically grounded recommendations to the leaders of each system each year about how they might revise their policies or strategies for instructional improvement to make them more effective. Follow-up analyses indicate that leaders in all the partner systems attempted to implement many of our recommendations.

In the course of the study, we compiled a longitudinal data set. The data we collected each year included interviews conducted with 120 middle-grades mathematics teachers, with the mathematics teacher leaders and school leaders from the participating teachers' schools, and with system leaders across several administrative units that have a stake in mathematics instruction (200 participants total); surveys completed by the mathematics teachers, mathematics teacher leaders, and school leaders; video-recordings of the 120 teachers' classroom instruction; assessments of the teachers' and teacher leaders' mathematical knowledge for teaching; audio- and video-recordings of mathematics teacher collaborative planning meetings; video-recordings of professional development; and a network survey completed by all mathematics teachers in the participating schools. We have established several teams to conduct retrospective analyses of these data that focus on the teachers' knowledge and practice, and on key aspects of the school and district contexts in the teachers work and in which they developed and revised their instructional practices. The findings of these analyses and the insights we developed while formulating actionable recommendations for system leaders have informed the ongoing revision of our initial conjectures about large-scale instructional improvement.

The resulting theory of action comprises six interrelated components. I will report our findings as they relate to each component. The first component is a coherent system that is itself comprises four elements: The instructional materials that teacher use, the professional development in which they participate, formative assessments to improve instructional improvement, and additional supports for currently struggling students. There is strong evidence that improvements in the quality of instruction are unlikely to occur unless system leaders deliberately coordinate these elements so that they constitute a system. In reporting on this component, I will describe two measures of teachers' knowledge that we developed. The first assesses the sophistication of their visions of what high-quality mathematics instruction looks like and appears to be a leading indicator of improvement in their instructional practices. The second assesses teachers' views of their currently struggling students' mathematical capabilities and is associated with the quality of their instruction even when controlling for their mathematical knowledge for teaching.

The second component of the theory of action concerns teachers' informal advice seeking networks (i.e., who they turn to for advice about instruction and with what frequency). Our findings indicate that turning to a more accomplished colleague for advice is associated with improvements in the quality of instruction. The third component is time for mathematics teachers to collaborate that is scheduled regularly during the school day. Our findings indicate that while teacher collaborative time can support instructional improvement, it often fails to do so. In order for collaborative time to be productive, it appears essential that teachers connect students, mathematical content, and their instructional practices. The fourth component focuses on teacher leaders' practices in providing job-embedded support for other teachers' learning. Our findings concern the types of activities in with teacher leaders might engage both groups of teacher and individual teachers in their classrooms to support their learning. In addition, we have investigated the capabilities that teacher leaders might need to develop in addition to being effective mathematics teachers if they are to support their colleagues in improving the quality of their instruction.

The fifth component focuses on school leaders' practices as instructional leaders in mathematics. As background, U.S. school leaders are increasingly expected to act as instructional leaders who directly support teachers in improving the quality of their instruction. Our findings suggest that most of the school leaders in our study were not able to be effective instructional leaders in mathematics. However, we conjecture that they might be able to support mathematics teachers' learning indirectly by creating conditions such as a school culture characterized by trust that foster professional learning. The final component of our theory of action concerns system leaders' practices in supporting the development of school-level capacity for instructional improvement. I will describe two conflicting orientations to supporting improvements in students' mathematical learning that we have identified, clarify the difficulties that arise when leaders in different administrative units adopt opposing orientations, and suggest how these difficulties might be addressed.

As I will make clear, we currently conjecture that all six components of the theory of action are necessary. In addition, I will illustrate that the current research base becomes increasingly thin the further one moves out from the classroom, first to the school level and then to the system level. These observations point to a range of issues that need to be investigated as current research can provide only limited guidance to school and system leaders who are attempting to support mathematics teachers' development of ambitious, inquiry-oriented instructional practices.

MODELING THEORY AND MODELING INSTRUCTION FOR STEM EDUCATION

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Cognitive Theory: All humans create mental models to plan and guide their interactions with the physical world. Science has greatly refined and extended this ability by creating and validating formal scientific models of physical things and processes. Research in physics education has found that mental models created from everyday experience are largely incompatible with scientific models (Hestenes, Wells & Swackhamer, 1992). This supports a view that the fundamental problem in learning and understanding science is coordinating mental models with scientific models. Modeling Theory (Hestenes, 2008a; Hestenes, 2008b) has drawn on resources of cognitive science to work out extensive implications of this view and guide development of an approach to science pedagogy and curriculum design called Modeling Instruction (Hestenes, 1997).

Science Pedagogy: Modeling Instruction is centered on making and using scientific models of the physical world as the core of scientific knowledge and practice. Modeling pedagogy and instructional materials were first developed and thoroughly tested for high school physics. Exemplary outcomes and enthusiastic teacher response to summer Modeling Workshops have driven continued growth of the program and extension to chemistry and biology.

Delivery and Support: Intensive 3-week summer Modeling Workshops have proven to be an ideal mechanism to upgrade knowledge and skills in science and pedagogy for in-service teachers. The Workshops were developed and widely offered across the United State with fifteen years of support from the National Science Foundation. The program was so popular among teachers that, when NSF funding ceased in 2005, to sustain it they created their own organization to sustain it, the American Modeling Teachers Association (AMTA). The AMTA now has nearly 2000 members. More than 7000 teachers have taken at least one Modeling Workshop, and more than 50 Workshops are offered each year. This makes Modeling the largest coherent STEM education program in the United States.

Education Reform: Over the last two decades, Modeling Instruction has evolved into a promising program to drive rapid, deep and sustained STEM education reform on a national scale (Hestenes, 2015).

References

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher 30*, 141-158.

Hestenes, D. (1997). Modeling methodology for physics teachers. In E. Redish & J. Rigden (Eds.), *The changing role of the physics department in modern universities*. American Institute of Physics Part II, p. 935-957.

Hestenes, D. (2008a). Modeling theory for math and science education. In D. Lesh (Ed.), *Mathematical modeling ICTMA-13: Education and design sciences*, Indiana.

Hestenes, D. (2008b). Notes for a modeling theory of science, cognition and instruction. In E. van den

Berg, A. Ellermeijer & O. Slooten (Eds.), *Modelling in physics and physics education*, U. Amsterdam.

Hestenes, D. (2015). A role for physicists in STEM education reform. *Am. J. Phys, 83*(2), 101-103.

Wells, M., Hestenes, D., & Swackhamer, G. (1995). A modeling method for high school physics instruction. *Am. J. Phys. 63,* 606-619.

American Modeling Teachers Association (AMTA). Website <http://modelinginstruction.org>

[Most of these articles and other materials can be downloaded from < http://modeling.asu.edu>]

GEOGEBRA: A DISRUPTION IN STEM EDUCATION

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Disruption is not a word regularly used when discussing a positive event or experience. Indeed, to disrupt is to ‘introduce confusion, disorder, create disarray or confusion and turmoil and generally wreak havoc’. But of course, ‘disruption’ can also be a good thing - particularly when the status-quo being disrupted is less than optimal or desirable. In fact, disruption seems to have taken on a whole new meaning in recent times, particularly when discussing changes to the hermeneutics - ways of knowing and doing - that have governed teaching and learning for generations. In this new nomenclature, disruption is viewed as a positive stochastic event, where inefficiencies and inequalities are exposed; replaced with new processes and practices where, for example, innovations in technology, resources, and pedagogy are introduced in a way that augments the best practices of educators, in support of advancements in teaching and learning opportunities for all.

GeoGebra has itself been described as a disruptive force in STEM education, by putting the world’s leading software and materials into the hands of students and teachers everywhere - the very same quality of software, service and support which is on par with the many of the world’s leading institutions and curricula.

In this talk I will share a few examples of the disruptions in STEM education through GeoGebra, and how this applies across the four conference themes. By doing so, I will suggest that in order to be properly identified as a positive disruptive force in education, GeoGebra must create opportunities for new ways of knowing and doing which contribute to the expansion of universally accessible, free and open education.

Historical, Philosophical, and Socio-cultural Studies

There is perhaps nothing more compelling for students than stories of the great minds and discoveries of the STEM education community, from recent to distant past. What student doesn’t wonder at the remarkable engineering underpinning the Mars expeditions [http://ggbtu.be/m80865], while also marvelling at the seeming simplicity in the diffraction of light to form a rainbow [http://ggbtu.be/m1428461]. Both of these ideas, concepts, are relevant to our everyday, and both retain a universal cultural significance, rooted in fundamental mathematical principles. Prior to the availability of dynamic geometry software, these concepts were difficult to demonstrate in a classroom, and near-impossible for students to explore and model independently. GeoGebra disrupts the barriers to access mathematics and the exploration of key cultural and historical concepts in primary through tertiary education.

Cognitive and Affective Studies

GeoGebra has often been described as a ‘playground’ or ‘laboratory’ for exploring mathematics. While the need for pencil, paper and 2D constructions in geometry and algebra remains ever-relevant, it is difficult to argue with the idea that the way in which we conceive and represent ideas hasn’t been profoundly changed through dynamic geometry. This is perhaps represented best by examples in teaching and learning 3D geometry. For example, teaching conics couldn’t be simpler for both teachers and students through the use of resources such as this GeoGebraBook shared across the GeoGebra global community [http://ggbtu.be/b334273]. Suddenly, through GeoGebra, teachers and students can assemble and disassemble 3 dimensional objects, expanding the possibilities for representation, reasoning and learning anywhere in the world.

Curriculum and Pedagogical Studies

It could be said that, aside from access to inspiring teachers, the single greatest barrier to advances universal access to a quality education is the lack of teaching and learning materials and personalized support. Teachers and students in just about every country of the world are creating and sharing dynamic mathematics materials, e-books and lesson plans through GeoGebra's web services. Where teachers were once solely dependent upon the textbooks and resources of their schools or purchase, through GeoGebra they can search, copy, and adapt freely available teaching materials on just about any STEM education topic, supporting just about every aspect of the curriculum, from primary through tertiary education. What's more, teachers and students can collaborate with each other across borders and topics, sharing expertise, materials, and a passion for learning through collaboration. Consider, for example, this remarkable member of the GeoGebra community, who has shared over 4000 materials with teachers and students from around the world [http://tube.geogebra.org/ccambre].

New Media

This fourth and final thread of the conference agenda is perhaps the only area where GeoGebra might not be considered a disruptive force. On the contrary; in the area of New Media, GeoGebra is a leading constructive force, shaping the technology and education space through its global ecosystem. However, even here there is an opportunity for GeoGebra to remain a disruptor and instigator of positive change by creating and supporting the world's largest software, service and community network for open and free teaching and learning.

It is in this category, New Media, that GeoGebra must continue to work the hardest to ensure it/we/us continue to innovate and create new opportunities for STEM education - contributing to and creating as many or more historical, cognitive, and pedagogical opportunities than it disrupts. And it is through gatherings like this one where GeoGebra is shaped by creative and critical minds to imagine the future of STEM education again, and again...

RESEARCH IN CHEMISTRY EDUCATION AND ITS IMPLICATIONS FOR TEACHING AND LEARNING OF CHEMISTRY AT TERTIARY LEVEL

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Chemistry Education Research (CER) from its inception has addressed issues related to teaching and learning of chemistry at various levels. There are two distinct but related aspects of CER; one is to empirically analyze students' difficulties and misconceptions in chemistry, the other is to develop methods for effective learning of chemistry.

Though a relatively young field, the goals, norms and methodologies of CER are now fairly standardized; the field draws on the more established disciplines of chemistry, psychology, sociology, philosophy and education. CER studies, conducted over the last five decades, have provided valuable insights to teachers, curriculum planners and policy makers engaged with chemistry education.

A comprehensive review, published by Teo et al. (2014), analyzed 650 empirical papers (2004 - 2013) in CER. The review found the following three major trends in CER - a) students' and teachers' conceptions and conceptual change, b) examination of different pedagogies used for teaching of chemistry, and c) classroom contexts and learner characteristics (e.g. attitudes and beliefs of participants, factors affecting students' performance in chemistry, classroom interactions, etc.). The reviewers further observed that majority of these studies were conducted in the context of chemistry education at tertiary level. Geographically, these studies span across several countries in different regions (North/Central America, Europe, Asia, Oceania, Africa and South America). The review highlighted the lacunae in studies exploring historical/philosophical aspects of chemistry and nature of chemistry.

An earlier review by Towns and Kraft (2011), analyzed 379 empirical CER papers (2000-2010) particularly related to undergraduate chemistry education. This review included two additional areas, namely, CER studies in the context of chemistry laboratories and development of reliable and valid instruments for measurements in chemistry education (used for-conceptual understanding, beliefs about chemistry and learning chemistry, attitudes towards chemistry, etc.). These authors have separately focused on studies related to understanding particulate nature of matter (PNOM) and included work that use static visuals, handheld ball and stick models and 2D perspective drawings for understanding PNOM.

On the whole, there are fewer studies on the strategies to be used to address misconceptions and effective pedagogies to assist conceptual change. Thus, this aspect of CER needs urgent attention. Also, in general, transfer of knowledge across contexts has not been addressed adequately in CER studies.

Eilks and Byers (2010) have suggested that chemistry teachers at tertiary level should know about CER studies and research based practices. They have argued that people opting for teaching profession in chemistry up to secondary level, are required to have qualifications both in chemistry and pedagogy. This requirement recognizes the fact that chemistry teachers need to know about pedagogy (in its general form) along with content expertise. Ironically, the same is not considered essential for chemistry teachers at tertiary level, and hence at this level, teachers are often content experts with no exposure to general and/or domain specific pedagogy. This is also very much valid in the Indian context.

The most dominant mode of teaching chemistry in India, and perhaps elsewhere, till date, is lecturing. Chemistry teachers who themselves have been exposed only to this mode (perceived to be successful) will continue to practice the same when they opt for the teaching profession. Often, classroom experiences and assessment provide sufficient evidence indicating that students understand and learn chemical concepts differently from what is being taught. All these facts, undoubtedly, indicate the pressing need to pay attention to CER studies and the insights that can be drawn from them.

A working group formed by European Chemistry Thematic Network (ECTN) has identified different areas for innovation in teaching and learning of chemistry in higher education (Eilks & Byers, 2010). Some of these areas are: a) addressing uniqueness of chemistry (nature of chemistry), b) context and problem-based learning, c) research-based teaching and learning, d) innovating practical work, e) use of cooperative learning, f) role of ICT in chemistry learning and assessment, g) using innovative assessment to promote meaningful learning and h) training programmes for newly appointed university chemistry teachers.

In the Indian context too, the above areas are relevant. Today, the chemistry education scenario, in India, is dynamic as several new institutions devoted to science education and research at tertiary level have become functional in the recent past. These institutions have experimented with the chemistry curricula and the process is still being continued. A sizable number of young personnel are entering into teaching chemistry at higher education. In addition, under National Mission on Education through ICT (MHRD initiative in India), development of virtual laboratory and e-content in chemistry has been undertaken. Homi Bhabha Centre for Science Education (TIFR) and Association of Chemistry Teachers (ACT) have started an International Conference on Education in Chemistry (ICEC- 2010 and 2014). This initiative will help to catalyse, support and consolidate sporadic CER work in India. Thus, the time is apt to reflect on CER studies and their implications in Indian academics.

References

Eilks, I. & Byers, B. (2010). The need for innovative methods of teaching and learning chemistry in higher education - reflections from a project of the European Chemistry Thematic Network. *Chemical Education Research and Practice, 11*, 233-240.

MHRD, http://www.sakshat.ac.in/aspx/frmrelatedlink.aspx (accessed in October 2015).

Teo, T. W., Goh, M. T., & Yeo, L. W. (2014). Chemistry education research trends: 2004-2013. *Chemical Education Research and Practice, 15*, 470-487.

Towns, M. H., & Kraft, A. (2011). Review and synthesis of research in Chemical Education from 2000-2010. A white paper for the National Academies National Research Council Board of Science Education, Committee on Status, Contributions, and Future Directions of Discipline Based Education Research.

WHEN IS A GROUNDING 'GOOD', FOR WHOM, AND HOW CAN WE BUILD THEM?

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What is it that makes a mathematical form a good grounding for a mathematical discipline? This is a question that has been extensively discussed in cognitive science over the last decade (Barsalou, 1999, 2008; Lakoff & Nuñez, 2000). Intuitively, some mathematical forms seem to serve as very good 'groundings' of a mathematical domain. For instance, the number line has been shown to be useful for students attempting to understand numerical magnitude (Siegler, Thompson & Schneider, 2011; Thompson & Schneider, 2010); negatives as reflections (Tsang et al., in press), basic arithmetic operations (e.g., addition and subtraction as rightward and leftward motion; multiplication and division as scaling). The unit circle has been seen to be useful for grounding trigonometric identities (Mickey & McClelland, 2013). Multiplication has many intuitively 'good' grounds, including repeated addition, area, and scaling.

It has been argued that good groundings occur when the abstractions of mathematics are made meaningful, and that this happens when abstractions are situated in everyday physical activities (Lakoff & Nuñez, 2000; Braithwaite & Goldstone, 2013), and in visuo-spatial—as opposed to formal, systems (e.g., Mickey & McClelland, 2013). For instance, the number line can be further grounded as beads on a string. Linear functions can be grounded in terms of constant motions (Nathan, Kintsch & Young, 1992). Although the trigonometric functions are uniquely specified by the definitions

$C(x-y)=C(x)C(y)+S(x)S(y)$ and

$S(x-y)=S(x)C(y)-C(x)S(y)$

With x ,y in R and C, S not identically zero (Robison, 1968; this characterization due to Steven Taschuk), it seems that the sine and cosine functions become meaningful when interpreted as the coordinates of points on the unit circle (or even more the signed height and width of inscribed triangles).

Symbol systems, on this account are not good groundings because they are arbitrary (rather than meaningful), non-spatial, and unrelated to everyday physical experience. On this hypothesis, good groundings are 'embodied' or 'situated' groundings.

In my talk, I'll suggest instead that symbol structures and classical diagrams are the same sort of creature, and that 'embodiment' is at best correlated with the features that make for good groundings. In particular, I'll argue that most or all mathematical models (like most or all mental models) comprise a depicted spatial structure and a deontic structure—a set of appropriate and inappropriate behaviors (Wittgenstein, 1978). This level of description unifies spatial symbol systems such as the algebra of arithmetic equations and other diagrams such as function graphs, networks, or the unit circle. It is worth emphasizing that on this account of grounding, the degree of grounding is a function of the state of the reasoner. Symbol systems can be good groundings for those steeped in them; embodiment provides routinely good groundings only because physical experiences tend to be widely shared.

A common proposal for differentiating diagrams from symbol systems is that diagrams may be diagrammatically—that they may carry meaning 'directly', while symbol systems carry meaning only indirectly or through interpretation (Stenning, 2000). This distinction is real, but it is continuous, not categorical, across systems of representations. There are, in all mathematical models, two sorts of meaning: one sort inheres in the system; this is the sense by which symbol systems are deeply meaningful, in that they written inscriptions depict the spatial structure of some (imagined) physical situation—a situation made of symbols. This is also the sense at work in Cantor's diagonalization proof, in which numerals are taken themselves as objects. Another sense of meaning is referential, in which a mathematical model is taken to stand in for another situation, and is aligned with that situation. Both traditional diagrams and symbols systems may be used either diagrammatically or referentially, and meaning is built out of both through combinations of reasoning about surface form and referential meaning (Landy, Allen & Zednik, 2014).

So then what does make some models so amazingly good at grounding understandings of broad domains? I'll suggest that this comes down not to some categorical or qualitative distinction to be drawn on the basis of the semiotic properties of the sign systems, but to good old-fashioned cognitive constraints and limitations. A mental model is good when the depicted space (mediated by an inscriptive practice) is easy to remember and reconstruct, the deontology is simple to remember and easy to physically instantiate, and the collection of important inferences are easy to draw within capacity limitations and using available or easily adapted perceptual-motor routines. A situation or mathematical model serves as a good grounding for another domain when the other domain does not have these features, the grounding does, and the mapping between the two is easy to traverse. Symbolic systems are poor groundings because of the ways they mismatch the cognitive state of the learner, and therefore carry high memory burdens, many opportunities for error, and few opportunities for inference.

That everyday physical experiences are often good groundings can now be seen to be a contingent, not a constitutive, characteristic. It is often the case that we have already adapted our perceptual-motor processing to the deontic requirements of everyday situations, that we are familiar with many inferences about them that can be readily exported, and that we are familiar enough to be able to reconstruct them with high regularity. This, and not any deeper notion of 'embodiment', is what makes everyday experience so often a good conceptual grounding for higher mathematics. This perspective unifies the kind of grounding a novice gets from understanding 'more' as 'rightward on the line', or 'rightward on this string of beads', and the kind of grounding an algebraic topologist gets from identifying deformations of topological spaces in high dimensions with abstract algebraic groups.

Once we have seen good grounding for what it is, a function of cognitive economy and useful prior experience, we can then design symbolic systems that are more effective—that have lower load, that yield better generative and predictive models for making inferences, that are easily exported, and that better align with pre-existing implementation systems in human reasoners. I'll present one such attempt, the 'Graspable Mathematics' system, and show how this dynamical algebra potentially lowers the burden on the algebraic reasoner, improving the intrinsic meaningfulness of the mathematical model and better grounding other mathematical models.

References

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–624.

Barsalou, L.W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577-660.

Braithwaite, D. W., & Goldstone, R. L. (2013). Integrating formal and grounded representations in combinatorics learning. *Journal of Educational Psychology, 105*(3), 666.

Lakoff, G. & Nuñez, R. E. 2000: *Where mathematics come from: How the embodied mind brings mathematics into being.* New York: Basic Books.

Landy, D., Allen, C., & Zednik, C. (2014). A perceptual account of symbolic reasoning. *Frontiers in psychology, 5,* 275.

Mickey, K.W. & McClelland, J.L. (2013). Running circles around symbol manipulation in trigonometry. In M. Knauff, M. Pauen, N. Sebanz, & I. Wachsmuth (Eds.), *Proceedings of the 35th Annual Conference of the Cognitive Science Society* (p. 4048). Austin, TX: Cognitive Science Society.

Nathan, M. J., Kintsch, W., & Young E. (1992). A theory of algebra-word-problem comprehension and its implications for the design of learning environments. *Cognition & Instruction, 9*, 329–389.

Robison, G. B. (1968). A new approach to circular functions, II and lim (sin x)/x. *Mathematics Magazine,* 66-70.

Siegler, R. S., Thompson, C. A., & Schneider, M. (2011). An integrated theory of whole number and fractions development. *Cognitive Psychology, 62*(4), 273-296.

Stenning, K. (2000). Distinctions with differences: Comparing criteria for distinguishing diagrammatic from sentential systems. In *Theory and application of diagrams* (pp. 132-148). Berlin, Heidelberg: Springer.

Taschuk, S. (2015). Axiomatic definition of sin and cos? Retrieved October 10, 2015, from http://math.stackexchange.com/questions/1303044/axiomatic-definition-of-sin-and-cos/1303259#1303259

Thompson, C. A., & Siegler, R. S. (2010). Linear numerical-magnitude representations aid children's memory for numbers. *Psychological Science, 21*(9), 1274-1281.

Tsang, J. M., Blair, K. P., Bofferding, L., & Schwartz, D. L. (2015). Learning to "see" less than nothing: Putting perceptual skills to work for learning numerical structure. *Cognition and Instruction, 33*(2), 154-197.

Wittgenstein, L. (1978). *Remarks on the foundations of mathematics*. In G. H. von Wright (Ed.), R. Rhees and G. E. M. Anscombe (trans.), revised edition, Blackwell: Oxford.

A STUDY ON THE EPISTEMOLOGICAL BELIEFS OF UNIVERSITY TEACHERS IN INDIA

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Belief systems are crucial in shaping one's perception and are one of the major guiding forces behind our actions. Thus within a classroom, teachers' beliefs play a fundamental role in determining classroom practices. In addition research suggests they strongly affect the quality of student cognition as well as students' personal constructs. Therefore this area renders itself crucial for research. Our work aims at exploring vital aspects of this area i.e. interface between teacher beliefs and pedagogy. Semi-structured interviews were used to investigate how university teachers' epistemological beliefs influence their pedagogical knowledge. The outcomes explicitly exhibited that there remains a considerable gap between teaching and learning. The research strongly puts forth the growing need for creating platforms for university teachers, wherein interaction between their practices (and hence their personal constructs) and research could be discussed. This endeavour could significantly contribute towards facilitating teachers' professional development.

INTRODUCTION

Teachers are one of the major stake holders in the process of teaching and learning. They influence students' learning in more than one way. Their pedagogies and behaviour in the classroom is not only affected by their knowledge of the subject matter but also their conception about the subject, about the students, about learning or in other words their belief systems as a whole. There are numerous researches indicating that teacher beliefs in some way influence their instructional plan and instructional practice (Nespor, 1987; Pajares, 1992; Abd-El Khalick, Bell & Lederman, 1998; Lederman, 1992; Lederman, 1999). Furthermore, impact of teachers' beliefs do not restrict to their pedagogical practices but also have a bearing on the quality of student cognition (Maor & Taylor, 1995) and even students' personal constructs. Hence, it is not only important to concentrate on what goes on in the classroom; but what goes on in the learners' head and also what the teacher makes out of it. In order to appreciate this point, it is necessary to analyse teachers' perceptions and interpretations of the interactions within the classroom. Therefore, there is a need in research to unravel teachers' beliefs about what can be counted as knowledge, where knowledge is located, and how knowledge increases (Schraw & Olafson, 2008) - i.e. their epistemological orientation.

Keeping in mind the importance of this area, there is a growing body of research to explore teachers' beliefs through various means. Many studies have attempted to measure epistemological beliefs using self-report scales (Hofer, 2000; Schraw & Olafson, 2002), but according to some researchers, it is not an easy task to measure epistemologies (Hofer & Pintrich, 1997). The very nature of belief is not quantifiable, it "*does not lend itself easily to empirical investigation*" (Pajares, 1992, p. 308). Hence, such methods need to be used which help in digging beneath the surface of conscious to reach the subconscious relationship between epistemological orientation and perceptions of practice Researchers have also tried to use methods like interview techniques to determine a holistic epistemological view (King & Kitchener, 1994; Perry,1970; Hewson & Hewson 1989; Luft & Roehrig, 2007), open-ended questionnaires (Yang, 2005), and content analysis of verbal explanations (Slotta & Chi, 2006), and written vignettes (Schraw & Olafson, 2002). Most of these researches have tried to classify teachers on the basis of their beliefs. For instance, Mulhall and Gunstone (2008) have tried to categorize a group of Physics teachers as 'traditionalists' and 'conceptual'. Study by Tsai (2002) explored the relationships among teachers' beliefs about teaching science, learning science and the nature of science. He categorized teachers' beliefs as either 'traditional', or 'process', or 'constructivist'. Schraw and Olafson (2008) while assessing teachers' epistemological and ontological worldviews, tried to place teachers on a continuum ranging from 'realist' to 'relativist'. Many researchers have espoused that participants belonged to singular epistemological worldviews (Schraw & Olafson, 2002) however, some others have also shown a fusion or mix of more than one epistemological orientation (Sfard, 1998; Patchen & Crawford, 2011).In our research, we have adopted a bottom up approach, where we are not defining any pre-categorization, and rather look at the themes emerging from the data.

In this research we have made an attempt to unravel university teachers' epistemological beliefs. Here, we mainly focus on exploring teachers' views on 'process of knowing' aspect of epistemology, i.e. learning. Novelty of the study could be derived from the fact that the participants are university teachers who do not have any formal orientation in the field of education. This is markedly different from contemporary researches which primarily focus on pre-university and school teachers. The teachers' beliefs, therefore, are assumed to be guided by their experiences as students and their practice as teachers.

RESEARCH QUESTIONS

1. How 'learning' is perceived by university teachers?
2. How 'learning' is assessed by them?
3. What is university teachers' perception about students' alternate conceptions?
4. How do they deal with alternate conceptions in the class?

METHODOLOGY

Participants for the study consisted of ten university Physics teachers from an urban university in India. This university offers courses starting from bachelors to doctorate level (B.Sc., M.Sc. and PhD).All the participant teachers for this study had taught both bachelors as well as masters level students with a typical class size varying from 25-35 students.

To explore teachers' perceptions and interpretations of the interactions within the classroom, detailed semi-structured interviews were conducted with them. The focus of study is on teachers' epistemological orientation, i.e. what can be counted as knowledge, where knowledge is located, and how knowledge increases (Schraw & Olafson, 2008). The interview was transcribed verbatim followed by content analysis. In addition, the teacher interviews were carried out without any explicit pre-framed categories which resulted in adoption of a bottom-up approach where we tried to ascertain themes emerging from the data.

Themes emerging from the data are presented under the broader sections corresponding to the above questions. To maintain the anonymity of teachers they have been referred to as T1, T2, T3.....T10.

DATA SUMMARY AND ANALYSIS

In the following section, a summary of data followed by its analysis has been presented under major themes.

Learning and Assessment of Learning

Learning was conceived variously by participants. For T1 and T5 learning is anonymous with 'application'. According to T5 most of the times it is difficult to immediately ascertain if students are able to make sense of the concept; only when they are able to apply that concept in the advanced courses, it shows they have learnt it.

T3 perceived learning to be able to understand various perspectives. Conceptualization for him meant going beyond and not restricting to what is taught in the class. He said, "*in case they have been taught with the physics perspective they should be able to understand in chemistry perspective on their own.* To shed some more light on the concept of 'learning', some teachers cited the modes they used to ascertain whether students have learnt. T2 said he deliberately committed mistakes and expressed his confusion and inability to solve further to students. He observed that if the concept he taught was learnt by students then, "*this class invests its brain collectively to help the instructor to get over the crises".* T4 dealt with majorly lab courses in which he generally used quiz and viva. In viva, he often tried to confuse students by providing incorrect hints. According to him, if the student caught the clue and attempted to prove the teacher wrong, it clearly indicated student understands of the concept. On the other hand, if the student accepted that wrong hint and tried to analyse the situation based on it, then it meant he did not understand and was trying to invent answers.

On the basis of differences in 'conceptualization' some teachers also tried to categorize students. T7 said that 'conceptualization' varied amongst students and he observed three categories "*some of them go really deep into the subject ... Some people would understand the concept but they cannot do anything with it and some people will generally find the difficulty in understanding the concept itself may be because of their background problem.*" T8 noticed two types of students, one who conceptualized theoretically and the other who tried to visualize the physical picture, and he endorsed a balance between the two approaches. For T3, exam questions were not only the medium to asses learning, but for categorizing the students also.

T4 used students' performance in an experiment as a mode to assess understanding and also perceived a categorization on that basis. According to him a huge fraction of students only followed the manual provided in the lab however another fraction, while following the manual also analyzed. He said "*they are trying to reinvent things with simple set up- how the experiment can be done in some other way which is physically feasible and correct. Hence there are people who just follow it and there are those who analyse*".

It is observed that amongst the given participant teachers, although the notions of 'learning' were varied, but they largely pointed towards the ability of the students to apply the concepts or learning as problem solving. T1 and T5 clearly mentioned about application, T3 identified learning from questions solved in tests, T2 through problem solving in class and T4 through the methods used in the lab by students to perform the experiment. These views indicate that for them, learning was not only restricted to internalizing or the process of cognition but extended to retrieval of the relevant information for solving the problem at hand. It included the use of 'memory' (to retrieve essential information), 'fine-tuning' and 'performance' (i.e. being able to solve problem). This is quite similar to the way Norman viewed learning as a deliberate act of study of specific material so that it can be "retrieved at will and can be used with skill" (Norman, 1982, p. 3).He argues that if a learner cannot solve a problem , he has not learnt it. Apart from application , T2's view of identifying learning by the method of detecting errors in a problem points towards the notion of learning through group problem solving where the participants are constructing knowledge together. T5 also indicated towards gradual learning. When he said that it is difficult to ascertain learning immediately; it indicates that he is viewing learning as an evolutionary process which involves assimilation and accommodation so as to form new schemas which are qualitatively different from previous ones.

Another idea apparent from teachers' views was of 'reflective abstraction'. When T3, mentioned that whether a concept is used in chemistry perspective or physics perspective, but students should be able to appreciate it, that is students must understand the various perspectives of the concept, he indicated towards being able to identify and understand the focal idea of the concept from various forms it is applied in. The application may be in specific contexts, but through the process of reflection, students should be able to abstract and internalize the central embedded idea. T3's idea can also be looked at from the point that learning is being referred to as the ability to view and approach the concept learned through multiple modes and perspectives.

Diversity in Cognition

Almost all teachers acknowledged that there could be difference in students' cognition. However, the idea of 'different' was not the same for everyone. T3 was of the view that if the environment is the same, students should understand the same way. According to T1, ideally students should understand the same way and make same pictures in their minds which the teacher gave them. However he observed that some students didn't understand the same way rather adopted different ways. By 'different ways' he meant 'different techniques' of solving a problem here or making different pictures with the same core concept. T2 was of the view that students should build up their own understanding of the concept and not replicate teachers' understanding. He said "*I think everything we teach and do have an analytical side and has a phenomenological side and there has to be an optimal balance of these two.*" However, he firmly believed that although he gave scope of variety in conceptualization but all these understandings must converge. According to T4, students in beginning semesters followed manuals to perform an experiment resulting in similar understanding. At advanced level, students read the catalogues, which did not provide instructions for doing the experiment, thus students had to think how to perform the experiment due to which their understandings could differ.

T10 was not so sure and according to him students might be conceptualizing differently. His repeated observation was that students did not understand the concept immediately after they were taught. It was only after he took few classes and when he started using the concept, some kind of *foggy pictures* about the concept started emerging in students' minds. These foggy pictures were sometimes same and sometimes not but if students continued with this subject then after few semesters students' pictures might start resembling teachers' pictures.

According to T6, almost all the students learnt in slightly different way. He had observed that students came with many preconceived notions. So from all what is taught, students only picked out some parts which were closest to the notions they already had. Teachers attributed various reasons for difference in conceptualization by students. For T3 and T5, difference in environment could result in dissimilar conceptualization. From environment he meant interaction of students with their seniors and other students. For T4, combination of interest or sincerity and intelligence level of the student varied from students to student and so did the level of understanding. According to T6, preconceived ideas of students, one of which was their area/topic of interest affected learning process. He observed that, from all what is taught, students only pick out some parts which are closest to the notions they already have.

Teachers identified differences in students' conceptions mostly through the questions students asked to the teacher or the responses they gave to teachers' questions in the class. Similarly T1 and T10 got a clue, about students' understanding, when they started asking questions in the class.T6 expressed that "*I am giving a mental picture to them, and then they will ask questions. Many times I realized ...I was trying to say something else, but then you will realise that this person already has some other mental picture and they are trying to connect to your mental picture.*" From these questions he realized that he needed to get into students' mind and teach from the perspective through which they understood.

Regarding the question of whether students conceptualize differently, although most teachers agreed, but their notions of 'different' only pointed at superficial level and not at conceptual level. For T1, 'difference' meant different techniques of problem solving theoretically and for T4 practically in lab; for T2, it meant the way of visualizing the problem (physically or solving mathematically). All teachers except T6 supported the belief that the concept can be understood only in singular way. At the conceptual level, there is only one correct way in which the concept can be perceived. Only T6 cognized the possible variation in the way students conceptualized. He also attributed this variation to the previous conceptual schemas with which students study the new material. When he said that students try to adapt whatever teacher teaches to their mental picture, he pointed towards learning involving the process of 'assimilation', hence suggesting that students tried to relate new information to their previous information. His ideas were in line with the constructivist ideas.

Alternative Conceptions

All teachers except T3 acknowledged that students did carry alternate conceptions. T3 believed that science students do not have any alternate conceptions, and he added that alternate conceptions are found in only arts courses such as history. On asking, then why some students give incorrect answers, he reasoned that those students are not hard workers.

Although all the other teachers agreed that students carry alternate conceptions, but their idea of alternate conceptions was varied. T9 cited some mistakes and mentioned that students remember the laws but they forget the conditions, and apply it in inappropriate situations. T2 explained alternate conceptions through an example where students picked ideas of potential energy, kinetic energy and total energy from the domain of Classical Mechanics to Quantum Mechanics which was again incorrect extrapolation.

T6 did not think that students were aware or conscious of their alternate conceptions, he said, "*they have a mental picture but ..., it is not conscious it is not fully thought of in their own minds also, so naturally it contains a lot of misconceptions*"

Teachers attributed various reasons for these misconceptions. T1 felt that since students might visualize concepts variously thus this difference might lead to misconceptions. T4 observed that sometimes students had some partial pictures which they tried to complete by themselves leading to misconceptions. He explained through an example, "*Like in vacuum technology, they don't know how a diffusion pump works completely, they just think ... that something is* *diffusing, so there has to be fluid.*" T6 found gradual shift in concepts from concrete to abstract as a reason for misconceptions.

Teachers identified students' alternate concepts through various modes. T1 cited two ways – one was through interaction in the class and second one was exams, T2 came to know about students' conceptions through the questions and problems he discussed in the class. Therefore he felt that class needed to take part actively in the discussions, but that was not the case with all the students, he had to provoke a lot of them to ask questions. He expressed that although he encouraged students to understand concepts in their own way but while doing so they should acknowledge that there were other ways of understanding also. He further added that in case any of students' representations were leading to wrong answer, then it was teachers' responsibility to correct their thought. T4 while handling lab, observed students committing mistakes in Quizzes because of their alternate conceptions, and in viva he noticed students making up the answers.

All teachers except T3 agreed that students while learning may carry misconceptions, but their notion of 'misconception' did not concur with the technical meaning associated with it in academic community. When T9 said that students remember the law but they fail to remember the conditions in which that law is applicable, he identified misconception with committing repeated errors due to inability of few students to either retrieve all associated information may be because they were unable to transfer data to long term memory in the first place. He also mentioned the errors in which few students inappropriately extrapolated the conceptual understanding from one domain (subject) to the other domain (subject), due to apparent similarities. It indicated that dissimilarities between the concepts have not been identified or focussed by the students while learning. T1 identified misconceptions with errors committed by students due to difference in problem solving techniques. Only T4 and T6 to some extent, pointed towards misconceptions arising due to inaccurate conceptualizing, i.e. focussing at the conceptual level. T6 attributed misconceptions to the formation of inaccurate gestalts, when partial information is provided. It indicated towards human tendency to perceive information in complete wholes rather than parts, hence when partial information is provided, mind tries to complete the picture through the closest information available, which many times lead to erroneous concepts.

Strategies to Deal with Alternate Conceptions

Most of the teachers dealt with 'alternate-conceptions' by re- explaining the concept. T1 said if a student's conception is wrong, he just pointed it out in the class so that everybody could benefit from it. T8 also mentioned that whenever he found a problem with students' perspective, he indicated the limitation in that. For lower semester students, T4 explained the concept again, but for higher semester students he just mentioned the point of divergence and asked them to find the solution on their own. T5 also revised the concept again, but while revising, he tried to change his pedagogy.

Since T3 did not believe that students could construct alternate conceptions, so whenever he found errors in exams, he only told them *"you have not done well, you have not worked hard"*. He further said that students should come to the teacher themselves to clarify their doubts. T6 dealt by asking students a trail of questions and as a consequence, they eventually hit a wrong solution and realise the inconsistency in their conceptions. Most of the teachers were of the opinion that their strategies worked, although not all of them checked for its success.

Regarding the approaches/ techniques used to deal with students' alternate conceptions, most of the teachers expressed that they repeated the concept or re- explained it. Even without checking if their strategies worked, most of them believed that their technique was effective in removing the alternate conceptions. Only T6 suggested an approach which, to an extent aimed towards 'conceptual- change' as suggested by Posner et. al (1982). Another crucial point brought out explicitly by T3, was that *students* need to approach the teacher to clear their doubts, which implied students need to identify their own alternate conceptions. Teachers failed to recognize students (or anyone else) are actually unaware of their alternate concepts because their interpretation of the concept fits their (personal) conceptual framework.

DISCUSSION AND CONCLUSION

Amongst the given participant teachers, notions of learning were varied and most of them viewed it as cognitive process. In spite of this, no evidence was found of their awareness about alternate conceptions. Regarding diversity in Cognition, teachers' perceptions varied but most of them considered diversity as deficiency in learning or diversity due to degree of learning. They could not view difference in learning as difference in conceptual structures which learners construct. All teachers except one agreed that learners may carry misconceptions but their notion of misconception did not concur with the technical meaning associated with it in the academic community. They associated misconceptions with the errors committed by students rather than recognizing them as personal constructs which did not align with the well negotiated scientific knowledge (of that time). The data indicated that varied interpretations of the same concept or diversity in cognition were not acknowledged by most of the teachers. The phenomenon of subjective construction of reality/knowledge was also not acknowledged by most of the teachers. Consequently, the technique of 're-explaining' was adopted by most of them. A few of them, however, did indicate towards the importance of making learners reflect on their own mental models.

Their notions about the process of knowing also indicate to some extent their conceptions about the nature of knowledge. While many of them believed that there is no variation as far as understanding of the concept is concerned, it depicts somewhat absolutist assumption about knowledge. It shows that knowledge is 'out there' for such teachers and not constructed by learners. There is plethora of research which has revealed that students' understanding of science ideas may not always match with those of scientists (Halloun & Hestenes, 1985; Goldberg & McDermott, 1987; Styer, 1996; Hammer, 1996). Hence existence of 'alternate concepts' in science is a common phenomenon. To address this issue, conceptual –change approach is suggested by many researchers (Posner et al., 1982), which involve recognizing that learners construct their own understanding based on their prior concepts which they have developed to explain their everyday experiences. From this perspective, learning occurs when new constructions are made and it is the role of the teacher to try to influence these so that the students are consistent with scientific thinking. Thus, most of the teachers seemed to be unaware of the process of knowledge construction among students. Hence a student might have idiosyncratic construction, but it is not recognized by the teachers. The results of the study indicate a gap between the way learners conceptualize (as revealed by researches across globe) and the way teachers view learning. This has direct implication on their pedagogical approaches. This gap can be bridged, when teachers reflect on their own epistemological beliefs about the nature of knowledge (science in this case), the process of learning and the pedagogical techniques to be used in the class to achieve desired learning. As beliefs are assumed to be affecting teachers' planning, decision-making and classroom interaction, it is worthwhile to explicate and reflect upon such beliefs. Teachers need to be cognizant of their belief system in order to challenge the ones which are not congruent with the way learners conceptualize, and replace those with the more compatible ones. In order to make such alterations happen, this study makes a strong case for creating forums for university teachers where strategies of bringing out their beliefs are discussed. This attempt will subsequently, help teachers make active reflection an ongoing process of their professional life. Hence, this endeavour will not only contribute towards teachers' professional development but this will also help in creating a more conducive environment for learning.

References

Abd-El Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural nature. *Science Education, 82*(4), 417–437.

Goldberg, F. M., & McDermott, L.C. (1987). An investigation of student understanding of the real image formed by a converging lens or a concave mirror. *American Journal of Physics, 55*(2), 108-119.

Halloun, I. A., & Hestenes, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics, 53*(11), 1043-1055.

Hammer, D. (1996). Misconceptions or P-prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions? *The Journal of the Learning Sciences, 5*(2), 97-127.

Hewson, P. W., & Hewson, M. G. A. B. (1989). Analysis and use of a task for identifying conceptions of teaching science. *Journal of Education for Teaching, 15*(3), 191–209.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25*, 378–405.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67,* 88–140.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults.* San Francisco: Jossey-Bass.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331–359.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916–929.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education 11*(2), 38-63.

Maor, D., & Taylor, P. C. (1995). Teacher epistemology and scientific inquiry in computerized classroom environments. *Journal of Research in Science Teaching, 32*(8), 839–854.

Mulhall, P., & Gunstone, R. (2008). Views of physics held by physics teachers with differing approaches to teaching physics. *Research in Science Education, 38*(4), 435-462.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317–328.

Norman, D. A. (1982). *Learning and memory.* New York: W. H. Freeman and Company.

Patchen, T., & Crawford, T. (2011). From gardeners to tour guides: The epistemological struggle revealed in teacher-generated metaphors of teaching. *Journal of Teacher Education, 62*(3), 286-298.

Pajares, M. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307–332.

Perry, W. G. Jr. (1970). *Forms of intellectual and ethical development in the college years.* New York: Academic Press.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66,* 211–227.

Schraw, G., & Olafson, L. J. (2002). Teachers' epistemological worldviews and educational practices. *Issues in Education, 8,* 99–148.

Schraw, G. J., & Olafson, L. J. (2008). Assessing teachers' epistemological and ontological worldviews. In M. S. Khine (Ed.), *Knowing, knowledge and beliefs: Epistemological studies across diverse cultures* (pp. 25–44). New York: Springer Science.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*(2), 4–13.

Slotta, J. D., & Chi, M. (2006). Helping children understand challenging topics in science through ontology training. *Cognition and Instruction, 24,* 261–289.

Styer, D. F. (1996). Common misconceptions regarding quantum mechanics. *American Journal of Physics, 64,* 31-34.

Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science *International Journal of Science Education, 24*(8), 771-783.

Yang, F. (2005). Student views concerning evidence and the expert in reasoning a socio-scientific issue and personal epistemology. *Educational Studies, 31*(1), 65-84.

PATHS TO ACHIEVEMENT MOTIVATION OF WOMEN PHYSICS MAJORS IN INDIA: MEDIATIONAL ROLES OF CAREER VALUES AND FAMILY VALUES

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Aim of the study was to compare mediational roles of career and family values in causal pathways from variables viz. college, year of study and facets of locus of control to achievement motivation. Participants were random sample of 300 women Physics majors of West Bengal (India).A general information schedule and three standardized instruments were used to collect data from participants. Path analysis revealed feeble mediational roles of career and family values. Participants' achievement motivation seemed to reduce with increment in year of study. Internal locus of control facilitated achievement motivation.

INTRODUCTION

In India, women's engagement with science encounters difficulty. Patrifocal culture resulting in gendered socialization poses problem. Women's intellect is generally undervalued; they are denied autonomy and groomed for domesticity. Society considers science careers unsuitable for women as these require more time, money and effort. Among sciences, Physics is regarded highly abstract therefore masculine. So Physics major is not preferred for women in India. Often they are prevented from choosing it. Besides, many women leave the subject (Chandra et al., 2009; Hazari & Potvin, 2005). Thus it is worthwhile to study causal trajectories of achievement motivation of women majoring in Physics. It may suggest ways of sustaining or augmenting their achievement motivation so that underachievement and attrition are reduced. Such path analytic investigations are scarce in India. The present study tries to plug the lacuna. With achievement motivation as dependent variable, search for pertinent predictors led to variables like college, year of study, locus of control, career values and family values of women Physics majors. Various aspects of college experience e.g. teaching, teacher-student interaction, student-involvement in college activities and peer culture have been found to influence students' achievement motivation (Astin, 1993; Haque, 2014; Pascarella & Terenzini, 1991). Year of study refers to the duration a major (in this case Physics) was studied and hence it's influence on pupil's achievement motivation. Slump in achievement motivation over undergraduate years was noted. Achievement motivation of German freshmen (mostly STEM students of either gender) was found to drop over the first semester due to change in reference groups, disillusionment and increased task-difficulty (Dresel & Grassinger, 2013). Researches in India generally reveal close relation between locus of control and achievement motivation of females (Ghosh, 2013; Sreekala, 2010; Vasudeva & Lehal, 1986). Sreekala (2010) reported that high school students' achievement motivation rose with enhancement in tendency of attributing personal causation. Vasudeva and Lehal (1986) studied college women and found that self-oriented sex-role attitudes were associated with internal locus of control and higher need for achievement. Ghosh (2013) reported that volitional choice of a science major by women undergraduates fuelled their achievement motivation while imposed discipline-choice hampered it. Most researches affirm positive association between career values and achievement motivation of women (Perron & St-Onge, 1991; Research Papers Center, 2010). Perron and St-Onge (1991) reported that majority of undergraduates (including women) stated that their main goal was to receive education and secure employment. They intended to start families after settling in careers. Research Papers Center (2010) recorded an investigation which confirmed powerful relationship between career values and achievement motivation of college students of either gender. There is repeated corroboration of inverse relation shared by family values and achievement motivation of women (Bhargava, 1985; Etzkowitz et al., 1994; Gupta & Sharma, 2002; Schweitzer et al., 2011). Bhargava (1985) found lack of achievement motivation due to family and socio-cultural pressures among female medical students in India. Etzkowitz et al. (1994) stated that in the USA women in science either focused on career or juggled family and career. The latter were stronger believers in family values but trailed the former in achievement motivation. Gupta and Sharma (2002) studied women scientists at the Indian Institutes of Technology and universities. Responses of these women manifested how primacy of family values obstructed achievement motivation. Schweitzer et al. (2011) worked with Canadian post-secondary students. Girls lacked career expectations as they intended to balance personal lives with careers.

Variables viz. college, year of study and locus of control were reportedly linked with career and family values of female undergraduates. Influence of college (through teacher-student interaction, role models etc.) on women's career values has been found (Almquist & Angrist, 1971; Astin, 1993; Pascarella & Terenzini, 1991). Mixed results have emerged from investigations on relations of year of study with career values (Armenio et al., 2012; Wilson et al., 2006). Armenio et al. (2012) detected rise in career expectations with increase in years of study at undergraduate level. But Wilson et al. (2006) failed to find significant difference in top-career ambitions and reasons for career choice between first and final year pharmacy students. Mitchell et al. (2008) held studying natural science major responsible for diminished importance of family among pupils. In this investigation, influences of college and year of study appear to mingle and manifest as student-engagement with major. Researches generally suggest that career-oriented women tend to display internal locus of control while externals are less career-oriented; strong family values seem consonant with external locus of control (Chanana, 2004; Marecek & Frasch, 1977; Vasudeva & Lehal, 1986). Chanana (2004) found lives of females in India to be largely controlled by authority figures. Vasudeva and Lehal (1986) reported that individualistic sex-role attitudes tended to be closely associated with self-determination among college women in India. Marecek and Frasch (1977) studied female undergraduates in the USA. It emerged that those with external locus of control expected to be less career-oriented and felt uncomfortable over violation of sex-role stereotypes. Survey of pertinent researches reveal paucity of studies conducted in India. Findings of those set in India concur with those conducted elsewhere. However studies in India highlight pronounced patrifocal culture; gendered socialization; consequent dominance of family over career values; deficits in autonomy and achievement motivation among females (Bhargava, 1985; Chanana, 2004, Chandra et al., 2009, Gupta & Sharma, 2002; Vasudeva & Lehal, 1986). Therefore results of the present study could be illuminating. As similar factors apparently influenced achievement motivation and career / family values; and these values in turn were found to influence achievement motivation, a path analytic study with career / family values as mediators was planned. It was intended to compare mediational roles of career and family values due to their conflicting roles (Bhargava, 1985; Etzkowitz et al., 1994; Gupta & Sharma, 2002; Perron & St-Onge, 1991; Research Papers Center, 2010; Schweitzer et al., 2011).

PRESENT STUDY: HYPOTHESES

Ho_1: Achievement motivation of women majoring in Physics cannot be predicted by their college, year of study, locus of control and career values.

Ho_2: Achievement motivation of women majoring in Physics cannot be predicted by their college, year of study, locus of control and family values.

METHODOLOGY

Participants

The sample comprised 300 women enrolled in Physics (Honours) courses in 22 colleges spread over 6 districts of West Bengal (a state in India) viz. Kolkata, North 24 Parganas, South 24 Parganas, Howrah, Hooghly and Nadia. Area sampling was used to randomly select colleges. From women Physics majors in these colleges, random sample was drawn for selection of participants. Participants were aged between 19 and 22 years. Students of all 3 years of study in college were included in the sample. But about 83% of participants were 1^{st} year students. This was because most college authorities denied permission to collect data from senior students lest their classes were hampered. Consenting students participated in the study.

Operational Definitions of Variables

1. Achievement Motivation: Tendency to attempt to succeed in contest with others with some benchmark of merit set by the person (Deo & Mohan, 2011).
2. Career Values: Attitudes towards remunerated work, occupational interests and motivation to work capably (Tanwar & Singh, 1988).
3. Family Values: Attitudes towards marriage, family relationships and interest in home management (Tanwar & Singh, 1988).
4. College: Ethos of a particular college embodying unique combination of location, guiding philosophy, history, institutional type, type of affiliating university, infrastructural facilities, faculty strength and qualifications, student strength and background, level of performance of institution on curricular, co-curricular and employment prospect indicators etc. In this study, colleges were not categorized but each was regarded unique.
5. Year of Study: 1^{st} (freshman), 2^{nd} (sophomore) or 3^{rd} (final) year in college indicating duration of student-engagement with a particular major – Physics (Honours) in this case.
6. Locus of Control: Belief about one's outcomes in life being controlled by internal or external determinants. It has the following 3 aspects: - Powerful Others: belief that one's outcomes are determined by powerful people; Chance Control: belief that one's outcomes are determined by random events; Individual Control: belief that one's outcomes are determined by oneself (Vohra, 1992).

Instruments

1. General Information Schedule: Devised by the author to collect participants' particulars.

2. Achievement Motivation Scale (Deo & Mohan, 2011): Has 50 statements with scale for responding. Covers academic motivation, need for achievement, achievement anxiety etc. Suited for persons aged at least 13 years.
3. Career and Family Values Scale (Tanwar & Singh, 1988): Has 40 statements with Likert scaling. 20 items each assess attitudes towards occupational and family lives of women. Devised for use with women undergraduates.
4. Levenson's Scale for Locus of Control, Indian Adaptation (Vohra, 1992): Has 24 statements on perceived control over personal outcomes. Statements can be responded to on Likert scale. 3 scores emerge –1 each for powerful others, chance and individual control. Devised for use with youth and adults.

Instruments were administered to women Physics majors in groups of about 20 students each. Data were collected at colleges.

RESULTS AND DISCUSSION

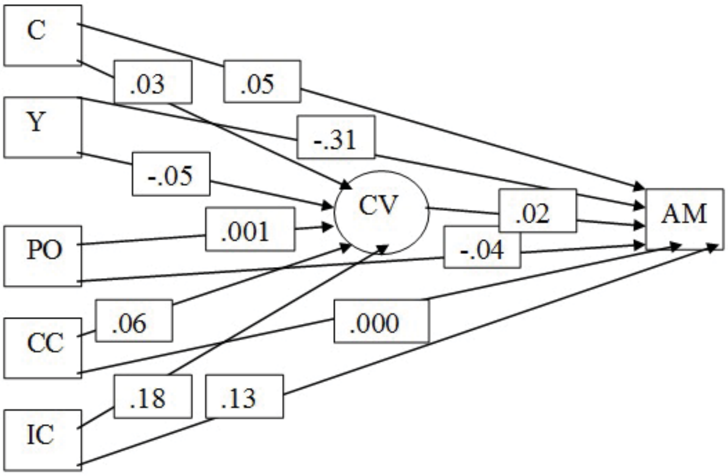

Figure 1: Causal pathways (bearing Beta values) to achievement motivation via career values of participant women physics majors [C: college; Y: year of study; PO: powerful others; CC: chance control; IC: individual control; CV: career values; AM: achievement motivation]

Figure 1 presents outcomes of primary and final steps in path analysis with career values of respondents as mediator and their achievement motivation as ultimate dependent variable. In the figure, values of standardized regression coefficient (Beta) appear. Causal pathways from predictors – college; year of study; perceived control exerted by powerful others, chance and the individual herself to the intermediary i.e. career values of participants are primarily charted. Then paths are traced from predictors viz. college; year of study; locus of control; and career values of participants to their achievement motivation. In the primary step, value of coefficient of multiple correlation (R =.19; df 298; p<.01) indicates that participants' career values bear significant relation with variables viz. college, year of study and three aspects of locus of control. Value of coefficient of multiple determination (R2 =.04) suggests that only 4% of variance in participants' career values scores can be predicted by these variables. F-value of 2.22 (df 5, 294; sig. .05) shows that career values cannot be significantly predicted by the select variables. However, Figure 1 shows that individual control (belief that outcomes in life are self-governed) with Beta-value of .18 contributes the most to prediction of career values of sampled women. This is congruent with Vasudeva and Lehal's (1986) finding that career oriented Indian women manifest internal locus of control. In final step of path analysis, R is .32 (df 298; p<.01) pointing out that achievement motivation of participating women Physics majors share somewhat strong and significant relation with variables viz. their college, year of study, facets of locus of control and career values. R2 is .10 demonstrating that 10% of variance in sampled women's achievement motivation scores can be predicted by these variables. F-value of 5.50 (df 6, 293; sig. .000) indicates that achievement motivation of participant women Physics students can be significantly predicted by their college, year of study, aspects of locus of control and career values. Thus Ho1 is rejected; evidence points towards alternative hypothesis. This outcome agrees with those of Astin (1993), Dresel and Grassinger (2013), Ghosh (2013), Haque (2014), Pascarella and Terenzini (1991), Perron and St-Onge (1991), Research Papers Center (2010), Sreekala (2010) and Vasudeva and Lehal (1986). Figure 1 reveals that strongest determiner of participants' achievement motivation is year of study (Beta=-.31). It is followed by an aspect of locus of control viz. individual control (belief that outcomes in life are under own control) with Beta-value of .13. Negative sign of Beta value for year of study and it's coded categories indicate that participant women's achievement motivation apparently drops with more years of engagement with Physics major. This finding endorses that of Dresel and Grassinger (2013) which holds change in norm, disenchantment and elevated academic demands responsible for declining achievement striving. These issues probably plague the present sample and can be addressed by ensuring that women who are apt are drawn to Physics major; and the academic experience stimulates; includes; and promises bright prospect. The outcome – participants' achievement motivation are promoted by their perception of autonomy over events in their lives echo those of Ghosh (2013), Sreekala (2010) and Vasudeva and Lehal (1986). Plausibly tendency of self-determination leads to development of traits of independence and industry in women – traits which ignite desire for success.

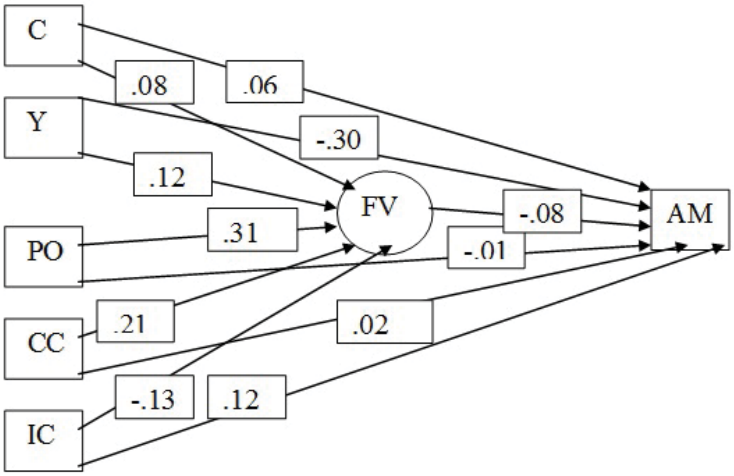

Figure 2: Causal pathways (bearing Beta values) to achievement motivation via family values of participant women physics majors [C: college; Y: year of study; PO: powerful others; CC: chance control; IC: individual control; FV: family values; AM: achievement motivation]

Results (Figure 2) pertain to primary and final steps of path analysis with family values of participants as mediator and their achievement motivation as eventual dependent variable. In the primary step, R is .53 (df 298; p <.01) suggesting that participants' family values is associated significantly with variables viz. college, year of study and facets of locus of control. R2 is .28 indicating that as much as 28% of variance in sampled women's family values scores can be predicted by these variables. F-value of 22.96 (df 5, 294; sig. .000) also shows that family values can be significantly predicted by the select variables. This finding is supported by those of Marecek and Frasch (1977) and Mitchell et al. (2008). Moreover, Figure 2 manifests that powerful others (belief that one's outcomes in life are controlled by authority figures) bearing Beta-value of .31 is prime determiner of extent of family values of sampled women majoring in Physics. This result agrees with those of Bhargava (1985), Chanana (2004), Gupta and Sharma (2002) and Marecek and Frasch (1977). The predictor viz. chance control (belief that outcomes in one's life are determined by random events) with Beta-value of .21 also contributes substantially to prediction of family values of sampled women. Thus externally controlled women revere family as power-hub and refuge. In the final step of path analysis, R is .32 (df 298; p<.01) indicating that achievement motivation of participating women Physics majors share fairly potent and significant relation with variables viz. their college, year of study, facets of locus of control and family values. R2 is .11 showing that 11% of variance in sampled women's achievement motivation scores can be predicted by these variables. F-value of 5.73 (df 6, 293; sig. .000) suggests that achievement motivation of participant women Physics majors can be significantly predicted by their college, year of study, facets of locus of control and family values. Thus Ho2 is rejected; alternative hypothesis seems tenable. This outcome agrees with those of Astin (1993), Bhargava (1985), Dresel and Grassinger (2013), Etzkowitz et al. (1994), Ghosh (2013), Gupta and Sharma (2002), Haque (2014), Pascarella and Terenzini (1991), Schweitzer et al. (2011), Sreekala (2010) and Vasudeva and Lehal (1986). Figure 2 shows that chief determinant of participants' achievement motivation is year of study (Beta=-.30). It is followed by individual control (belief that events in life are self-governed) with Beta-value of .12. Negative sign of Beta value for year of study and coding of the variable imply that sampled women's achievement motivation decreases with more years of involvement with Physics major. It supports Dresel and Grassinger's (2013) outcome and plausibly reflects students' disappointment which can be reduced by attracting suitable women to Physics; and making the course invigorating; inclusive; and a foundation for better future. The finding regarding participants' achievement motivation being facilitated by their perceived self-determination agrees with those of Ghosh (2013), Sreekala (2010) and Vasudeva and Lehal (1986). Autonomy seems to foster self-reliance and effort which possibly spawn aspiration for success.

CONCLUSION

Mediational roles of career and family values appear weak. Direct effect model seems justifiable. Year of study and perceived autonomy substantially influence achievement motivation of sampled women Physics majors. The result about year of study is based on the sample which comprises a minority of senior students. But stringent sampling and parametric testing ensured that the finding was dependable. So women Physics students' achievement motivation must be boosted through interactive teaching, peer study groups, collaborative projects and seminars on career prospects. These would reduce gradual disenchantment and uphold Physics as good career-choice for females. Besides, women Physics majors in India need greater autonomy for promoting their achievement strivings. Given the patrifocality in India, regular parental counselling should be organized by institutions so that women's lasting involvement with Physics is encouraged. Guidance programmes must be nationally implemented so that diffidence of females in shaping their careers is dispelled.

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References

Almquist, E. M., & Angrist, S. S. (1971). Role model influences on college women's career aspirations. *Merill-Palmer Quarterly of Behaviour and Development*, *17*(3), 263-279.

Armenio, B., Deslippe, A., Duffin, J., McGill, L., Meludie, S., Naiman, A., & Sawatsky, K. (2012).Change in career expectations among undergraduate students. Retrieved on 01.05.2015 from http://seanlyons.ca/wp-content/uploads/2012/01/ChangingExpectations.pdf.

Astin, A.W. (1993). *What matters in college? Four critical years revisited*. San Francisco: Jossey-Bass.

Bhargava, G. (1985). Professional identification: A study of female students at a medical college in India. *Social Science and Medicine*, *20*(11), 1169-1175.

Chanana, K. (2004). Gender and disciplinary choices: Women in higher education in India. Retrieved on 02.05.2012 from portal.unesco.org/…/Colloquium+-+December+04+-+Chanana.doc.

Chandra, N., Godbole, R. M., Gupte, N., Jolly, P., Mehta, A., Narasimhan, S., Rao, S., Sharma, V., & Surya, S. (2009). Women in physics in India: 2008. In B.K. Hartline, K.R. Horton, & C. M. Kaicher (Eds.), *Proceedings of 3rd IUPAP International Conference on Women in Physics* (pp.120-121). New York, USA: American Institute of Physics.

Deo, P., & Mohan, A. (2011). *Manual for achievement motivation scale (n-ach)*. Agra: National Psychological Corporation.

Dresel, M., & Grassinger, R. (2013). Changes in achievement motivation among university freshmen. *Journal of Education and Training Studies*, *1*(2), 159-173.

Etzkowitz, H., Kemelgor, C., Neuschatz, M., & Uzzi, B. (1994). Barriers to women in academic science and engineering. In W. Pearson Jr. and I. Fechter (Eds.), *Who will do science? Educating the next generation*. Baltimore: Johns Hopkins University Press.

Ghosh, P. (2013). Choice of a science major: Fashioning a model for female undergraduates in India. In G. Nagarjuna, A. Jamakhandi & E. Sam (Eds.), *epiSTEME5 International Conference to Review Research on Science, TEchnology and Mathematics Education: Proceedings* (pp. 36-41). India: Cinnamon Teal.

Gupta, N., & Sharma, A.K. (2002). Women academic scientists in India. *Social Studies of Science*, *32*(5-6), 901-915.

Haque, Z. (2014). Implications of college peer culture on achievement motivation. *Psychology and Society*, *6*(2), 39-56.

Hazari, Z., & Potvin, G. (2005). Views on female underrepresentation in physics: Retraining women or reinventing physics. *Electronic Journal of Science Education*, *10*(1). Retrieved on 20.03.2010 from www.unr.edu/homepage/crowther/ejse/potvin.pdf.

Marecek, J., & Frasch, C. (1977). Locus of control and college women's role expectations. *Journal of Counselling Psychology*, *24*(2), 132-136.

Mitchell, C., Kimball, M., Thornton, A., & Young-Demarco, L. (2008). The reciprocal relationship between college major and values: Family, careers and society. Retrieved on 27.04.2012 from www.princeton.edu/~cmitchel/index_files/values.pdf.

Pascarella, E.T., & Terenzini, P.T. (1991). *How college affects students*. San Francisco: Jossey-Bass.

Perron, J., & St-Onge, L. (1991). Work values in relation to gender and forecasted career patterns for women. *International Journal for the Advancement of Counselling*, *14*(2), 79-90.

Research Papers Center (2010). Occupational values of college students and the relationship between achievement motivation. Retrieved on 27. 07.2013 from www.hi138.com/?268680_e.

Schweitzer, L., Ng, E., Lyons, S., & Kuron, L. (2011). Exploring the career pipeline: Gender differences in pre-career expectations. *Relations Industrielles / Industrial Relations*, 66(3), 422-444.

Sreekala, E. (2010). Academic achievement of students: Implementation of a theoretical model of personal causation in the classroom. *E-Journal of AIAER, 22*(1), 66-75.

Tanwar, S., & Singh, K. (1988). *Manual for career and family values scale*. Meerut: MAPA.

Vasudeva, P., & Lehal, N. (1986). Personality correlates of sex-role attitudes amongst Indian female college students. *Indian Journal of Social Work, 46*(4), 515-521.

Vohra, S. (1992). *Manual for the Levenson's locus of control scale*. New Delhi: Psy-Com.

Wilson, K., Jesson, J., Langley, C., Hatfield, K., & Clarke, L. (2006). *Pharmacy undergraduate students: Career choices and expectations across a four-year degree programme*. London: Royal Pharmaceutical Society of Great Britain.

PRESENTATION OF STRUCTURE OF ATOM IN CHEMISTRY TEXTBOOKS IN INDIA BASED ON A HISTORY AND PHILOSOPHY OF SCIENCE FRAMEWORK

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Background knowledge about the History and Philosophy of Science (HPS) will avoid questions like theories and models which have been proved false are useless. Rather students will appreciate the contribution of scientists whose theories/models have become the base for further progress of Science. The textbooks however fail to create this connection between the historical theories and contemporary theories. This discontinuity not just creates an incomplete picture of Science but also is a cause for increasing disinterest in science among students. Structure of Atom is one such topic which has tremendous scope to address HPS issue. The present paper is an attempt to study how Structure of Atom is dealt with in four commonly used Chemistry textbooks in Delhi.

Keywords: history and philosophy of science, structure of atom, textbook

INTRODUCTION

The 'Structure of Atom' is an important topic in school chemistry which lays the basis for further understanding of properties of matter. It is introduced in class IX Science textbooks and is discussed in detail in class XI. The chemistry textbooks of class XI deal with structure of atom in a historical manner discussing Thomson, Rutherford, Bohr and Quantum Mechanical model. This paper is an effort to analyze one of the chapters; 'Structure of Atom', of the textbooks used most frequently by teachers at senior secondary level, from a historical and philosophical perspective. The textbooks have been selected on the basis of discussion with teachers and students regarding the most widely used books by them. The framework developed by Niaz (1998) has been used for the analysis of textbooks. The same framework has been used by Niaz to analyse 53 chemistry textbooks in USA and by Niaz and Coştub (2009) to analyse 21 chemistry textbooks in Turkey, 41 physics textbooks by Maria Rodriguez and Niaz (2004).

NEED FOR STUDY

Historians and philosophers of science have recognized the importance of controversies in the progress of science. Research shows that there is a need to address questions related to philosophy/ nature of science and history of science. The notion often conveyed through the transaction of science curricula is that science has a neat, systematic process and old theory gives way to the new theory without contradictions. It appears as if all scientists work under the reigning paradigm and development of a new theory or novel discoveries occur overnight with a certain spark; EUREKA. The philosophical aspect of science is neglected in textbooks used throughout the world. The textbook contain inadequate information about the rival theories and tentative nature of scientific knowledge while more emphasis is on passing on information to the students.

During informal interviews with students of class XI and XII, it was found that students find the chapter 'Structure of Atom' difficult and fail to appreciate the need to study contribution of Thomson, Rutherford and Bohr models. Further, the manner in which, for example, the cathode ray experiment is described in the textbooks gives an impression that as soon as cathode rays were discovered, the electron was discovered, identified and named without any controversy or further probe. These observations created an interest to find out how the evolution in the model of atom is discussed in the textbooks.

Structure of atom is discussed in a chronological order in the textbooks which does point at the tentative nature of scientific theories but other important aspects of method of science like progress in science occurs through competition between rival and conflicting frameworks, importance of mathematical and philosophical issues are often ignored. Moreover, it develops scientific reasoning skills like creating models to explain experimental findings, making inferences from observations. The study of Rutherford or Bohr's model makes students understand through reasoning how based on few observations, new models are built and old models discarded (McKagan, Perkins & Wieman, 2008).

Various studies by Niaz on the controversies related to the developments in the structure of atom and his analysis of chemistry textbooks in USA to look into the philosophical and historical aspect represented in the textbooks created an interest to find out how the topic is dealt in India.

OBJECTIVE OF STUDY

The objective of the study is to evaluate general chemistry textbooks published in India based on the eight criteria developed by Niaz (1998).The textbooks widely used by chemistry teachers were analyzed.

METHODOLOGY

Using the framework of analysis used by Niaz to analyze the chemistry textbooks (From Cathode rays to alpha particles to quantum of action: A rational reconstruction of structure of the atom and its implications for chemistry textbooks) here I present the evaluation of 4 Indian general chemistry textbooks:

Textbook A: Chemistry Class XI Part 1, NCERT 2002

Textbook B: Chemistry Class XI Part 1, NCERT 2006

Textbook C: Saraswati Chemistry a textbook for class XI (2010)

Textbook D: Pradeep's New Course Chemistry for class XI (2010)

It is important to note that the criteria used in this study are precisely the same as used by Niaz (1998) to evaluate general chemistry textbooks published in U.S.A. To refer to the criteria based on the three models, the following symbols are used: T = Thomson; R = Rutherford; and B = Bohr.

ANALYSIS

Atomic structure chapter is introduced in class IX (All three models introduced), but not in a detailed manner. The description starts with Dalton's model, followed by Thomson's model. Thomson's plum pudding model is explained but the cathode ray experiment is not mentioned. The α- rays scattering experiment is explained with diagrams and satisfactory description of observations of the experiment. The limitation of Rutherford's model to explain stability thus formulation of Bohr's model is discussed in brief.

Class XI textbooks discuss the structure of atom in detail. The analysis of the three models (Thomson, Rutherford and Bohr) is as follows:

Thomson Model:

T1 – Cathode rays as charged particles or waves in the ether.
T2 – Determination of mass-to-charge ratio to decide whether cathode rays were ions or a universal charged particle

In all the books analyzed the discussion on structure of atom starts with Dalton and the mention that number of scientists like Faraday worked on cathode ray discharge tubes. The cathode ray experiment result is summarized and regarding the effect of magnetic and electric field it says, "In presence of electrical or magnetic field, the behaviour of cathode rays are similar to that expected from negatively charged particles suggesting that cathode rays consist of negatively charged particles called electrons" (p. 28, Textbook B)

However, the controversy related to Hertz (1883) experiment that showed cathode rays were not deflected by an electrostatic field, thus questioning the particle nature of the cathode rays is not mentioned. The existing ether theory and particle nature debate is nowhere mentioned. In fact, on basis of information informal interactions with students and teachers it is found that there existed ether theory, is not known to them.

The properties of cathode rays are summarized in the book. The text also mentions finding the e/m ratio by Thomson and the value is constant but there is no mention of the need to determine e/m ratio. The impression one gets from the text is that electron was known at that time and the experiment was to prove that electrons are constituent particles of all atoms. The fact that e/m ratio would help Thomson to identify cathode ray particles as ions or a universal charged particle, is not mentioned in the book.

The fact that other scientists like Schuster also had determined the e/m ratio, but lacked "Thomson's ability to speculate , elaborate alternative hypotheses and models, and perhaps most importantly formulate a theoretical framework for his experimental findings, led him to foresee and conceptualize what his contemporaries ignored" (Niaz, 1998). Thus along with experimental data bold novel ideas that help to explain the data are also important for the progress of science. This description is lacking in the book.

The textbook B mentions the experimental details but lacks on account of an overall interpretation of the event. The following two examples are presented to illustrate how some of these textbooks present scientific knowledge as 'rhetoric of conclusions':

"The results of these (cathode ray discharge tube) experiments are summarized below ------- in presence of electrical or magnetic field------ the characteristics of cathode rays (electrons) do not depend upon the material of electrodes and the nature of the gas present in the cathode ray tube. Thus, we conclude that the electrons are basic constituents of all atoms." (p. 28)

However in textbook A, there is no mention of the cathode ray discharge tube experiment, its results or nature of cathode rays which led to discovery of electron. The description appears to convey that scientists discovered the electron, proton and neutron and then different models were framed instead of looking into the aspect historically starting from cathode ray experiments.

The new edition of NCERT, textbook B, takes into account the importance of the historical aspect and there is discussion of how electron, proton and neutron were discovered.

Thomson's model is described in vacuum, i.e., in absence of any experimental or theoretical background that led to his proposed model.

Textbook C mentions that number of scientists like Goldstein, Plucker, Crookes and Hertz worked on cathode ray discharge tubes gives an idea of how different scientists work on the same problem and only few can explain the observations using a theoretical framework.

Textbook D mentions that number of scientists like Crookes, Thomson worked on cathode ray discharge tubes. The cathode ray experiment result is summarized and regarding the effect of magnetic and electric field it says, "They (cathode rays) are deflected in presence of electrical or magnetic field in such a manner which suggests they are negatively charged particles" (p.55)

Thus none of the books analyzed mentioned the historical background and philosophical aspect of Thomson model. There is no mention of criteria T1 and T2 in any of the 4 textbooks.

Rutherford model:

R1 – Nuclear atom.

Rutherford model discussion in all the analyzed textbooks starts with alpha ray scattering experiment. Thomson's model was unable to explain the alpha ray scattering experiment, so Rutherford proposed a model. The controversy about which model is correct continued. The textbooks give an impression that after the alpha ray experiment the Rutherford model was accepted overnight and Thomson's model was discarded.

However, textbook C mentions Rutherford designed an experiment to verify Thomson model but the experimental observations were to the contrary. The inability of Thomson model to explain the result of the α rays scattering experiment and the formulation of Rutherford's atomic model is dealt with satisfactorily, but the reader gets an impression that accepting the new model was a smooth transition (from Thomson to Rutherford model).

In all the four textbooks analyzed, satisfactory explanation of Thomson's plum pudding model and its limitation to explain experimental result of α- particle scattering experiment is given.

"The results of scattering experiment were quite unexpected (diagram given). According to Thomson model of atom, the mass of each gold atom in the foil should have been spread evenly over the entire atom, and α- particles had enough energy to pass directly through such a uniform distribution of mass. It was expected that the particles would slow down and change directions only by small angles as they passed through the foil." (p. 31, textbook B)

R2 – Probability of large deflections is exceedingly small, as the atom is the seat of an intense electric field.

There is a satisfactory explanation of observations and conclusions drawn from α- particle scattering experiment in all four textbooks analyzed.

"Rutherford and his students [Hans Geiger and Ernest Marsden] bombarded very thin gold foil with α- particles. ………………… a very few α- particles (~1 in 20,000) bounced back, that is were deflected back by nearly 180^o. ………………The positive charge and most of the mass of the atom was densely concerted in extremely small region." (pp. 31-32, Textbook B)

R3 – Single/compound scattering of alpha particles.

There is no mention of the rivalry between two conflicting frameworks, namely Rutherford's hypothesis of single scattering and Thomson's hypothesis of compound scattering, put forward to explain Rutherford's alpha particle experiment in any of the textbooks.

Bohr's Model:

B1 – Paradoxical stability of the Rutherford model of the atom.

Formulation of Bohr's model in the textbooks is discussed in the backdrop of limitations of Rutherford's model being unable to explain stability of the atom and two major developments: Dual nature of electromagnetic radiations and atomic spectra. The model follows the description of work of Maxwell and Planck and the dilemma related to nature of matter. The paradox is satisfactorily discussed in all the textbooks.

"The motion of electrons around the nucleus contradicted the James Clark Maxwell's theory of electromagnetic radiations. According to this theory, when any charged particle moves under acceleration, it loses energy in the form of electromagnetic radiations. The electron is a charged particle and revolves around the nucleus. The circular motion being accelerated motion, the electrons will consciously lose energy in the form of electromagnetic radiation. So the electrons should move in a spiral and fall into the nucleus."(p.61, textbook C)

B2 – Explanation of the hydrogen line spectrum.

The book provides explanation of hydrogen spectra and considers dual behavior of electromagnetic radiation and experimental result of atomic spectra to have led to the formulation of Bohr's model. Thus there is an attempt to historically show the development of Bohr model, but a spectroscopic version of the model is discussed, though "the Rutherford Memorandum", shows he was not fully aware of the implications of spectroscopic research for his problem" (Niaz, 1998; Bohr, 1913; Bohr, 1922). The text mentions about fixed values of energy and angular momentum of the orbits mentions that it was the first model based on "quantization".

Textbook B, mentions about fixed values of energy and angular momentum of the orbits but does not mention the term "quantization". Quantization is explained in textbook D in detail (p. 2/34)

Textbook C deals satisfactorily with B2 and the text provides explanation of hydrogen spectra. The development of Bohr's model however is linked to the paradoxical stability of the Rutherford model of the atom, but does not link hydrogen spectra with formulation of Bohr's model, which most of the books do. (Niaz, 1998)

"It was a young Danish physicist Niels Bohr who, while working with Rutherford, made theoretical calculations and showed that according to the laws of classical physics, the electron in Rutherford model of an atom would not be stable and fall into the nucleus in about 10^{-8} second. In 1913, he proposed a most unconventional model of the atom. He argued that since classical physics leads to wrong conclusions about the behavior of electrons in an atom, these laws do not apply to them" (p. 69, textbook B)

Thus an idea that it is not just experimental data but also strong theoretical framework that leads to questioning of existing theories or models is put across to the readers.

B3 – Deep philosophical chasm.

All four textbooks satisfactorily discuss the deep philosophical chasm. There is a description of electromagnetic wave theory and quantum mechanical theory. The text mentions observations like black body radiations, photoelectric effect (in detail) and line spectra of hydrogen (in detail) and also interference and diffraction leading to leading to bold assertion of dual nature of matter. Showing how scientists when faced with difficulties often resort to such contradictory “grafts”.

Procedure for Implementing the Criteria

The following classifications used by Niaz (1998) were used to evaluate the textbooks:

Satisfactory (S): Treatment of the subject in the textbook is considered to be satisfactory if the role of conflicting frameworks based on competing models of the atom is briefly described.

Mention (M): A simple mention of the conflicting frameworks or controversy with no details.

No mention (N): No mention of the conflicting frameworks

Each textbook was awarded points on the following basis: Satisfactory (S) = 2 points; Mention (M) = 1 point; No mention (N) = 0 point.

S. No	Textbook	Criteria								Total
		T1	T2	R1	R2	R3	B1	B2	B3	
1.	NCERT (2006)	N	N	S	S	N	S	M	S	9
2.	NCERT (2002)	N	N	S	S	N	S	M	S	9
3.	Saraswati Chemistry (2010)	N	N	S	S	N	S	S	S	10
4.	Pradeep’s New Course Chemistry	N	N	S	S	N	S	M	S	9

Table 1: Evaluation of chemistry textbooks based on a history and philosophy of science framework*

Result of analysis of all four textbooks on basis of Mathematical details to understand the atomic model, Illustrations of experimental apparatus and Illustrations of models:

1. Thomson and Rutherford model have no mathematical details. Bohr’s model details of energy, radius and angular momentum expressions of orbits are given.
2. Illustrations of the experimental set up used are given for Thomson (except textbook A) and Rutherford model in each textbook. The diagram showing Lyman, Balmer and Paschen transitions (line spectra of hydrogen) is given.
3. Only Thomson’s model is illustrated in textbooks A and B, both Thomson and Rutherford model in textbook C and all three models; Thomson, Rutherford and Bohr are illustrated in textbook D.

CONCLUSIONS AND EDUCATIONAL IMPLICATIONS

The appreciation of the work, creativity and insight of scientists and the importance of sound theoretical background for discoveries made in the past is lacking in the students as the textbooks fail to create an awareness of the same. Historical treatment will help students understand how revisions are made in pre-existing models and theories. The HPS treatment will help create an understanding of models in terms of usefulness, thus giving scope for imaginative variations which will create deeper interest and understanding instead of rote learning. The progress of science is seen a sudden event of an apple falling and Newton formulating the law of gravitation, Kekule dreaming of snakes and coming up with the structure of benzene and not as a result of continued effort of scientists and their curiosity. Most of the textbooks deal with experimental details based on observations and generally ignore the "heuristic principles" (Schwab, 1974). The textbooks analyzed lacked a philosophy of science perspective; the developments in the formulation of structure of atom are not seen within a historical framework. The following observations are made on analyzing the textbooks:

(i) Thomson's experiment on cathode rays are mentioned in all books except the older edition of NCERT, but the emphasis is on experimental details and observation not on the controversy with regard to nature of cathode rays i.e. charged particles or waves in ether.

(ii) Thomson's determination of e/m ratio and the value of the ratio are mentioned but the need to find e/m ratio i.e. to identify cathode rays as ions or as universal charged particles is nor discussed neither mentioned.

(iii) The alpha particles scattering experiment is mentioned in all the textbooks along with the crucial finding that 1 in 20,000 particles deflected through large angles and how this observation was not in agreement with the Thomson model.

(iv) Rutherford model had to compete with rival framework of Thomson model and the acceptance of Rutherford model was not overnight event. Rutherford's hypothesis of single scattering and Thomson's hypothesis of compound scattering to explain the observations of alpha particle scattering experiment is not discussed in any book.

(v) All the books mention Bohr proposed a model to explain the paradoxical stability of Rutherford model but the Hydrogen spectra as a main contributing factor is also mentioned by most of the books.

(vi) The books discuss "quantization" of energy and angular momentum as the major contribution of Bohr.

All books take into account the historical events- Maxwell's electromagnetic waves theory; Planck's quantum theory and the inability of both to explain the nature of light alone thus dual nature of light being accepted to resolve the dilemma is discussed in detail.

Thus, the textbooks fail to look into the topic with a historical perspective, laying more emphasis on experimental details. The ignorance of textbooks to discuss the importance of competition between rival frameworks in progress of science gives an impression to the students that science follows a smooth transition from one theoretical framework to the other with help of experiments to show the limitations of existing theory (Many a times experiments are done to support the existing theory, the result might prove otherwise). The mathematical and theoretical means to point out the drawback of theories (mentioned in the books in case of limitations of Rutherford's model on basis of classical physics) shows the importance of thought experiments in science (the term is not mentioned in any of the textbooks).

The study of history of science is a neglected field. The importance of history and philosophy of science has been emphasized in various researches in science education. Not just the appreciation of the work of scientists but an understanding of nature of science is important for creating and reviving the lost interest in science. Knowing about the way the theories are developed, understanding the importance of observation, hypothesis, control experiments and thought experiments will help in understanding the method of science.

The tentative nature of science has been taken up in the textbooks but the coexistence of rival theories needs to be discussed in textbooks so that an idea of a sudden overnight change (that exists among students) is replaced. I would once again emphasize on the need to create an understanding of history of science so that students do not carry wrong information about how science progresses. The paper was an attempt to show how the historical and philosophical aspects are overlooked or wrongly stated in the textbooks, leading to an understanding of nature of science which does not actually represent the nature of science.

References

Arora, K. K., Handa A. C., & Vijay, S. (2010). *Saraswati chemistry: A textbook for class XI.* New Delhi: Goyal Offset Printers.

Bohr, N. (1913). On the constitution of atoms and molecules. *Philosophical Magazine, Series 6, 26,* 1-25.

Bohr, N. B. (1922). The structure of the atom. Nobel Lecture, December 11, 1922.

Dhawan, S. N., Khterpal S. C., & Kapil, P. N. (2010). *Pradeep's new course chemistry, Vol. I Class XI (23rd Edition)*. Jalandhar: Pradeep Publications.

Hertz, H. (1883). Uber kathodenstrahlen. *Annalen der Physik und Chemie, 19*, 782.

McKagan, S. B., Perkins, K. K., & Wieman, C. E. (2008). Why we should teach the Bohr model and how to teach it effectively. *Physical Review Special Topics: PER*. 4, 010103.

NCERT. (2002). *Chemistry textbook for class XI.* (pp. 47-69). New Delhi: NCERT.

NCERT. (2006). *Chemistry textbook for class XI.* (pp. 26-49). New Delhi: NCERT.

NCERT. (2006). Science, textbook for class IX. New Delhi: NCERT.

Niaz, M., & Coştub, B. (2009). Presentation of atomic structure in Turkish general chemistry textbooks. *Chemistry Education Research and Practice, 10*(3), 233-240.

Niaz, M. (1998). From Cathode ray to alpha particles to quantum of action: A rational reconstruction of structure of atom and its implications for chemistry textbooks. *Science Education*, *82*(5), 527-552.

Niaz, M., & Rodriguez, A. M. (2004). A reconstruction of the structure of the atom and its implications for general physics textbooks: A history and philosophy of science perspective. *Journal of Science Education and Technology, 13*(3).

Schwab, J. J. (1974). The concept of the structure of a discipline. In E.W. Eisner and E. Vallance (Eds.), *Conflicting conceptions of curriculum.* Berkeley, CA: Mc Cutchan.

TEACHERS' PERCEPTIONS OF DEALING WITH MIXED ABILITY CLASSROOMS

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The paper reports a qualitative study of the perceptions of secondary school teachers towards mixed ability classrooms. Semi-structured interviews and classroom observations were conducted to gauge teachers' ideas about incorporating quick learners and slow learners in the same classroom. Teachers' perceptions of ability grouping and their own application of proven instruction methods for inclusion, like collaborative projects, open ended questions and interaction in classroom have been reported. The study found that while teachers were aware and had practiced various possible classroom strategies to deal with mixed ability situations in classrooms, they felt incapable of implementing these strategies consistently due to constraints such as limited time, extensive syllabus and huge class size. Some possible solutions are recommended to take into account the day to day classrooms problems for effective learning.

Keywords: mixed ability classrooms, ability grouping

INTRODUCTION

Mixed ability classrooms that accommodate students having different learning styles, interests, prior knowledge, attitudes, strengths, personalities and skills, are commonly found. There is a pedagogic challenge associated with providing equal opportunities to different groups of students, who may be high-ability students consisting of 25% of the class, low-ability students consisting of 25% or the average-ability students constituting the rest 50% percent of the class (Webb, 1991). At the same time, achieving quality standards has led to performance based segregation known as ability grouping. The implications of ability grouping include negative effect on the self-concept of low-ability students (Oakes, 1985; Hallam & Deathe, 2002).

To deal with mixed ability classrooms, teachers resort to group activities, consciously creating heterogeneous groups with the motive of having the quick learners act as mentors for the slow learners (Webb, Baxter & Thompson, 1997) thereby aiding learning in slow learners. This technique does not affect the progress of the quick learners (Lou, et al., 1996; Saleh, Lazonder & De Jong, 2005). Interactive classroom environment, where precise and thought-provoking questions are put forth (King, 1998) are an effective teaching strategy, and instructors play the role of active guides by recognizing slow learners and assisting their process of learning. Differentiated instruction is a teaching method that takes into account different learning styles, pace, skills, knowledge and attitudes of different students (Koutselini, 2008). Using differentiated instruction coherent with different students' readiness, interests and learning styles (Landrum & McDuffie, 2010; Murawski & Hughes, 2009; Regan, 2009), teachers can maximize students' academic as well as personal growth.

Pedagogical Knowledge (PK) refers to teachers' expertise with reference to teaching-learning aspects, such as understanding how learning works, keeping students engaged and knowledge of how skills are acquired in differentiated ways (Harris, Mishra & Koehler, 2009). Shulman (1986) describes it as application of broad principles and strategies of classroom management, knowledge of learners and their characteristics. The concepts of Pedagogic Content Knowledge (PCK) elaborated by Shulman (1986) and Technological Pedagogical Content Knowledge (TPCK) (Harris, Mishra & Koehler, 2009) have been immensely discussed for the past two decades. In the current context, we shall ponder upon pedagogical knowledge specific to dealing with performance gap in classrooms, different learning speeds of children and assessment practices.

Ensuring maximum results while teaching a mixed ability classroom is a very challenging task. In many schools in Mumbai, one finds classes divided on the basis of students' achievements, that is, the A division may comprise of the very bright students, B and C may comprise of average students and the D division may include those who are doing poorly. Such ability grouping allows teachers to focus on a homogenous class and develop a teaching strategy accordingly. Often this system helps the schools achieve very good results in the final Board examinations. Research suggests that ability grouping has cognitive, behavioural, emotional and social repercussions (Ireson & Hallam, 2009; Marsh, 2006).

The current study explores the application of proven teaching strategies in real life scenarios and focuses on teachers' perceptions that in turn directly influence their classroom practices (Pajares, 1992). In this study a semi-structured interview schedule (Creswell, 2007) targeting the specific sections of pedagogy was conceptualized and teachers were observed in their regular teaching conditions to get a fair idea of the practices. The interview schedule included hypothetical situations (often extreme) to gauge the perceptions of the teachers about mixed ability. We conclude with pragmatic solutions that could be implemented to resolve the gap between existing research and actual classroom practices.

RESEARCH QUESTIONS

The following research questions (RQs) were addressed in the study:

- What are teachers' perceptions about having quick and slow learners in the same classroom?
- What are the teachers' perceptions about ability groupings and new pedagogic strategies to avoid such groupings?
- How do teachers act upon the mixed ability problem while teaching and designing assessments for the students?

Participants

The participants included 12 secondary school teachers teaching grades 6-9/10 in 3 urban schools of Mumbai. The teachers, who had different subjects of expertise, such as, Science, Mathematics, English, Hindi and Social Studies, voluntarily participated in the study after being approached. Nine of the 12 participants were female, and the teaching experience of all teachers varied widely, ranging from 2 years to 37 years. All the teachers held a B.Ed. Degree (some by distance learning) and many held a Master's Degree in one or more subjects.

Convenience sampling was used while choosing the sample due to practical constraints and limitations of the study. Thus the sample is subset of teachers in established schools in an urban set-up where there are no constraints based on infrastructure or availability of resources. We shall refer to the participants as teacher 1, teacher 2 and so on, to maintain anonymity.

METHODOLOGY

To serve the purpose of the study and find natural perspectives of the teachers, a qualitative research methodology was chosen. This methodology employs a less structured data collection process by means of direct observation and semi-structured interviewing of participants in real-life settings. One of the major drawbacks of qualitative research is experimenter bias (Kerlinger & Howard, 1999), thus extreme care was taken so that the interview protocol (questionnaire) would be free from the opinions of the researcher.

Interview Schedule

Interview questions were designed based on primary themes coherent with the research questions that included perceptions about performance gap, classroom practices to deal with mixed ability students, designing assessments for such a class and views about ability grouping. Hypothetical questions, for instance extreme doubts, as if put forth by weak students and very bright students were posed by the researcher to gauge the teachers' reaction toward different groups of students. Also, teachers were asked about their willingness toward implementing innovative activity based teaching-learning methods for better learning.

Prior to interviewing school teachers, pilot interviews were conducted with doctoral students of a prestigious institute who had prior teaching experience. The questionnaire was modified on the basis of the pilot to ensure clarity and conversational form of interviewing. While conducting the interviews, minor adjustments were made to the questions to incorporate examples relevant to the instructor's subject of expertise. The natural flow of the questions was ensured and depending on the individual interviewee's answers redundant questions were avoided.

Interviews with teachers lasted around 30 minutes. The interview consisted of open ended questions free from any bias of the researcher and the teachers gave answers according to their views and practices. Questions were formulated so that there was no unique socially acceptable answer but the teacher was asked to think before answering and reflect on their own classroom practices. Some of the questions were:

- Have you identified the problem of huge diversity in learning speeds of various students?
- What measures do you take to incorporate the slow learners and quick learners in the same classroom? If none, why?
- How do you design assessments for such a mixed ability classroom?
- What, in your opinion, are the pros and cons of ability grouping? Should it be practiced more often by schools and colleges?
- Would you try novel teaching methods for example instead of an official letter writing class assignment, get students to look for actual problems in their community and give a task of writing an actual letter to an official?

Classroom Observations

Direct classroom observations were carried out in an unobtrusive manner to maintain the authenticity of the data collected. A total of 6 classrooms conducted by 4 teachers were observed. The grades ranged from grade 6 to grade 9 and subjects taught were mathematics and science. The classroom interactions were audio recorded and the observations were targeted towards the instructor's way of conducting the classroom, as well as his/her reactions towards learners.

The interviews were audio-recorded with the consent of the participants and the recordings were then transcribed verbatim by the first author. The transcriptions were analyzed to find common themes in the perceptions of the teachers. We focused on the constraints of the teachers. Secondary themes were recognized to find similar views and practices. Classroom observations were correlated to the teachers' interviews and thus their opinions about the mixed ability classrooms.

FINDINGS

Most teachers mentioned the problem of dealing with differentiation in classrooms and suggested solutions of their own to tackle the same. While some teachers were more sensitive towards the slow learners and wanted to ensure that they were on-board before moving on to the next topic, others were also concerned about the quick learners getting disengaged and thus kept them busy with extra Higher Order Thinking (HOT) questions.

Classroom Practices

The classroom practices mainly employed have been categorized into three major categories:

(a) *Peer learning in mixed groups*: Teachers laid stress on the importance of peer learning. For instance, teacher 10 said that she made mixed study groups and allowed them to appoint their own leaders, with the slow learners learning from the bright students. Teacher 2 said that she consciously seated the students in a manner such that an average learner would sit beside a bright student to improve learning even in her absence. Teacher 10 also believed that such practices would also help students learn team work and embrace academic and social differences in a better manner. Some of the actual quotes are reproduced below.

> "*Moreover, it is a double benefit for those who are teaching… Apart from that we are also inculcating the value of helping in the class*." (Teacher 2)

> "*Sometimes I ask another student to explain. He may be able to explain better than me, so that he (weak student) can understand in a different way.*" (Teacher 8)

(b) *Nominal separation*: Another common practice was dealing with the weak students inside the classroom itself after engaging the rest of the class in some other exercises (Teacher 11 and Teacher 3). Nevertheless, teacher 1, teacher 4 and teacher 9 conducted remedial classes for the weak learners giving personal attention to them and two of them (Teacher 4 and Teacher 9) believed that this was the best possible solution for the extremely weak students.

(c) *Interaction based/activity based practices*: Some teachers use a positive interaction based approach to scaffold learning especially for the weak learners. For instance, teacher 5 intentionally involved the weak learners in a discussion and specifically directed questions at them to ensure that they understood the concepts. A practical activity based learning approach was used by teacher 3, who formed groups for weekly presentations by students encouraging wider participation, so that students could learn by seeing others' work.

> *"I know a few children, I know the names fairly well, may not have understood… I ask those children to answer."* (Teacher 5)

Views about Ability Grouping

With the exception of two teachers (Teachers 4 and 9), the rest were against the idea of ability grouping. Some of the teachers engaged in loud thinking and weighed the pros and cons of ability grouping and finally voiced their opposition to it. The three main themes that emerged out were:

(a) *Effect on academic learning*: According to teacher 2, creating divisions on basis of academic performances would cause the quick learners to think that they are very intelligent and thus stop putting in greater effort. On the other hand, teacher 1 believed that in separate classes the excellent group could be given extra work and taught in a manner so that they could achieve maximum results. However he had concerns about the performance of weak students being hampered in the absence of regular interaction with brighter and more motivated students. Teacher 8 believed that the bright students would perform well academically regardless of segregation.

(b) *Psychological effects*: The repercussions of ability grouping on social, behavioural and emotional aspects (Ireson & Hallam, 2009; Marsh, 2006) of the students were also mentioned by some of the teachers. The brighter students often look down upon the lower section students (Teacher 3) and develop arrogance or a superiority complex which is not good (Teacher 10). On the other hand the weak students, who shall one day all go out and work in the society, shall develop inferiority complex (Teacher 10). Such a practice affects the mental growth of the child as it is very demotivating and humiliating for the child to be in the lower performing section (Teacher 7). An advantage of mixed classes would be to inculcate values such as working with people difficult to get along with, accepting the academic and social differences and being empathetic toward others' weaknesses (Teacher 10).

> *"They feel that they don't know, and once the child believes that he doesn't know something, it is really difficult for him to cope up with it."* (Teacher 5)

> "*(when an easy question is explained again)…the intelligent ones get very impatient, make all kinds of noise and even try to pull the other person down."* (Teacher 4)

(c) *Teachers' perspective about teaching homogenous classes*: As mentioned earlier 2 of the 12 teachers were for ability grouping practice and one of them, teacher 9, had concerns about no teacher wanting to teach the weaker section. Although teacher 6 was not in favour of ability grouping, felt that a homogenous class could be easily taught as all the students would be at the same thinking level. On the other hand teacher 7 felt that it would be a challenge to teach a class of low achievers alone, as teachers generally use the help of quick learners for the same.

Assessment and Innovation

While talking about assessment most teachers did keep in mind the classroom diversity and designed the question papers in order to cater to the majority, i.e., the average students. But, this did not stop them from including a couple of high order thinking questions for the above average students. Also, the teachers said they try and include some very simple questions to ensure that majority of students can pass the exams. The major constraint faced by the teachers is the CBSE (Central Board of Secondary Education) rule of promoting all kids till 8^{th} grade, which makes it important for the teacher to ensure that everyone passes the exam.

When asked their opinions about implementing an innovative active learning method in the classroom, some teachers had doubts about its feasibility due to practical constraints like limited 40 min lectures (Teacher4), length of syllabus as compared to shortage of time and huge class strengths (Teacher 8) to name a few. Teacher 10 and teacher 12 had concerns that all students might not end up participating whole heartedly in the assignment/assessment and create chaos in the process. Nevertheless, teacher 8, along with many others, was keen on using innovative practices as it would help students relate textbook content to their everyday lives. Teacher 1 also felt that such an activity would prepare them for the kind of work they would be doing in the future.

CONCLUSION

The participants who volunteered for the study belonged to various age groups, backgrounds but almost similar urban school environment. But, being a qualitative study (Kerlinger & Howard, 1999), the results really be extrapolated to the vast group of teachers belonging to different school settings.

School dropout is a major problem in India, and while various factors like adverse school environment, financial aspects and out-of-school employment are responsible (Jordan, Lara & McPartland, 1994), major contributing factors are student's academic failure and losing interest in school (Watt & Roessingh, 1994). The problem of mixed ability and performance gap in students can thus eventually lead to the weak students dropping out of schools. The objective solution for improving results via ability grouping tends to worsen the classroom environment and is detrimental for the holistic development of the child. In a democratic society, our aim should be to provide equity in education, which means equal opportunities for all students. Some possible ways to achieve the above are stated below.

Firstly, more autonomy should be given to the teachers and their opinions should be given weight as many teachers have years of experiences of dealing with various classroom problems all at the same time. In our study, we found that the teachers already had a fair idea of various classroom practices for mixed ability classes and were employing the best possible strategies. Bringing a few representative teachers on board is crucial while making policy decisions.

Secondly, teachers as well as parents should actively be involved in the implementation of the policy changes. For instance the practice of CCE itself can help tackle the mixed ability problem if implemented successfully. The students can be assessed using several means and thus the students can develop a practical approach of learning. The practice aims to helping all students as their strengths can be highlighted in one way or another. The teachers and parents should thus be conveyed to look at such a practice with the sole purpose of better learning for students.

Lastly, there is a huge divide between the existing research and the awareness of the teachers and parents about the same. There should be a platform that brings together the educationists, researchers and teachers to find ways to broaden the reach of research with the help of existing institutions. The implementation could be done by means of several workshops where teachers could discuss their specific classroom problems and all possible solutions for the same. Teachers could then implement these solutions according to their local scenario.

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References

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Thousand Oaks, CA: Sage Publication.

Hallam, S., & Deathe, K. (2002). Ability grouping: Year group differences in self-concept and attitudes of secondary school pupils. *Westminster Studies in Education, 25*(1), 7-17.

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393-416.

Ireson, J., & Hallam, S. (2009). Academic self-concepts in adolescence: Relations with achievement and ability grouping in schools. *Learning and Instruction, 19*(3), 201-213.

Jordan, J. W., Lara, J., & McPartland, J. M. (1994). *Exploring the complexity of early dropout causal structures.* Baltimore, MD: Center for Research on Effective Schooling for Disadvantaged Students, Johns Hopkins University.

Kerlinger, F. N., & Howard, B. L. (1999). *Foundations of behavioural research* (4th ed.). Belmount, CA: Wadsworth.

King, A. (1998). Transactive peer tutoring: Distributing cognition and metacognition. *Educational Psychology Review, 10*(1), 57-74.

Koutselini, M. (2008). Listening to students' voices for teaching in mixed ability classrooms: Presuppositions and considerations for differentiated instruction. *Learning and Teaching, 1*(1), 17-30.

Landrum, T. J., & McDuffie, K. A. (2010). Learning styles in the age of differentiated instruction. *Exceptionality: A Special Education Journal, 18*(1), 6-17.

Lou, Y., Abrami, P. C., Spence, J. C., Poulson, C., Chambers, B., & D'Apollonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research, 66*, 423-458.

Marsh, H. W. (2006). *Self-concept theory, measurement and research into practice: The role of self-concept in educational psychology.* Vernon-Wall Lecture: British Psychological Society.

Murawski, W. W., & Hughes, C. (2009). Response to intervention, collaboration, and co-teaching: A logical combination for successful systemic change. *Preventing School Failure, 53*, 267-277.

Oakes, J. (1985). *Keeping Track: How schools structure inequality.* New Haven, CT: Yale University Press.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.

Regan, K. (2009). Improving the way we think about students with emotional and/or behavioural disorders. *Teaching exceptional Children, 41*(5), 31-47.

Saleh, M., Lazonder, A. W., & De Jong, T. (2005). Effects of within-class ability grouping on social interaction, achievement, and motivation. *Instructional Science, 33*(2), 105-119.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Watt, D., & Roessingh, H. (1994). Some you win, most you lose: Tracking ESL dropout in high school (1988-1993). *English Quarterly, 26*, 5-7.

Webb, N. M. (1991). Task-related verbal interaction and mathematics learning in small groups. *Journal for Research in Mathematics Education, 22*(5), 366-389.

Webb, N. M., Baxter, G. P., & Thompson, L. (1997). Teachers' grouping practices in fifth-grade science classrooms. *Elementary School Journal, 98*(2), 92-113.

REVISITING “TELEVISION FOR SOCIAL EDUCATION”

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Now faded from the public memory, an insightful “Social Education through Television” sponsored by UNESCO, telecast by AIR-TV Delhi received by about 70 community TV sets constituted nascent beginnings of the history of educational TV in India. Conceived as a citizenship education project, this social experiment aimed to educate and inform the public on topics related to public health, sanitation and civic behaviour. In today's world of numerous commercial satellite TV, prolific use of ICT in education, the effort may look archaic, but when information communication technologies (ICTs) per se are euphorically projected to provide access to the new technologies and thereby improve education, foster citizens' participation and open new economic opportunities, it is imperative to revisit the enchantment and elation educational television, Aladdin's lamp sans genie, offered for education five decades ago. The paper critically evaluates this public educational experiment drawing lessons for contemporary times.

INTRODUCTION

Television promptly evokes the images of entertainment, tinsel, glamour, sex, violence, consumerism and in the recent past hate speech and intolerance. Fashion, lifestyle, sports particularly cricket, gadgets and celebrities dominate the television times and even news segment. Yet in its nascent years even while entertainment and recreation were part of the agenda, TV was public service oriented was and educational.

To deflect the charge that TV will inevitably have a ' corrupting influence' on the society and culture, leading to indolence, early defenders argued for education and not entertainment as the primary goal of television (Briggs & Burke, 2010, p. 228-29). Japan NHK introduced a separate educational channel in 1957; USA FCC reserved more than 200 TV stations for educational broadcasting in 1952. Swedish TV of 1947s, 'heavy' with education and science content, was partly financed by the Swedish board of education. Television was deployed for spreading adult education in post-war France (Dumazedier, 1956), National Education Association of US advocated use of TV for instruction (NEAUS, 1958) and TV was seen “to help teachers accommodate the rapidly expanding student bodies in all institution” (NRC 1957; iii); and as an answer to 'teacher shortage' (Martin 1959; Whaley 1957). The third international meet of the UNESCO took note of the growing clamour for use of TV for education and promoted Instructional TV.

Galvanised by the UN General Assembly Report which pointed out that then, 70% of the world's population had inadequate access to information, calls to improve mass communication systems of underdeveloped countries were made. Positing that 'backward attitudes' were the impediments and that mass media such as TV can engender major behavioural change and thus entice and enrol publics for 'development', an avowed goal of the nation-states such as India, the case for television was made (see Schramm 1964 for a contemporary imagination).

Early decades of Indian television, was marked by communication experiments such as '*citizenship education project*' in 1959, massive '*Delhi School Educational Project*' of 1961 which had a reach of one and a half million students in nearly three-hundred Delhi Secondary Schools (Mathur, 1960; 1961) and *Delhi Agriculture Television* (DATV) Project (*Krishi Darshan*) in 1966 using television (Sharma & Singh, 1972). This paper revisits the enthralling history, which has faded from contemporary memory, to garner lessons for contemporary times when again with the ubiquitous ICT devices, gaming software, cloud sourcing and internet, technology is seen as the 'silver bullet' curing all the ills of education.

Arrival of Television

Although the invention of television is ascribed to John Baird in 1924, it was the erstwhile USSR that commenced regular TV broadcast in 1931 and by 1938 there were two regular full-fledged TV stations telecasting programmes on a regular basis. The Britain followed in 1936 and the BBC was established. While the first TV station in US was established in 1939, the commercial broadcasting began in 1948.

Concern for expending precious foreign exchange towards what was seen as expensive 'toy', fear it becoming a conduit for electronic imperialism (Ohm, 1999, p. 77-78*)*and perceived as morally 'corrupting' medium promoting indolence[1] (Roy, 2008, p.31) clamour for introduction of television in India was resisted for long. However India stumbled into TV when Philips, participated in a trade exhibition organized at Delhi in 1955 and demonstrated TV. As their initial effort to set up a commercial TV in Bombay[2] using the production and transmission equipment like camera and small transmitter imported for the exhibition was thwarted by the Government stating that only AIR[3] had the monopoly for radio-TV transmission in India, Philips came forward to donate the 21 receivers and sell other equipment at subsidized cost to AIR.

Thus a TV unit under the AIR was established, AIR-TV was born and experimental transmissions were conducted during 1958 using the low power transmitter, a mast of just about 80 meters height, reach of just 25 kilometres and just 21 TV sets installed in the houses of bureaucrats and senior minsters. The regular transmission commenced on September 15, 1959 but the telecast was limited to duration of 60 minutes on two days of the week, during which 40 minutes were devoted to educational aspects and 20 minutes to entertainment items in variety of formats. Bhaskar Ghose, who later come to head Doordarshan, reminiscing his childhood days as a child of a senior bureaucrat provided with a TV at home, recalls with amusement and with a tinge of presentism, that his early memories of television included listening to music on television; the accompanying video of the gramophone playing it (Ghose, 2005, p.22). The fare was a melange of *Krishi Darshan* (agriculture educational programmes), school educational programmes, Film Division's cartoons, Films projected on to a screen and captured by the TV camera and live telecast of puppet shows etc. performed by the Song and Drama unit of the Government.

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1 'Frivolity is all the country is going to get if television in India is going to pay its way', said an newspaper (cited in Dizard, W. P. 1966)

2 Now 'Mumbai'

3 All India Radio, a public broadcast service established by British

Project: Citizenship through Television

Vikram Sarabhai (1969), architect of India's satellite communication experiments, famously argued that backward countries can and should tap the most advanced communication technologies including television for leapfrogging into rapid economic growth and social transformation. Dr. Rajendra Prasad, the President of India in his inaugural speech stated that he "*hope[d] television will go a long way in broadening the popular outlook and bringing people in line with scientific thinking*" (JSIR 1959, p. 454). The conference of UNESCO held at Delhi during November 1956 also suggested that member states, in particular India to commence pilot project of using Television as a medium of education. These being the policy guidelines, once the AIR-TV had acquired experience and expertise to conduct regular TV telecast, it chose to use TV for education rather than yield to middle class clamour for entertainment.

The proposal '*Citizenship through Television'* made to UNESCO way back in 1956 by AIR stated that "*pilot project will be set up....for experimental television unit to conduct investigations in the techniques of transmission, reception and the also production so that the experience gained by this project may be made available to member states in south and South East Asia*". India was seen to share with other Asian countries, teeming population, rampant illiteracy, 'conservative' social norms, it was expected that the lessons learned in Indian experiment of the use of TV for social communication could be transposed to other Asian Countries.

The proposal was accepted in 1958 and the actual implementation commenced in 1959. UNESCO provided a grant of 20,000 dollars to produce programmes that would help improve urban and rural conditions especially with respect to adult literacy, health education and promotion of community recreational activities. In a small way the programmes were also expected to act as educational TV for schools. The experimental project commenced on 23 December 1960 and was continued until 5 May 1961.

The project implied that the specific TV programmes would be designed and developed on the themes such as *Traffic and Road Sense*: *Dangers to Community Health*: *Adulteration of Foodstuffs*, *Drugs*; *Manners of a Citizen*; and *Encroachment of Public property and Town Planning* with the objective of informing and educating. Further it was envisaged that the TV receivers would be placed in a location accessible to public such as schools and the whole community would be invited to watch the programmes during the scheduled telecasts. Rather than passive viewing, 'tele-clubs', consisting of select adult members from the local community were to be organized. The tele-clubs were expected engage in discussion and dialogue subsequent to the wathing the telecast of programmes so as to internalise the messages of the programmes. Keeping these objectives in mind programmes were designed to add to the information of viewers on these topics, to influence, if possible, their attitudes towards various aspects of these issues and to encourage follow-up group action and behaviour. The project also stipulated that proper evaluation would have to be conducted to evaluate the impact of the medium and asses the usefulness of TV as a mass medium for social education, and hence a pre-project baseline survey and post project 'impact' was conducted and the project was evaluated on number of parameters (Saksena, 1960; Mathur & Saksena, 1963)[4].

4 All the references to the evaluation of the project in this paper unless stated are from this comprehensive documentation.

By the time the project commenced in 1959 AIR could source additional 71 TV receivers (in addition to 21 that were already installed for home viewing in senior bureaucrats residences). Locations were selected in the urban and semi-urban localities in and around the Delhi municipal corporation by involving civil society organizations, adult literacy advocacy groups and municipal officials for placing the community TV receivers. These location were neither posh upper class areas nor were marginalized poor; but consisted of largely aspiring lower middle class citizen. Usually the local higher secondary school was favoured for locating the community TV receiver, as they were common secular space accessible to all and the receiver could be kept secured. Further the same TV set could also be used by the school students for receiving the school TV programmes. Due to novelty of television, in the initial days it was popular and overcrowding[5] was the norm. However as the novelty waned with time the attendance was uneven, and stabilized in the range of 150-300 per location.

The three elements of tele-clubs were watching the TV broadcast, regular discussion and follow-up activity. The enrolment in the tele-clubs was although voluntary the facilitator of the tele-club was expected to actively recruit members for the club. The facilitators, who were mostly civil society activists or adult literacy officials, were advised to visit the locality, talk to people and urge 'important' people from the locality to be associated with the tele-club, not so much to accord any special status to them, but to ensure that no hostility or ill feeling is not aroused due to imagined neglect or slight. Further they were to contact all civil society voluntary groups such as social committees, cooperative society, office bearers of community centers and people connected with educational centers and seek their membership. There was a conscious effort to make the composition of tele-clubs mirror as far as possible the local society in-terms of vocations and effort was made to keep the age spread such that the members could freely discuss amongst themselves without deference to elders or indifference to youngsters[6]. It was ensured that the members of the tele-clubs is not dominated by school or college going youth or unemployed youth. Thus the composition of the teleclubs were largely males, middle age and upwardly mobile middle class engaged either in government employment of professional vocations.

The convener of the tele-clubs recorded the proceedings and a report was sent to TV Unit of AIR. Often tele-clubs sought additional information and clarification and at times also voiced critical opinion differing from the experts who 'talked' to them through the TV screen. Even government employees at the lower rungs of the establishment were as vocal as 'public' in voicing critic of the governance.

Dilemmas of Programming

The serials that were produced and telecast as part of this project were *Chalti Duniya* -Traffic and road sense, *Hazaar Niyamat* -Good health is thousand blessing, *Asal aur Naqual* – on adulteration of food stuff, *Lakshaman Rekha* – encroachment of public property, *Ghar aur Bahar* – manners of a citizen. Perceived intent of the project being informing and educating, the dilemma of the imperative for presenting dry facts and the need to infuse artistic and aesthetic television production value, was pervasive. Take the case of the serial in 'community health'. The serial were expected to educate the viewers with the health laws, health administration system and the role of various staffs deployed and inform citizens about

5 One tele-club even reported attendance of 1000 people.

6 The project was acquiescent to the tradtional Indian social ethos that demand not speak or voice contrary opinion in presence of the 'elders'.

vaccination, inoculation, sanitary measures and medical care facilities provided through public funded dispensaries and hospitals. In addition scientific information on how contagious diseases spread, care that one needs to take with regard to food and clean water and statistical data on health issues were provided through the programme and the citizens were to be extolled to take active part in the civic life by way of keeping their living environment clean and healthy.

Shooting such programmes was not easy. Jai Chandiram who returned to India in 1961, with training in TV from England, recalls how they had to struggle to get live demonstration recorded with the basic of studio equipment that was available with AIR-TV. She says "*...for demos on the nature of light, we found that the studio window between 4:00 to 4:20pm gave us the rays of the sun to go through the prism and demonstrate VIBGYOR. What an achievement, catching light and going live!...The technical staff, Madan Mohan, Mr. Desikachar and others were fully involved in finding solutions to record these simple experiments....*" (Chandiram, 2009)

The programme producers came up with number of creative solutions to meet this challenge. Early TV shows were influenced by Radio format as most script writers and producers were drawn from the talent of AIR, and a style akin to the radio-drama was adopted and adapted for the television. Fictionalized story of a 'typical Delhi family' was made as the peg and realistic situations were interspersed with facts and figures presented thought charts, films and diagrams to communicate information. Various the broadcast narratives such as features, talks, plays, were incorporated deftly into the programme production. Studio drama was blended with actual reporting and shots from the field.

In the plot development of such dramatized episodes, protagonist or a character usually tended to convey the 'message', often becoming a character to exhort, rattle information and facts like a sermon, making the programme dull and drab. Scriptwriters had to be mindful and a lively stock character, *Shanka Prasad*, a sort of doubting Thomas, eccentric and curious, was contrived. Mirroring the intuitive feeling of ordinary citizen, often in the initial part of the episode, *Shanka Prasad* sounded cynical of the officials and schemes, but interaction and dialogue with experts converts him into a protagonist for reform and development in the latter half of the episode. Further, the real life experts, such as food inspectors, doctors and nurses were weaved into the fictional narrative and made to 'act' a part in the television play. Moreover innovative narrative drawn from traditional drama troupe such as allegorical play '*prabodha chandrodayasya udaya',* which attempted to communicate profane philosophical ideas through the medium of performing arts, were harnessed. In a sense these were forerunner to 'development soap opera', *sans* 'soaps', treating the audience as discerning rational person, rather than attempting to manipulate from a behaviourist perspective. Unlike today's Doordarshan and AIR with heavily Sanskritised Hindi, it is interesting to note that there was no hesitation to use the colloquial 'boli' Hindi spoken in and around Delhi, with a fair proportion of Urdu words and expression, perhaps contributing to its positive reception and acceptance amongst the audience.

Television for Social Change

While informing and educating, the tele-clubs were anticipated to become of agents of social change. The tele-club members persuade the people for inoculation; they undertook testing of adulteration of milk and other products as described in the TV episode and acted like a watchdog. The tele-clubs also informed the citizens in the locality about the role state institutions such as Municipal Corporation and health department should play to provide public health and sanitation facilities in their habitation. Tele-clubs extolled people to draw benefit from the amenities provided by the government institution as well as voice dissent when the governance failed. Thus the tele-clubs became a bulwark for creating public demand on the governance institutions.

On an average the 60 to 70 reports were received by the AIR TV unit every week indicating the earnestness of the tele-clubs. The level of enthusiasm shown by the tele-clubs impelled the AIR to commence a reprographed fortnightly periodical "*Teleclub pathrika*" providing space for the tele-club members to share their ideas and indulge in a *Hebermasian* dialogue with experts and state officials. The *patrika* became a printed publication very soon and carried cartoon, illustration and even extract from programme scripts apart from practical information useful for the tele-clubs.

Tele-club supervisor at the AIR TV abstracted the questions and clarifications sought by the tele-clubs and passed it on to the experts and government officials for suitable response. The responses were telecast next week. Some questions were simply seeking additional information like "what is the procedure to sell a vehicle registered in one's name to another?"; "is it possible for women to get professional driving license". There were also curious and inquisitive questions such as "is there vitamins in rice?"; "is there any difference in the nutritive value of cow and buffalo milk?" Some were voicing dissent and criticism 'Master plan of Delhi is not for the lower middle class at all...[does not consider] practical difficulties of lower income group in the community".; "to be very enthusiastic about modern architecture may not help us to change the face of the Delhi for better. Delhi is a historical city...[we should not turn] Delhi into another Chandigarh." In the initial period clarifications and explanations were obtained from experts/ officials and narrated by the TV anchor; however later the project team decided to confront the officials directly and answers were recoded and telecast as part of the programme, bringing a sense of transparency and responsive governance. Such feedback influenced the content of the programming too.

The tele-clubs were imagined to be the bud, from which the modern citizen civic bodies would flower, transcending the old social divisions of caste, region, religion and language. Meaningful opportunity for public action that the tele-clubs provided was crucial for public mobilization in tele-clubs. Along with the obligation placed on the coordinator to undertake some follow-up, possibility of their club being mentioned in the *Patrika* galvanised the clubs for civic action. Delhi, having attracted migrants from various parts of the county was to be nurtured into a cosmopolitan exemplar for the new India that was to emerge[7]. However the bureaucracy were cynical and were not expecting any useful sustained follow-up activity on the part of the tele-clubs. To their utter surprise and perhaps alarm, most tele-clubs became responsive vocal and demanding. The project showed albeit in a small way that passive pedagogic activity could be endangered also as a communicative collective social action for development.

DISCUSSION

Dominated by the behaviourist media theories, during 1960s, it was argued that the social problems can be solved through the enlightened application of expertise. Behaviourist social science and technology were seen as a means to bring in 'development' of underdeveloped sections of the society and the institutions such as public broadcasting were seen as an

7 A particular tele-club noted that the municipal sweepers felt unwelcome by other white collar workers; reality of caste was staring at the face.

instrument of the 'third force' that could assist the enlightened application of 'behavioural sciences' effecting social change. It is in this background that the Carnegie Commission on Educational Television (1967) suggested potential of TV “as a broad vehicle for public enlightenment and social amelioration, makes us better citizens.” (Killian, 1967)

Revisiting the project of 'social education through television', embedded in this behaviourist media ideology is important in current context where it appears not possible to imagine television in any other way other than commercial private media driven by the chimera of TRP. Radically differing from even the then television deployment elsewhere, treating TV receivers as consumer goods and TV viewing as leisure to be enjoyed in the company of the family, the project boldly emphasized community TV viewing and the community ownership of TV receivers.

The topics identified and communicated under this project were locally relevant for then fast expanding urban area like Delhi, highlighting the potential of spread of epidemic in over-crowded city spaces. Issues such as adulterated food, a burning issue in those times, need for 'discipline' in an Industrial society, public hygiene related issues like spitting in public spaces as well as etiquette required for harmonious urban living along with the fears of nation-state towards 'unruly mob' encroaching public property were the main themes identified for 'citizenship education'.

Although as the project progressed a section of the tele-club members, in particular people with higher educational level, stopped attending, on an average the post viewing discussion lasted for 28 minutes with about 70% of the tele-club members taking part in it. The official baseline survey and a terminal survey of 20 clubs and their 418 members measured the impact of 20 special telecasts and found that the “greater success was realised in bringing about shifts in information than in attitudes” (Mathur & Saksena, 1963). However, the 'attitudes' of the tele-club members saw shift not in the directions that the state anticipated but in different directions. One of the consequences of the project was that taste of the members of tele-clubs could be cultivated and they came to regard TV as an engaging but primarily a serious medium. To great extent the tele-club members eschewed flippancy, and welcomed programmes that promoted a lively and stimulating discussion.

Although programmes were primarily pedagogic, imparting information to viewers they also contained deliberative elements that enabled the tele-club viewers to critically examine their living conditions and promoted 'critical consciousness'. While the aim of the programme was to instil citizen responsibility, the programmes could not overlook common complaints and grievances of the citizens. In the course of the project it became clear that it was the “question-answer” item at the end of every episode, wherein the expert/official was made to answer, was vital to its success, so much so the duration of this segment was increased from five minutes to ten minutes.

The candid discussions in the tele-clubs upset and unsettled some of the bureaucrats who viewed citizens as 'children' needing chaperoning sought to use mass media, including TV, as a social control tool. They were weary of the tele-clubs becoming a forum for ventilating grievances and constantly criticizing government and authorities. AIR-TV programme producers had to walk a tight rope and had to guard against ceaseless sermonising on the one hand and thoughtless criticism on the other. In short the experiment turned out to be a “community experience in the democratic process”.

Until 1972 when the Bombay TV was established, Delhi TV remained as the only television station in India. For many years, TV sets were not available in the Indian market, as there were import restrictions and they could be obtained only from the stock of AIR or from the additional sets made available by UNESCO. Slowly and steadily, as the number of home TVs grew, the middle class demands for entertainment could not be ignored. City-viewers failed to appreciate the educational programmes, which they came to see it with amused distaste and with antipathy as it took up a daily slot on the only channel available to them. Over a period of time when the privately owned sets became so dominant, the nation-state shed the pretensions and Indian TV succumbed to 'commercialization', without any real 'public broadcasting' left worth its name.

References

Briggs, A., & Burke, P. (2010). *Social history of the media: From Gutenberg to the internet.* Cambridge: Polity Press.

Chandiram, J. (2009). Untold stories of the Doordarshan years. *The Hoot*, September 14, 2009.

Chaudhuri, A. K. (1955). Television for India: A plan for television in India based on a study and analysis of world television systems. Doctoral dissertation, Ohio State University.

Dizard, W. P. (1966). *Television: A world view.* Syracuse, NY: Syracuse University Press.

Dumazedier, J. (1956). *Television and rural adult education: The 'tele-clubs' in France*. Paris: UNESCO.

Ghose, B. (2005). *Doordarshan days*. New Delhi: Penguin Viking.

JSIR (1959). Television service: The inauguration of the experimental television (TV) service of the All India Radio. *Journal of scientific and industrial research, 18*, 454.

Killian, R. J. Jr. (1967). Public television: A programme for action: A Report of the Carnegie Commission on Educational Television. New York: Bantam Books.

Martin, P. (1959). Television: Answer to teacher shortage. *The Rotarian,* July.

Mathur, J. C. (1961). First steps towards educational television, *EBU Review* (Geneva), *No 69B* September, 47-50.

Mathur, J. C., & Saksena, H. P. (1963). Social education through television, An All India Radio-UNESCO Pilot Project. *Reports and Papers on Mass Communication, No. 38*.

Mathur, J. C. (1960). Television in India. *International Communication Gazette*, *6*(2), 249-254.

NEAUS (1958). Television in instruction: An appraisal. national education association of the United States: Dept. of Audiovisual Instruction.

NRC. (1957). The use of films and television in mathematics education. *National Academy of Sciences Research Council Publication no 567.* Washington: NRC.

Ohm, B. (1999). 'Doordarshan: Representing the nation state'. In Bosius C and Butcher M (Eds.), *Image Journey; audio visual media and cultural change in India* (pp 63-98). New Delhi: Thousand Oks, London Sage.

Roy, A. (2008). 'Bringing up TV: Popular culture and the developmental modern in India'. *South Asian Popular Culture, 6*(1), 29 – 43.

Saksena, H. P. (1960). Community organization in social education: A conceptual analysis. *Indian Journal of Adult Education*, *Vol. 21*(10), 9-14; 15-21.

Sarabhai, V. A. (1969). *Television for development.* India: Rajratan Press.

Schramm, W. (1964). *Mass media and national development: The role of information in the developing countries* (Vol. 117). CA: Stanford University Press.

Sharma, S. K., & Singh, J. (Eds.). (1972). *Television in agricultural transformation*. New Delhi: Indian Council of Agricultural Research.

Whaley, R. M. (Ed.). (1957). *Proceedings of Southern California Industry-Education Conference*, National Academy of Sciences, Publication no 591. Washington: NRC.

IMPACT OF PARENTAL SOCIO-ECONOMIC FACTORS ON STUDENTS' PERFORMANCE IN JEE-IIT EXAMINATIONS

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Impact of socio-economic factors (SEF) has always been a matter of debate on students' academic performance. Earlier studies established relationship between SEF and students' performance in examinations arguing that students from low socio-economic background lagged behind as compared to the students from economically high socio-economic families. However, there are also arguments who ruled out this notion. Therefore, this paper attempts to examine the impact of parental SEF on the student's performance in IIT-JEE Examinations, which is considered one of the tough and esteemed examinations for engineering admission in the India. Although, there are some limitations of the analysis due to paucity of time series data of the relevant attributes. The analysis shows that parents' income and level of parents' education unlikely influence the performance of students while parents' profession like engineering shows a positive influence on the students' performance in JEE-IIT examination.

INTRODUCTION

Joint Entrance Examination (JEE) is one of the prestigious examinations which is conducted every year for admission in undergraduate courses in engineering and technology in different National Institute of Technology (NITs) and Indian Institute of Technology (IITs). More than one million students appeared every year in the JEE examinations out of around 20,000 students qualified for the admission in IITs for different streams of engineering and technology courses. The volume of students appeared in the examinations shows a high degree of competition where success ratio is very low nearly 1:60 which leads to a tough competition. To get admission in IITs is a dream of most of the science students that prompts to do coaching in privately managed institutions. Consequently, the private coaching institutions are mushroomed in almost all the big and small cities such as Kota, a small city of Rajasthan which emerged a big coaching hub for engineering and medical aspirants. It was estimated that in Kota only there was an Rs 300 crore coaching industry during 2012-13, where 1.5 lakh students took coaching for cut-throat competition to crack IIT-JEE (Mishra, 2013). As a result, the coaching for admission in the IITs and other premier engineering colleges has acquired the status of a big coaching industry in India. According to the Associated Chambers of Commerce and Industry, the size of the coaching industry was about Rs 10,000 crore during 2008. ASSOCHAM's conclusion was based on the assumption that six lakh students attend engineering coaching classes every year and the average cost for each student was Rs 1.7 lakh (TOI, 2008). These estimates were only for preparation for admission in IITs and other engineering colleges. Apart from there are coaching institutions for the preparation of GATE, CAT and other competitive examinations such as Banking, Staff Selection Commission (SSC) and Civil Services examinations. Thus the magnitude of coaching industry is very big with a huge potential in future due to increasing volume of potential students for such competitive examinations. The demand for private coaching to get admission in IITs and other institutions raised a strong debate on the fairness of such examinations as underprivileged students are unlikely getting an equal opportunity for admission in these premier institutions.

Sociological studies established a relationship between family's socio-economic status and the academic performance of children (Sparkes, 1999). The socio-economic factors like ethnicity, parental educational attainment, parental income type, housing type and student age as reflected by school level were found statistically significant variables and predictors of academic performance. However, it was also argued that family's socio-economic structure, the main source of family income and geographical location did not significantly predict variation in school performance of the students (Considine & Zappala, 2002). It was found that the academic achievement was influenced by the socio-economic status and those who aspirants belonged to high socio-economic status showed better performance (Ahmar & Anwar, 2013). Chandra and Azimuddin (2013) also argued that there was a positive correlation between SEF and academic achievements at secondary level students. Although, there are arguments both in favour and against the association of socio-economic factors with performance of the students. This leaves fair scope of further analysis of the hypothesis whether SEF and performance of students are associated statistically. So, this paper attempts to analyse the influence of socio-economic factors on the performance of aspirants in IIT- JEE examinations.

RELEVANCE OF THE PROBLEM

Several earlier studies established that the distribution of personal incomes in society is fairly related to education of the people (EFA Global Monitoring Report, 2005). Studies from the United States highlighted that there was a direct and fair correlation between test performance on earnings (Mulligan, 1999; Murnane et al., 2000). As there were arguments in the earlier studies in support of positive relationships between socio-economic factors and students' performance in the examinations. Therefore, this issue needs to be addressed, as large number of aspirants for IIT-JEE and other similar examinations are coming from small towns and rural areas who generally do not enjoy required economic assess. As a result, aspirants from economically underprivileged class are supposed to be at disadvantage in the cut throat competition for admission in country's such premium engineering institutions. The analysis could be useful for the policy makers as well as students writing for IIT-JEE examination and similar other competitive examinations. The analysis could be able to high light the issues of emerging trends of private coaching for competitive examination. This is relevant as the issue is frequently discussed that such practices are not in favour of fair chances of success to all the aspirants to get admission in various entrance examinations such as IITs which are comparable premier institutions globally.

EARLIER CONTEXTUAL STUDIES

A family's socioeconomic status is based on family income, parental education level and parental occupation which affect performance of students (Okioga, 2013). This implies that students from high socioeconomic status often have more chances of success because they have access to a wide range of resources that help them to promote and support in their education and development. The parents of such students able to provide their young children with high-quality care, books, and other various learning resources like private coaching in addition to regular school education. In a study of American students it was found that parents' involvement affect child's education, however, there could be a debate on definition of involvement (CPE, n.d). Apart from parents' years of schooling was also found to be an important socioeconomic factor to take into consideration in both policy and research when looking at school-age children (Davis-Kean, 2005). Studies were also conducted to analyse linkages between academic performance of students' and their family's SEF and a positive correlation was found between the attributes.

Amutabi (2003) discussed the impact of socioeconomic status on children's readiness for school. Mayer (2002) argued that parental income is positively associated with a wide range of children's outcomes. Mayer's report advances beyond simple analyses of the connection between parental income and children's outcomes by focusing on research that attempts to separate the effect of income from the effect of other potentially confounding variables. The report provides estimates of the effect of parental income on a range of children's outcomes to try to determine the magnitude of such effects (Mayer, 2002). American Psychological Association (2001) discussed the relationship of family socioeconomic status to children's readiness for school. Charles Kombo Okioga (2013) claimed that across all socioeconomic groups; parents face major challenges when it comes to providing optimal care and education for their children. For families in poverty these challenges could be difficult. Ominde (1964) found that even in families with above average income parents often lack of time and energy to invest fully in their children's preparation for school, and they sometimes face a limited array of options for high-quality child care both before their children start school and during the early school years. This indicates that families with low socioeconomic status lack the financial, social, and educational supports to their children. Therefore, poor families may have inadequate or limited access to resources that may help to promote and support their children's development and school readiness. Moreover, parents may have inadequate skills for such educational activities and they may lack information about their children's future career and professional exposure. This adversely affects performance of the school/college going students. Therefore, inadequate resources and limited access to the resources likely have negative effect on young children's development, learning and their academic performance. Thus inferences can be drawn that children from families with low socioeconomic status are at greater risk of getting admission in IITs and other premier institutions through competitive examinations and deprived of better schooling and good education except few exceptions.

RESEARCH METHODOLOGY

To analyse influence of parents' SEF like education, profession and income on students' performance in IIT-JEE examinations simple statistics of mean deviation (MD) and standard deviation (SD) techniques were applied. Both techniques are widely accepted for examining variability between dependent and independent variables. Variability between variables conveys certain kind of information that illustrates strengths and weaknesses of linkages between dependent and independent variables. Statistical measures of variation are used frequently for quantitative and qualitative variables. Accordingly, statistical variance approach is used to examine effect of prominent SEF namely parents' education, occupation and income on their children's performance in IIT-JEE examination. Data for the purpose was collected from various Reports of the Joint Implementation Committee by IITs. The Mean Deviation and Standard Deviation (σ) were calculated by using the following formulae respectively:

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

where $x_1, x_2, \ldots, x_n$ are variable and $\bar{x}$ represent mean of variables.
The Standard Deviation (σ) was calculated using the following formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

S.D. is a measure that is used to quantify the amount of variation or dispersion of a set of data values.

DATA ANALYSIS AND DISCUSSION

Descriptive statistics tools namely Mean deviation and Standard Deviation were used to analyze the collected secondary data regarding parental income, occupation and education of the successful students in IIT-JEE entrance examination. The data was collected from various years JEE (Advanced) Reports (JEE, 2013; 2014). Every year more than one million IITs aspirants appeared in the examination. The aspirants comprise students from all socioeconomic strata which make data unbiased and random. The collected data was analyzed with the help of SYSTAT (1988) statistical package and respective result are given in Tables-1, 2, 3.

Range of Parents' Income	Mean Deviation	Standard Deviation
< 1 lakh	12.900	8.397
1-3 lakh	7.827	4.926
3-6 lakh	27.065	18.490
6-10 lakh	19.207	11.839
> 10 lakh	19.360	14.170

Table 1: Mean deviation and standard deviation for different range of parents' income

Level of Parents' qualification	Mean Deviation	Standard Deviation
Both Graduate	32.050	24.326
One Graduate	15.705	18.816
Neither	9.880	11.795

Table 2: Mean deviation and standard deviation of parents' qualification

Parents' Profession	Mean Deviation	Standard Deviation
Agriculture	4.958	3.867
Business	10.625	7.778
Medicine	4.125	1.824
Engineering	3.860	0.987
Law	1.640	1.121

Teaching	3.853	1.703
Government	16.035	15.563
Private	6.008	5.105
Defence	1.490	1.103

Table 3: Mean deviation and standard deviation of parents' professions

Analytical results indicate that parents' socioeconomic factors affect the student performance in the IIT JEE entrance examination. As argued in the earlier studies that parental income, occupation and level of education are directly associated with academic performance of their children, the analysis provides the dissimilar results. Based on the summary findings, it was observed that the performance of those students was comparatively consistent whose parents' income was in the range of 1-3 lakh. Similarly, those students whose both parents were not graduate their performance was consistent in the examination than other students. Contrary, analysis indicates that performance of those students were consistent whose parents' occupation was engineering. This could be obvious as parents with engineering background and occupation encouraged their children to opt engineering as a career since their early schooling. Here, it may be argued that profession of engineering is considered as a noble profession in Indian society as compared to other professions. However, the argument that parents' socioeconomic factors like education level, income and profession affect performance of the students in JEE-IIT examination cannot be declined because maximum number of entrants in IITs are those who took regular coaching from private institution which are very costly. This analysis simple reflects that the performance of under privileged students is fairly consistent. It implies that if students from underprivileged section of society could get good opportunities and resources for their education they could perform better in entrance examination of like JEE-IIT. In this context an example of Anand's Super-30 is much relevant to cite as every year nearly 30 underprivileged students compete the JEE-IIT examinations.

CONCLUSIONS

It may be conclude that the SEF are not vital factors that influence performance of the students in IIT-JEE examinations. Performance of those students was consistent who were coming from low income strata and whose both parents were not highly educated. If they get good opportunities in respect of good schooling and financial resources they could likely perform better in such examinations which are evident from the analysis. However, students whose parents' profession was engineering they could perform better than other students. On the other hand it was observed that students from some selected education boards shown better performance in JEE-IIT examination over the years. This was substantiated by the Times of India report that in 2013, almost 80% students qualified for IIT-Advanced examination came from three school boards only namely Central Board of Education (CBSE), Andhra Pradesh state board and Punjab state board. While, in 2010, 58% qualified from CBSE board, 36% from state boards and 6% from Indian Certificate of Secondary Education (ICSE) board. However, in 2014, CBSE sent 42% students in IITs. Thus the statistics indicates that the IIT-JEE examination is unlikely gives fair chance to all the aspirants from all the state boards as the pattern of examination seems to be skewed towards very few boards. This can be argued that there was a quality divide between the CBSE board and other states boards that needs to be bridged. Hence, there is a need to break the dominance of private coaching institutions and domination of few education boards by integrating uniform syllabus across all the state boards and improving the quality of education.

References

Ahmar, F., & Anwar, E. (2013). Socio Economic Status and its relation to academic achievement of higher secondary school students. *IOSR Journal of Humanities and Social Science, 13*(6), 13-20.

American Psychological Association (2001). *Task force on socioeconomic status*. Report of the APA Task Force on Socioeconomic Status. Washington, DC

Amutabi, M. N. (2003). The 8-4-4 system of education. *International Journal of Educational Development, 23,* 127-144.

Centre for Public Education. (n.d). Back to school: How parent involvement affects student achievement. Retrieved on 18.03.2015 from http://www.centerforpubliceducation.org/Main-Menu/Public-education/Parent-Involvement

Chandra, R., & Azimuddin, S. (2013). Influence of socio economic status on academic achievement of secondary school students of Lucknow city. *International Journal of Scientific and Engineering Research, 4*(12), 1952-1960.

Considine, G., & Zappala, G. (2002). Factors influencing the educational performance of students from disadvantaged backgrounds. In T. Eardley and B. Bradbury (Eds.), *Competing visions: Refereed Proceedings of the National Social Policy Conference 2001, SPRC Report.* Retrieved on 17.03.2015 from https://www.sprc.unsw.edu.au/media/SPRCFile/NSPC01_7_Considine_Zappala.pdf

Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement: The indirect role of parental expectations and the home environment. *Journal of Family Psychology, 19*(2), 294–304.

EFA Global Monitoring Report (2005). Retrieved on 18.03.2015 from http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/efareport/reports/2005-quality/

Joint Entrance Examination (advanced). (2013). *Report of the Joint Implementation Committee*. Delhi: Indian Institute of Technology.

Joint Entrance Examination (advanced). (2014). *Report of the Joint Implementation Committee Volume-1.* Kharagpur: Indian Institute of Technology.

Mayer, S. E. (2002). *The influence of parental income on children's outcomes, knowledge management group.* Ministry of Social Development, Te Manatu Whakahiato Ora, Wellington.

Mishra, S. (2013). Revealed: Inside Kota's Rs 300 crore coaching industry, where 1.5 lakh students brave cut-throat competition to crack IIT-JEE. Retrieved on 16.03.2015 from http://www.dailymail.co.uk/indiahome/indianews/article-2313660/Inside-Kotas-Rs-300-crore-coaching-industry-How-students-aiming-crack-IIT-JEE-join-mushrooming-institutes.html

Mulligan, C. B. (1999). Galton versus the human capital approach to inheritance. *Journal of Political Economy, 107(*6), Part 2 (December), 184–224.

Murnane, R. J., Willet, J. B., Duhaldeborde, Y. and Tyler, J. H. (2000). How important are the cognitive skills of teenagers in predicting subsequent earnings? *Journal of Policy Analysis and Management, 19*(4), 547–68.

Okioga, C. K. (2013). The impact of students' socio-economic background on academic performance in universities, a case of students in Kisii University College. *American International Journal of Social Science, 2*(2), 38-46.

Ominde, S. H. (1964). *Kenya Education Commission Report*. Republic of Kenya. Government Printers Nairobi.

Sparkes, J. (1999). *Schools, education and social exclusion. CASE Paper 29*. London: London School of Economics, Centre for Analysis of Social Exclusion.

SYSTAT, SYSTAT Inc. (1988). 1800 Sherman Avenue, Evanston, IL60201, 312, 864-5670, 1988.

Times of India. (2008). IIT coaching classes a Rs 10k cr industry? Retrieved on 16.03.2015 from http://timesofindia.indiatimes.com/india/IIT-coaching-classes-a-Rs-10k-cr-industry/articleshow/3190000.cms;

EXPLORATION OF MATHEMATICS LEARNING OF SCHOOL GIRLS IN DELHI

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Despite being good at Mathematics right from the beginning the Researcher has often come across the prejudice that 'girls are not good at Mathematics'. After so much efforts put in by the government the same old mindsets still exists even in this era of 21st century. This disparity propagates not only among common men but also among teachers, parents and students themselves. So this action research is a small way of finding something related to Mathematics learning affected by gender perceptions. The paper summarizes a large number of lived experiences that the Researcher has gone through in her life as she is not only a researcher but a practitioner (senior secondary school teacher) as well. This study was undertaken to explore gender perception in Maths learning.The study sensed many dimensions of the relationships between gender and Mathematical learning viz. girls self concept, their socialization, Maths pedagogical issues, thinking pattern, role of teachers etc through semi structured interviews with Kendriya Vidyalaya students, parents and teachers. Comparisons were made in the performance of students in CBSE conducted board examination and sample examination paper prepared by the practitioner. Further, a deeper comparison of girls performance in regular examinations and in Maths Olympiad was done to arrive at conclusions.

INTRODUCTION

Prejudice of girls having taken the rear seat in Mathematics appears a reality. The belief has found many takers in the society as they encourage a girl-child to ignore Mathematics after her class XII and in some cases even after class X. It is further supported by the fact that fewer girls opt for Mathematics as an optional paper in Civil Services Main Examination. The data from UPSC Civil Service Examination 2014 shows that boys to girls ratio who opted for Mathematics as the optional subject stood at 19:1 against the overall boys to girls' ratio of 3.39:1.

Being a student and teacher of mathematics, the researcher has been facing this 'problem' continuously, proving herself time and again by fighting against the mind-set "Girls can't do better in mathematics". This mindset in turn seems to influence the performance and hence, identity of girls. When it is discussed with colleagues and other elementary school teachers, then an important fact emerged that girls perform at par if not better than boys in school/academic Mathematics (i.e. in text book Mathematical problems).

The following are some perceptions that emerged from the discussions of school teachers:

- *"Whenever we ask questions beyond prescribed syllabus or questions related to Intelligent Quotient (IQ) testing, then Boys start outscoring girls."*
- *"Boys perform better in Mathematics as they have higher I.Q"*
- *"Arts subjects are girlish, Maths is masculine subject."*

- *"Girls are meant primarily for Biology, only the right side brain of girls is developed."*

These days the notion of I.Q. is debated. Even if we talk about the intelligent quotient, it is independent of gender or sex then how does such a prejudice come into existence? Mathematics is the subject of logic and rationality by which mind can be channelized systematically. If it is so then does it mean that girls do not have 'power of conscience'? Certainly, the perception of society towards girls' ability to perform in Mathematics is questionable. 'Gender', is not related to biology, it is rather effect of socialization. In Indian context, household discussions may easily lead us to believe girls are trained to think differently than the boys. The famous educationist and psychologist Skinner (1938) has proved that our mind can be conditioned in a pre-determined way. Primary as well as secondary socialization helps in achieving this. While on one hand, Primary socialization has deformed their self-concept gradually; on other hand secondary socialization has created an environment which is different to the boys' environment. For instance girls are given dolls as their playing toy but boys are given 'cars/guns'. Clearly, boys are exposed to engineering skills more in their childhood itself. Mathematics can channelize our mind scientifically and logically.This research paper is an attempt to explore this silent conspiracy against the feminine gender. The Researcher is in search of a solution to the problem outlined above by being in resonance with the underlying concept.

CONTEXT OF THE RESEARCH

The researcher collected data from one of the Kendriya Vidyalayas following CBSE syllabus. The school is run by an autonomous organization – KV Sangathan established 1959 under Ministry of Human Resource Development. It is one of the 1498 schools in India run by it. KV schools are famous for the infrastructure and the excellent results that are produced by their students. The chosen school has about 1500 students with almost equal number of girls and boys.

OBJECTIVES OF THE STUDY

1. To explore the mathematics learning of girls at secondary and senior secondary level of schooling. To find if there are differences between the genders in terms of their conceptual understanding of the subject matter that impacts performance.
2. To find out the reason behind obstacles to mathematical learning if any, that girls face while solving a mathematics problem. To see if there are factors in social environment that deter girls performance in Mathematics ?

REVIEW OF RELATED LITERATURE

The research questions lie in the area of 'Gender and Mathematical learning'. "Gender is not a women's issue but people's issue, as gender is a social construct not biological. It means that gender relations are neither 'natural' nor given, they are constructed to make unequal relations seem 'natural' and can be naturalized only under the dresses of socialization." (Fennema, 2000).

Mathematics is a discipline by which we can strengthen ourselves not only being efficient in numeracy but through logical and rational thinking as mentioned in National Curriculum Framework, (2005). The document also mentions that the output of Mathematical learning is the Mathematization of thinking that encourages students to think in a different manner. A student cannot measure the width of a road but (s)he can judge the same just by lying on the road multiple times and equating with his own height/length.

The NCF, 2005 focuses on "Mathematics is for all and everybody can learn Mathematics". These "mathematical abilities are not innate but are properties acquired in life that are formed on the basis of certain inclinations…… anyone can become an ordinary mathematician" (Orton, 2004, p. 361).

Elizabeth Fennema (2000) in her longitudinal research for thirty years on toppers in achievement cum diagnostic test in mathematics in the age group of 4-12 years found that there are a number of complexities regarding mathematics learning. The complexities are not only related to conceptual understanding but also to variables like mental ability, social barriers, teacher's perception, classroom environment, self-concept and many more. But apart from this, a devastating reality exists that is there is gender gap in Mathematics learning. This gap has been shown by several researches and the data from sources like International Mathematics Olympiad which has been conducting test for extremely talented young students since 1959 over 100 countries. The data from this international evidence clearly shows that only 5.7% (185 of 3246) are female. The rate of qualified female has increased over the years but at a very slow pace (IMO Website) i.e.

1988-1997	7.5%
1998-2008	9.7%
1999-2014	10.8%

In another research in Indian context, Vibha Parthasarathy (1988) remarked that "Girls are poor in Mathematics; Mathematics are for boys; such gender stereotypes are so deeply imbibed that now we felt originally" She highlighted that if a thing is repeatedly done for years, then it appears as a truth and becomes a part of process of socialization. She reiterated the fact that gender stereotypes begin to form at a very early age and social norms set by patriarchal members, acceding women and media are so deeply absorbed by child that they accept them wholly.

If we go into the depth of such 'Mindsets', we'll get certain facts that a girl may feel a conflict between wanting to be seen as a female and doing well at mathematics and mathematics is generally not associated with being feminine (Nosek, Mahzarin & Greenwald, 2002). Even though young boys and girls have generally equal Mathematics ability as they get older, girls do not do as well as boys because they convince themselves that they are not good at Mathematics and being good at Mathematics is more "appropriate" for boys than them leading girls to doubt their ability, consequently, affects their decisions for future enrollment in Mathematics Class (Frenzel, Pekrun & Goetz, 2007).

In another research on the Coloumbia university girl student, the researchers during their calculus course observations found that 'Self-concept' is formed by believing that mathematics is a sort of gift by God. But the danger behind such belief isolates people from the subject's belongingness. Thus, researchers concluded that there is no difference in ability but difference in how students cope with experience that may call their ability into question" (Dweck, 2006).

Benbow and Stanley (1980) and Hill et al., (2010) found that there are several obstacles to mathematical learning for example: social barriers, stereotypes, gender bias and discouraging classroom atmosphere can deter women from pursuing careers in the areas and may explain why there are so few female scientists and engineers. These are controllable and more related to social pressures rather than actual ability and academic performance. However, in Indian context, several socio-cultural conditions like negative attitude of parents, early marriage, after marriage –attitude of husband and in-laws, future perspective, non-working women, and unequal opportunities of boys and girls many more are reflected by Giri's paper (2004).

A survey (2013) was done over 14000 engineers and graduates shows that a girl to boys ratio is as follows:

Applicant	1:2.27(IIT)
	15:100(MIT)
Selection Rate	1.9:100(IIT)

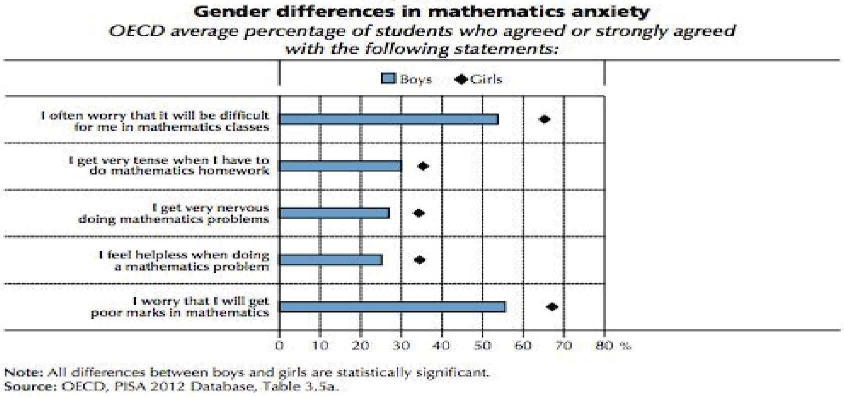

Figure 1: Graph showing gender difference in mathematical fear factor

It is inferred from the data that fewer numbers of girls are applying and even less is qualifying. These again bring back to ponder about issues like: Are there equal opportunities for boys and girls? What percentage of applicants are girls in any competitive examination based on mathematical skills? Whether the paper relates to their own environments ? Is classroom environment conducive to girls?

The review of research in the area of gender and mathematics learning indicated that there are a lot of obstacles to girls' performance in mathematics. With this background the researcher has tried to find answers for research questions.

RESEARCH SAMPLES

A sample set of students, teachers and parents were chosen as follows

Students

Students were chosen from Class XI, with 40 boys and 21 girls.Interestingly, despite the school strength equally distributed among boys and girls, the researcher could find only half the number of girls opting for mathematics in XIth class than boys.This in many senses reinforce the underlying mindset / perception this research is aiming to explore. Students are generally wards of Central Government Employees with transferrable jobs, belonging to lower middle class family, and living within a radius 2-2.5 km from School. The school charges a moderate fee of INR 800 per month with further exemptions for economically and socially disadvantaged students.

In addition, 5 boys and 5 girls of class Xth were also interviewed.

Teachers

2 Male Teachers and 4 Female Teachers, which makes a total of 6 teachers, were selected as a sample. Again, it is interesting to note that generally mathematics teacher would be a female.In other words, finding female Math teacher is a lot easier. Of the six teachers interviewed, 3 belong to Kendriya Vidyalayas from different branches (one each from INA Colony, Janakpuri, and Sector-2 R K Puram). The other three teachers are from a Private school, State government school in Delhi-NCR and third one from Sarvodaya Vidyalaya School run by Delhi Government. The selection of these teachers was made so that teachers from different parts of the city and teaching in different types of schools were chosen. All the teachers chosen in sample have experience of more than five years.

Parents

A total of 6 No of parents were chosen of which Three included those whose wards are in the research sample. The other two are from private school of Delhi-NCR and one from a state school run by Delhi Government. Data is collected from IIT-Kanpur and Guwahati also for comparing the boys to girls' ratio in these premier institutions. Further,Data is collected with respect to ratio of girls qualified in KVS Junior Mathematical Olympiads for last two years organized by KVS Junior Mathematics Olympiads every year. Both quantitative and qualitative data were collected and analyzed to get a comprehensive picture for answering research questions.

TOOLS FOR RESEARCH

The following tools were developed by the researcher:

Semi-structured Interview Schedule: It is an open ended interview schedule which is separately prepared for unstructured conversation with parents, teachers and students.Some exemplars from these interviews are: *"When you go shopping, who calculates faster at the shop—your son or daughter of similar age?"*or *" Do you think, you need to study Maths for your dream career? If yes, would you still opt for that or would you like to change your option?*

Achievement test paper for Mathematics: One previous year Central Board of Secondary Education (CBSE) mathematics paper was chosen and other was prepared by researcher. These two tests varied in terms of nature of questions. CBSE papers primarily contain text book questions with little change in data values and are repetitive with respect to previous years. They will seldom go to check the deep understanding of the subject matter. The achievement test paper contained thought provoking questions as confirmed by five different experts in the field of mathematics as well as the students who took the test. These items are more of practical in nature and led to "Mathematization of Thinking". Some of the questions asked in the paper are given below:

1.In a cricket match consisting of 22 players, the probability that at least two of them share a common birthday lies between 0.45 and 0.5. Am I serious or joking? (4 Points)

2. From a point inside an equilateral triangle 3 perpendiculars are drawn to the sides of the triangle of lengths 3,4,5 cms. Find the area of the triangle. (4 Points)
3. Gold is known to weigh 19 times the weight of water and another metal M is known to be 9 times the weight of water. In what ratio should these be mixed to result in an alloy that is 15 times the weight of water? (4 Points)

Comparative study of results of Olympiad, IIT JEE with academic performance.

PROCEDURE

Both achievement tests for mathematics were conducted in class room setting. Semi structured interview were conducted with teachers, students and parents to know their perception about learner's identity and mathematical learning.

DATA ANALYSIS: ESTABLISHING DIALOGUES WITH DATA

Teachers' View: Out of six teachers interviewed four believed that there is a difference in mathematical ability between boys and girls. One of them said that this difference in ability is seen after third class. Almost all teachers said that boys outperform in mathematical reasoning / logic, calculations and specially visualizing spatial problems. Teachers mentioned that boys do not take interest in any type of projects /assignments but they question over questions and show excitement towards new questions/problems. Two teachers even generalized that projects made by girls are related to kitchen, fashion, households etc. One of the teachers put the onus on the process of socialization mentioning that girls have lesser exposure to real outside world problems like grocery shopping, travelling alone, filling gas cyllinders or paying electricity bills. Boys are frequently exposed to the outer world helping them make sense of directions, calculations, spatial things etc.

One teacher emphasized that there is no difference in performance of mathematics among boys and girls but the way they learn is definitely different. Like "13 year old boys are likely to be more interested in the context or how the concept originated than the same age group girls who tend to focus on real world applications of number theory than in remote abstractions .... To elaborate- if we want to discuss quadratic equation with boys then I must tell what necessities of that concept are.... and I have to start like:
The general form of such equation is $ax^2+bx+c=0$; Procedure of Finding its roots and its applications. But, If I project this concept to girls then I will start like: Think about a rectangular garden in which length is two units more than its breadth and its area should be 24 units.They frame this as $x(x+2)=24$ which implies $x^2+2x-24=0$;

Then boys will not only be excited but also oriented towards quadratic equations".

One teacher mentioned that he found differences in mathematics performance of urban and rural areas but no difference was found among rural girls and urban girls in mathematical ability.

Parents' View: One parent believed that girls have more analyzing capacity which is used in social sciences, literature etc. But in logical thinking and number ability boys are outperformers. Other parent, who is also a teacher linked it with notoriety ('KHURAPHAT') and exemplified through her son/daughter's actual behaviour in tackling mathematical concepts. She clearly explained - how her son tries to understand the concept but daughter tries to memorise the procedure of solving mathematical problem. Most of the parents tried to connect this ability through our social bringing up which for girls is different. Girls are imposed with several obstacles and hindrances of society. One parent explained as "20% of girls are genius and they do not get affected by any kind of hindrances, 50% of them are normal and they are deprived of several opportunities and exposures, and the remaining 30% of them lag by making such 'self-concept". One teacher and parent as well, referred to a news article (published on 8 March 2014 in Times of India) mentioning that *"even C.V.Raman, the great scientist had opposed the progress of a lady scientist in his time. In such scenarios* *confidence level of girls lower gradually".*Two parents mentioned that their daughter is better than their son in maths; But instead of saying that their girls are brighter than boys they attributed success to hard work.

Almost all parents accepted the existence of a type of 'Fear' factor behind learning mathematics or opting mathematics as a career. Parents primarily stressed upon 'fear' which is associated with pass percentage or future career. It is evident from the fact that number of students in commerce without mathematics is more than number of students with mathematics. Teachers also emphasized on fear which is related to confidence level (risk factor) like the type of questions given in exams.

Students' View: During the discussion with students, they revealed that they do have a 'fear' for performance in mathematics which is much higher than compared to other school subjects. Girls stated that they prefer to attempt questions which they had earlier practiced. They "will not take risk in examinations". Girls were more worried about their failure in terms of disappointing their adults but for boys it is a matter of lack of intetrest or knowledge in a specific area. Girls look up to teachers for motivation and emotional support but for boys teachers are facilitator.

PERFORMANCE IN ACHIEVEMENT TEST

It was found that girls attempted more items based on formula whereas boys attempted tricky items. Boys primarily populated the highest range position. Boys also found a lot of entries in the lowest marks range. However, the middle ranges were interspersed with boys and girls which is represented by a graph in Figure 2. While discussing their performance boys blamed lack of revision of concepts whereas girls blamed lack of awareness of pattern.

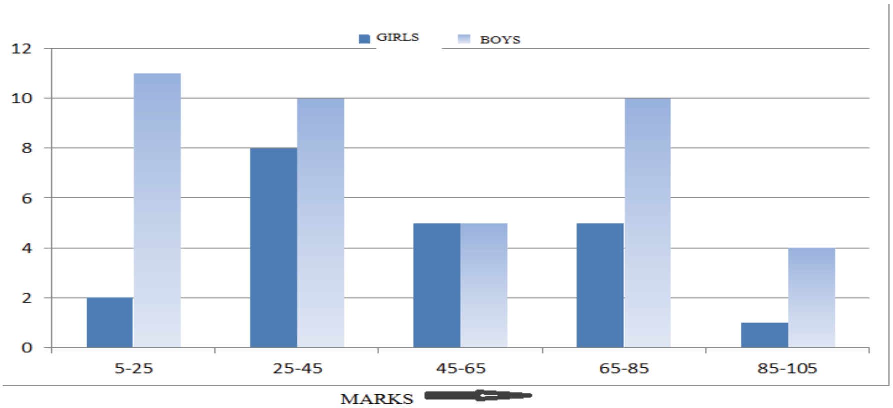

Figure 2:Comparative performance of boys and girls in achievement test paper

CONCLUSION

The above analysis leads to conclusion that there is indeed a striking difference between girls and boys performance in examinations. This also unveils some interesting facts like – Girls do manage to perform occassionally well-even sometimes getting the top rank. However, their position in the ranking charts are often ephemeral. While solving a problem it was evident that there is an inter linkage between gender and mathematics. At the same time, it could not be established that how learning a particular subject can depend so heavily on class of students learning the subject. Also, it does not matter what boys or girls can learn but big difference lies in the method adopted to make them learn. A lot of debate can be held on this, however, it can be easily concluded that ***perspective*** with which a student tackles a subject is gender dependent. Specially when this perspective is enhanced through family, schools and society, with time this perspective gets internalized as a ***"Self- Concept".*** Thus, ***girls' environment and their bringing up*** have been trying to keep them far away from this subject. Reasons for this are many: mathematics treated as 'Masculine subject' not meant for girls, fear of failing in mathematics, anxiety about performance and many others. Secondly, ***evaluation system***, ***thinking pattern, pedagogical issues and role of teachers*** should also be redefined or re-evaluated critically as performance was changed with the change in achievement test.

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References

Aspiring Minds Survey. (2013). Women in Engineering: A comparative study of barriers across Nations. Online report retrieved from http://www.aspiringminds.com/sites/default/files/womenInEngineeringComparativeStudyBarriersAcrossNations_1.pdf

Benbow, C. P., & Stanley, J. C. (1980). Sex differences in mathematical ability: Fact or artifact?. *Science, 210*(4475), 1262-1264.

Department of Education (1986). *National Policy on Education 1986.* New Delhi: Ministry of Human Resources & Development.

Dweck, C. (2006). Is math a gift? Beliefs that put females at risk. In S. J. Ceci and W. Williams (Eds.), *Why aren't more women in science? Top researchers debate the evidence* (pp. 47-55). Washington, DC: American Psychological Association.

Fennema, E. (2000, May). Gender and mathematics: What is known and what do I wish was known, In *Fifth Annual forum of the National Institute for Science Education.* Detroit, MI, USA.

Frenzel, A. C., Pekrun, R., & Goetz, T. (2007). Girls and mathematics—A "hopeless" issue? A control-value approach to gender differences in emotions towards mathematics. *European Journal of Psychology of Education, 22*(4), 497-514.

Giri, S. N. (2004). High achievement in mathematics and the girl child. *Proceedings of epiSTEME-1,* (pp. 114-116). Mumbai: HBCSE.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: AAUW, 2010.

International Mathematics Olympiad Organization (IMO). Details https://www.imo-official.org/organizers.aspx

Mukhopadhyay, C. C. (2004). A feminist cognitive anthropology: The case of women and mathematics. *Ethos, 32*(4), 458-492.

NCERT (2005). *National Curriculum Framework.* New Delhi: NCERT.

Nosek, B. A., Mahzarin, B., & Greenwald, A. (2002). Math = male, me = female, therefore math ≠ me. *Journal of Personality and Social Psychology, 83*(1), 44-59.

Orton, A. (2004). *Why do some pupils achieve more than others? Learning mathematics: Issues, theory and classroom practice.* London, UK: Bloomsbury Publishing.

Parthasarathy, V. (1988). *Socialization, women and education: An experiment.* New Delhi: Orient Longman.

Skinner, B. F. (1938). *The behaviour of organisms: An experimental analysis*. New York: Appleton-Century-Crofts.

UPSC (2013). *Annual Report of 2013*. Retrieved from www.upsc.gov.in

EXPLORATION OF WAYS SCHOOLS AND TEACHERS CAN NURTURE THE NON-COGNITIVE ASPECTS IN CHILDREN

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This note shares our understanding about the 'non-cognitive' domain (as it is traditionally called) within the ambit of school education. It discusses what this domain entails and how it can be nurtured in children. It explores the means through which schools and teachers adapt processes and practices to nurture these essential capacities and dispositions in students. Finally, it proposes the Personal and Social Well-Being Framework, which provides a way for schools and teachers to ensure comprehensive development of children.

BACKGROUND AND RATIONALE

Education while ensuring the all-round development of an individual to lead a meaningful life is also expected to be geared towards ensuring a citizenry with a broader perspective of the world in relation to their individual roles. Holistic development of an individual is a result of interplay of various influences from home, neighbourhood, peers, and society, from childhood. Though all these influences have a considerable part to play in an individual's growth, schools, with their structured approach, are expected to act as a mediator of all these and other influences in a child's life, ideally trying to minimize the impact of negative influences and provide or enhance positive ones.

The role of school, thus, involves providing comprehensive learning experiences for every learner in an equitable manner to ensure their holistic development to lead a meaningful life eventually. Learning in schools then must encompass linguistic, cognitive, moral, emotional, social and physical development. The curriculum forms the basis for schools to venture into taking responsibility of the holistic development of all learners. However, the emphasis of school curriculum that is generally transacted seems to be restricted to mere acquisition of information (vis-à-vis knowledge), and regurgitation of rote memorized facts at the time of examinations, which has become synonymous to education. Subjects like mathematics, science, social sciences and languages are considered core curricular subjects while music, arts and physical education are considered as co-curricular or extra-curricular. This skewed focus on mathematics, science and social sciences are also focused on teaching to the test or exam, most of which predominantly focus on the recollection of factual information rather than on conceptual understanding and higher order thinking based on the concepts in these subjects. The learning of subjects becomes limited to disassociated pieces of information that are mostly not seen relevant to one's context or life. Such a process of engaging with the subjects at a superficial level also results in the capacities and dispositions like creativity, empathy, critical thinking and social responsibility being overlooked. Thus, resulting in the much essential comprehensiveness in education being significantly and systemically overlooked in practice.

This work explores the premise of what constitutes comprehensiveness in school education. This includes unpacking of the so called 'non-cognitive' domain as understood thus far in various studies and attempts. The focus on understanding this domain is to help gain insights and use them to suggest teaching-learning practices – which are integrated to the various aspects of development and learning through the subjects taught, classroom experiences and school processes. This attempt led to the creation of a framework for teachers and schools that would help them to understand, articulate and plan for comprehensive teaching-learning experiences for overall development of an individual.

METHODOLOGY

The exploration began with examining the prevalent beliefs and understanding about childhood, schooling and education in the country. The key ideas about child development and education from the works of Aurobindo, Gandhi, Tagore, J. Krishnamurti, Blooms, Vygotsky, Piaget, Dewey and others were studied. National Policy documents that are based on the Constitution of India, i.e., The National Policy on Education, 1986 (NPE, 1986), National Curriculum Framework suggested by National Council of Educational Research and Training (NCF, 2005) and Right to Education Act (RTE, 2009) aided in further exploration. Alongside these, examining the different studies and programmes world over and in India such as Self-Regulated Learning, Social Emotional Learning Framework, CASEL, WHO Life-Skills and CBSE – CCE helped in understanding the various perspectives and approaches towards inclusion of the 'non-cognitive' domain in schooling thus far and reinforced the importance of nurturing all-round development of children.

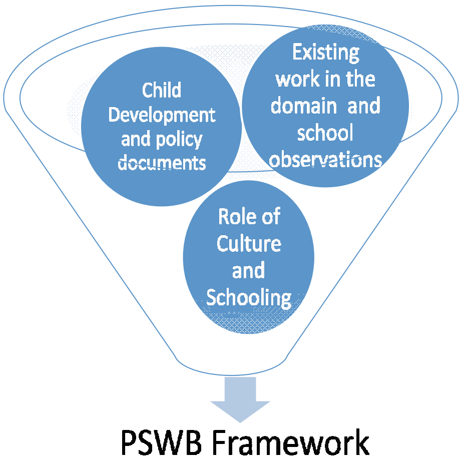

Figure 1: Representation of the methodology

To complement this conceptual understanding with evidences from practice, a process of observing a few alternative (not mainstream) schools was initiated. Student and parent interviews, field notes, conversations with teachers and head teachers and observations in these schools were guided by a set of questions (Box 1). These were analyzed to provide insights into the individual school's educational philosophy, curriculum, classroom practices, student-teacher relationships, teacher planning and involvement, assessments, reporting, community involvement etc. and was documented as a report of learnings. These observations were done at Abhaya – a Waldorf-Steiner School, Sri Aurobindo International Center for Education and Center for Learning and Patha Bhavana and Mrinalini Ananda Pathsala in Shantiniketan for a period of six to eight days, for an average of fifty hours in each of these schools.

1. What is the philosophy or concept of education of the school?

i. *What kind of processes and policies are practiced by the school that reflects the ideology of the school? Does it reflect in the school climate? If yes, how?*

ii. *How is discipline understood by the school? Is it assessed and reported?*

2. What does the school mean by comprehensive education/ all-round development of students?

i. *Does the school differentiate between subjects as scholastics/co-scholastics or curricular/co-curricular? Why/ why not? What is the nature of some of the literary, cultural, art, drama, crafts, sports / games related activities initiated by the school?*

ii. *What are the perspectives of teachers on these activities?*

iii. *What is the methodology of teaching/learning in these subjects?*

iv. *How are students' performances and products in these areas assessed in the school?*

3. How sensitive is the teacher/ adult to the different needs of the children?

i. *Are the teachers in tune with the child's needs as per the child's current developmental stage?*

ii. *Are activities related to co-scholastic areas promoting inclusion and allowing for enjoyment? Or is the environment competitive and favouring exclusion?*

iii. *Are those / how are those needs addressed through a sensitive and nurturing environment? Is there any method of documentation?*

4. Do teachers have independence to decide on issues related to their classrooms, students, any of the school wide issues? Are decisions made collectively with them or for them?

i. *Do teachers have independence / autonomy? If yes, in which areas? Were you able to observe these?*

ii. *What is the observed role of the school leader / HT in the kind of environment (whether nurturing) the school shows?*

Box 1: Questions explored

The personal and social well-being emerged as a conceptual framework with the five domains, indicators and descriptors, teacher practices and school processes. To validate this framework, an ongoing process of school observations was initiated in the Azim Premji School in Tonk. This involved one-on-one interactions, interviews, and school and classroom observations for four to five days every month over a period of six months. These school observations were used to analyse and validate each strand of the PSWB framework. This brought the academic exercise of developing a framework to a practical test-bed that modified and strengthened the proposed framework.

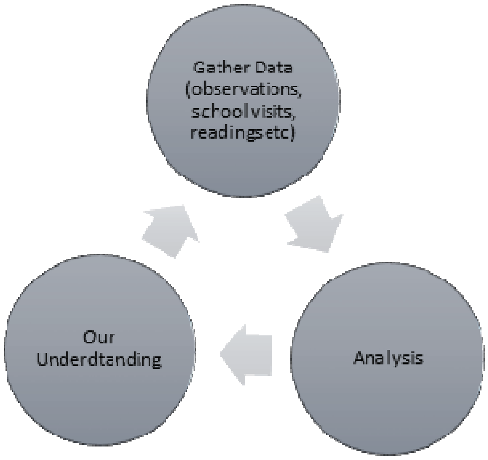

Figure 2: Data-understanding-analysis

REVIEW OF LITERATURE

Childhood is understood and handled in multiple ways across the country, given the variance in family structure, socio-cultural, economic and political settings, birth order, gender, linguistic dominance etc. For instance, childhood of one kind could involve playtime, toys, safe and stimulating and caring environment, while another has children being 'little adults', working and till recently earning money to help run their households.

Analysis of social position of children in India shows that children are perceived as dependents. These manifest in various marginalizing practices within adult-child relationship. These included children's experiences being shaped by adults, control over their activities, exclusion from decision-making, force for 'scholastic work', rigid expectations of obedience and weak ability to negotiate (Bisht, 2008).

And as per the National Curriculum Framework (NCF, 2005), childhood is described as

> "a period of growth and change, involving developing one's physical and mental capacities to the fullest. It involves being socialized into adult society, into acquiring and creating knowledge of the world and oneself in relation to others in order to understand, to act, and to transform."

It further highlights that

> "We need a curriculum whose creativity, innovativeness and development of the whole being, the hallmark of a good education makes uniform tests that assess memorised facts and textbook -based learning obsolete."

This need for comprehensiveness in education and expectations from schools to provide opportunities to children to ensure their all-round development is also seen in other policy documents such as National Policy on Education (NPE) 1986,

> "Education is for all. This is fundamental to all-round development, material and spiritual."

Many Indian thinkers, philosophers, and educationists have expressed similar aims for education in their works. Distilling the key ideas of Aurobindo, Gandhi, Tagore, J. Krishnamurti, Blooms, Kohlberg, Vygotsky, Piaget, Dewey and many others indicate the recurrence of focusing on an all-round development, as in, the need to focus on developing an individual's mind, body and soul. The key ideas in these works emphasize on integrated development of an individual's personality, attitude and disposition along with the traditional academic outcomes of schooling. These do not separate the development of conceptual understandings in various subject matter areas and the behavioural, emotional and social aspects of development in children. The all-round development of children is seen as a product of the comprehensive and inclusive approach to learning experiences of the children without any distinctions made in terms of academic or ancillary skills.

Attempts to study and quantify the 'non-cognitive' domain have been primarily aimed to ensure overall life satisfaction as reported by adult or geriatric population. While doing the secondary research it was found that different studies have emphasized on different skills as important (Self-Regulated Learning, SEL Framework, ETS NCS Framework, and WHO Life-Skills).

The 'Life skills Education' has become the new thrust area for World Health Organization. According to the WHO, Life Skills are "the abilities for adaptive and positive behaviour that enable individuals to deal effectively with the demands and challenges of everyday life". This programme was initiated with the intent to reduce high risk behaviours and promote responsible decision making skills for good citizenship in different countries.

Recently, Central Board for Secondary Education (CBSE) India, 2009 has adopted 'Life Skills Education as an integral component of their Continuous and Comprehensive Evaluation. As mentioned in the CBSE policy document, Life Skills have two components, thinking skills, which require an individual to think rationally and act responsibly; the other is the social skills. Social skills enable an individual to build healthy relationship with other, resist peer and family pressure for undesirable activities, and avoid high risk behaviours that are personally and socially harmful.

Department of Education (MHRD, GoI) has some guidelines on assessment of non-cognitive domain in the primary section. It lists few non-cognitive skills and has attempted to break them according to developmental phases. It helps list minimum learning levels and assess according to mentioned criteria. This list of non-cognitive skills draws heavily from the democratic values enlisted in our constitution. What is appreciable is that they have deconstructed the values into attainable for children according to age, and hence made easy for teachers to measure those at the end of designated stages.

The Collaborative for Academic Social, Emotional Learning, United States of America (CASEL, 2003) is a programme to "address gaps in high and low achievers by giving skills necessary for success in school and life". CASEL programme aims to enhance the social emotional skills in children through classroom instruction. The socio-emotional attributes covered by CASEL are self-awareness, social-awareness, self-management, relationship skills, and responsible decision making.

Social and emotional learning (SEL) is the process of developing the ability to recognize and manage emotions, develop caring and concern for others, make responsible decisions, establish positive relationships, and handle challenging situations effectively. SEL provides schools with a framework for preventing problems and promoting students' well-being and success. Findings suggest that SEL programmes increases students' performance on standardized tests and grades.

According to the literature review done on 'Self-Regulated Learning' by the Center for Research on the Wider Benefits of Learning, Self-Regulation refers to "thoughts, feeling, and actions that are planned and adapted to the attainment of personal goals". Self-regulation has been proposed to include both the cognitive and the affective skills and is seen as a process in which learners engage, as opposed to being fixed traits that one has or has not. Claxton (2007) suggests self-regulation is an educational process that can be used to help individuals build their own sense of psychological wellbeing.

Social Emotional Aspects of Learning (SEAL) is “a comprehensive, whole-school approach to promoting the social and emotional skills that underpin effective learning, positive behaviour, regular attendance, staff effectiveness and the emotional health and well-being of all who learn and work in schools”. (See Humphrey, Lendrum & Wigelsworth, 2010). The SEAL programme was rooted in the five aspects of emotional intelligence model by Daniel Goleman (1995). These are self-awareness, self-regulation (managing feelings), motivation, empathy, and social skills.

A model which takes the growth perspective of development of skills as opposed to fixed traits perspective is Habits of Mind “Habits of Mind has emerged as a framework of attributes that, proponents claim, comprise the myriad of intelligent thinking behaviours characteristic of peak performers, and are the indicators for academic, vocational and relational success” (Costa & Kallick, 2000). Habits of Mind framework appears a desirable framework for continuous personal growth. It recognizes the need of meaningful learning for success in academic and personal fronts in the 21st century. Keeping this in mind, they suggest a set of skills/strategies that will enhance an individual’s effectiveness. The ‘Habits’ as suggested by this framework is a combination of skills of effective people and rests on philosophy of ability to engage in lifelong learning, which is an essential component to deal effectively with increasingly complex and unpredictable future

UNICEF also has a psychosocial well-being programme for children. It aims to enhance the psychosocial wellbeing of children in countries that are facing conflict or emergency situations. It aims to promote sense of safety and security, normalize daily life, encourage participation and enhance resilience (UNICEF- Child Protection from Violence, Exploitation and Abuse). The UNICEF programme shows interest in the socio-emotional aspect of children only with a view to measure them as fixed traits acquired by children due to the external factors and not from the growth perspective.

CONCLUSION

The school curriculum which is expected to outline the means to achieve the broad aims of education is largely dedicated to what children need to learn and master subject-wise, i.e., in mathematics, sciences, social sciences and language arts. The larger educational aims are expected to be implicitly achieved as part of learning the subject- specific skills, content and understanding. That is to say that built into the process of learning (say for e.g. reading, writing and arithmetic skills, solving mathematical equations, constructing experiments to check on one’s hypothesis and realizing the relation between origin of agriculture and the fading away of the nomadic life of humans) are the opportunities for children to also develop the capacities to empathize, learn how to learn, make independent choices and appreciate beauty. These latter capacities need to become an integral part of the schools’ and teachers’ planning of the teaching –learning process. Objectives for a task, activity, concept in a subject or a program is then synthesized by combining the content objectives seamlessly to these overarching aims, which ensure the inclusion of the ‘non-cognitive domain’.

The PSWB emerged from the attempt to address these needs by translating our understanding of the ‘non-cognitive’ domain into a comprehensive structure that can be used by the teachers and school. It intends to help schools to nurture the necessary dispositions and capacities in children in a comprehensive manner at various stages during the schooling years. The structure of the framework is based on the aims of education as mentioned in the country's constitution and various educational policy documents. It has five personal and social domains. Table 1 lists the five domains in the PSWB framework.

Personal Social Well-Being Framework				
Sensitivity to Others	Participation in Democratic Processes	Learning to Learn	Independence of Thought and Action	Aesthetic Appreciation

Table 1: Personal social well-being framework

To understand and appreciate the framework in its true spirit, it is imperative that the concept of personal & social well-being is considered as not an absolutely attainable attribute, and rather, a more dynamic process as reported by the individual, in a particular context, in different stages of life. To define the construct of the framework,

> "Personal & Social Wellbeing is a capacity, of the individual, to experience and respond in constructive ways for oneself and for the milieu using the cognitive, affective, aesthetic, psycho-motor abilities".

The critical words in the above definition have been operationalized for clarity. Capacity is referred to as skills and competencies of an individual; these are the abilities that an individual uses to respond to a situation. *Constructive ways* refers to positive and conducive responses to both favourable and unfavourable circumstances. These responses have an overall positive impact on the individual. *Milieu* is the socio-cultural-economic context of the individual- this is expanded to include people, practices, and the environment.

The exploration helped evolve a conceptual note and a set of broad indicators under each of the five domains for elementary grade students. These broad indicators were then further detailed out to include a set of descriptors. To enable teachers plan for comprehensive learning experiences that would ensure personal and social wellbeing in children a list of essential teacher practices were also created. A sample of the student behaviours and teacher practices from the framework is included in Table 2.

Indicators and Descriptors for the 'Learning to Learn' Domain
1. Demonstrates intentions of engaging with the learning process
• *LTL 1.1 Is keen to explore and learn*
• *LTL 1.2 Persists through the learning process with due consideration to relevance, priority, time and resources*
• *LTL 1.3 Takes initiatives to participate in activities to learn*
2. Applies strategies, skills and competencies essential to sustain the learning process whether working individually or in a group
• *LTL 2.1 Plans and organizes learning and modifies plans and strategies to facilitate learning*
• *LTL 2.2 Able to learn individually or in a team*

• *LTL 2.3 Takes responsibility for continuous learning* 3. Thinks and reflects upon one's thoughts and approaches to learning • *LTL 3.1 Reflects and analyses current knowledge and information to assess, inform and plan future actions and learning* • *LTL 3.2 Is aware of one's learning strengths and needs and adapts oneself to support one's learning*	
Teacher Practices	
Opportunity for students	Modelling
• Provide an active learning experience, provides feedback, accommodates different learning styles, makes students' thinking visible, and provides scaffolding and tailored instruction to meet specific student needs • Encourages students to take control of their own learning by allowing them to make some decisions about what to learn and how • Focus on understanding rather than memorization and routine procedures and they engage students in activities that help students reflect on their own learning and understanding • Engage students in different kinds of activities to help them identify their abilities to sustain interest, persevere and take responsibility	• Understand subject matter and its structure, as well as the effective teaching practices to help students learn • Look for opportunities and share their discoveries with others so as to further one's understanding on subject matter / teaching learning methods • Continuously explores teaching in many ways • Takes ownership and ensures accountability for tasks they engage in • Regularly reflects on one's own knowledge, practices and interactions to learn continuously • Seeks participation of students in the learning process and is open to their feedback

Table 2: Indicators and descriptors for the 'Learning to Learn' domain/ Teacher practices

Structure and Expected Outcomes

The PSWB Framework can be used to collect information about students' strengths and weaknesses by mapping observable behaviours of learners to the descriptors. Teachers can then plan for the students' subsequent learning experiences that can further develop their capacities. The framework lends itself to doing this in a comprehensive manner thus initiating the move-away from the programmatic ways of approaching the acquisition of these capacities.

This framework could be used to plan and design interactions, discussions and engagements with teachers in this domain. It can guide teachers to explore, become aware, understand the various facets of holistic child development – including what enables it, the approaches that strengthen desirable capacities and dispositions and the ways to work on areas of improvement – and the interplay of it with the teaching-learning process.

The hope is also that as the need for focus on PSWB as an integral part of the school transactions is realized it would also impact policies to make school a centre for holistic development of children and thus bring about a systemic change in the way education is approached.

References

Aurobindo, S. (1990). (Reprint). *On education.* Pondicherry: Aurobindo Ashram.

Bhattacharjee, A., & Sarma, N. (2009). Status of co-scholastic activities in the school programme of the elementary schools. Assam, India, Retrieved January, 6, 2011.

Bisht, R. (2008). Who is a child?: The adults' perspective within adult-child relationship in India. *Interpersona 2*(2), 151-172.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals*. *Handbook I: Cognitive domain*. New York: David McKay Company.

Central Board of Secondary Education (CBSE). *Life Skills Education and CCE.* India: CBSE.

Claxton, G. (2007). Cultivating the means to be happy: What does it take? In Institute for the Future of the Mind, Transcript of the keynote seminar of the All-party Parliamentary Group on Scientific Research in Learning and Education: 'Well-being in the classroom', Portcullis House, London, 23 October 2007. Retrieved from www.futuremind.ox.ac.uk/downloads/transcript_well_being_08_v6.pdf

Collaborative for Academic, Social and Emotional Learning (CASEL). (2003). *Safe and sound: An educational leader's guide to evidence-based social and emotional learning programs*. Chicago, IL: Author.

Costa, A., & Kallick, B. (2000). *Habits of mind: A developmental series (Book I: Discovering and exploring Habits of Mind*. Alexandria, VA: ASCD.

Dewey, J. (1938). *Experience and education*. Toronto: Collier-MacMillan Canada Ltd.

Goleman, D. (1995). *Emotional intelligence.* NY: Bantam Books.

Government of India. (1986). National Policy on Education. *Minimum levels of learning*. New Delhi: Ministry of Human Resources Development.

Humphrey, N., Lendrum, A., & Wigelsworth, M. (2010). *Social and emotional aspects of learning (SEAL) programme in secondary schools: National evaluation.* UK: Department of Education.

Kohlberg, L. (1988). *Moral development in education* (Masters' theses). New York: State University of New York.

Krishnamurti, J, (1956). *Education and the significance of life.* London: Gollancz.

Krishnamurti, J. (1974). *Krishnamurti on education*. New Delhi: Orent Longman.

Krathwohl, D. R., Bloom, B. S., Masia, B. B. (1964). *Taxonomy of educational objectives: The classification of educational goals*. *Handbook II: The affective domain*. New York: David McKay Company.

National Council of Educational Research and Training (NCERT). (2005). *National curriculum framework 2005.* New Delhi: NCERT.

National Council for Teacher Education (1999). *Sri Aurobindo on education*. New Delhi: NCTE.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wadsworth, B. J. (1996). *Piaget's theory of cognitive and affective development:* White Plains, NY: Longman.

INTERACTIVE EFFECT OF META-COGNITIVE STRATEGIES-BASED INSTRUCTION IN MATHEMATICS AND SELF-EFFICACY OF STUDENTS ON THEIR META-COGNITIVE AWARENESS

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This paper attempts to ascertain the interactive effect of meta-cognitive strategies-based instruction in mathematics and self-efficacy on meta-cognitive awareness of students. For this purpose, an *intervention programme based on meta-cognitive strategies of about 35 hours was developed for students of standard eighth spreading over eight weeks. The aim of the research was to ascertain whether meta-cognitive strategies-based instruction facilitates the meta-cognitive awareness of students, and if so, for which level of self-efficacy of students. Structured tools were used in study. The participants of the study included 62 and 60 students in the experimental and control groups respectively. Students were found to be significantly influenced by the intervention programme as well as their self-efficacy. The effect size of the intervention programme on meta-cognition of students was found to be 0.64 which is moderate in magnitude and that of the self-efficacy was found to be 1.20 which is high in magnitude. It also needs to be mentioned that a students' self-efficacy had an effect on their meta-cognitive awareness.*

Keywords: meta-cognitive strategies, self-efficacy, meta-cognitive awareness

INTRODUCTION

Meta-cognition is a model of cognition, which acts at a meta-level and is related to the object-world, through the monitoring and control functions (Efklides, 2001). Meta-cognition is a regulatory system that helps a person understand and control his or her own cognitive performance. It allows people to take charge of their own learning. It involves awareness of what they know, understanding what they need to know for a certain task, how they learn, how to use their current skills to learn what they do not know, generating strategies to meet these needs and then implementing the strategies.

Bandura (2000) stated that the sense of self-efficacy is concerned with the belief that a person is having about his/her ability to organize the sequence of correct actions to achieve certain results and to succeed in a particular situation. Students who have a high sense of self-efficacy tend for example, to identify key objectives and are willing to make use of all their hard work and perseverance to achieve them. In contrast, students with low sense of self-efficacy are vulnerable to anxiety and are not able to conduct their own studies.

Thus, meta-cognitive strategies-based instruction is expected to enable a student to understand and control his or her own cognitive processes whereas self-efficacy enables a student to view challenging problems as tasks to be mastered, develop deeper interest in the activities in which they participate, form a stronger sense of commitment to their interests and activities and recover quickly from setbacks and disappointments. Both are therefore expected to influence students' meta-cognitive awareness.

Rationale of the Study

The essence of meta-cognition is awareness of one's cognitive processes, as well as an ability to develop a plan for achieving a goal and evaluating one's effectiveness of reaching that goal. The importance of meta-cognition for high quality learning and problem solving is widely accepted. The ultimate goal of a mathematics teacher is to enhance the knowledge of and performance in mathematics of a student. If a student's meta-cognitive awareness is high, he/she will be more strategic and will perform better than those with low meta-cognitive awareness, allowing individuals to plan, sequence and monitor their learning in a way that directly improves performance. Thus, in order to facilitate mathematics learning, it is essential to enhance meta-cognitive awareness of students (Young & Fry, 2008). It is expected that meta-cognitive strategies-based instructional programme would enhance meta-cognitive awareness of students. Moreover, self-efficacy is the measure of one's own ability. It is expected to enhance the perseverance of a student. If a student's self-efficacy is high, it is likely to enable him/her to complete tasks and reach goals. Besides, if such a student is taught to share his/her difficulties with peers to solve problems and regulate their academic work, their meta-cognitive awareness is likely to be high. Previous research suggests that self-efficacy may affect academic performance when combined with other factors; including working memory and metacognition (Hoffman & Schraw, 2009; Hoffman & Spatariu, 2008; Landine & Stewart, 1998). There is ample research on the relationship between self-efficacy and performance as well as between meta-cognitive awareness and performance. However, the link between effect of self-efficacy and meta-cognitive strategies-based instruction on meta-cognitive awareness is missing. It is therefore expected that the meta-cognitive strategies-based instructional programme will interact with the self-efficacy of a student and will have a combined effect on a student's knowledge concerning his/her own cognitive processes.

Review of Related Literature on Meta-cognitive Awareness and Self-Efficacy

Schraw (1998) studied two aspects of meta-cognition, knowledge of cognition and regulation of cognition, and how they are related to domain-specific knowledge and cognitive abilities. Four instructional strategies are described for promoting the construction and acquisition of meta-cognitive awareness. These include promoting general awareness, improving self-knowledge and regulatory skills, and promoting learning environments that are conducive to the construction and use of meta-cognition. Tobias and Everson (2002) completed 23 studies of knowledge monitoring and its relationship to learning from instruction. The work reported here attempts to address a number of general issues, e.g., the domain specificity of knowledge monitoring, measurement concerns, and the relationship of knowledge monitoring to academic ability. Hoffman and Spatariu (2008) studied a regression design which was used to test the unique and interactive effects of self-efficacy beliefs and meta-cognitive prompting on solving mental multiplication problems while controlling for mathematical background knowledge and problem complexity. Problem-solving accuracy, response time and efficiency (i.e. the ratio of problems solved correctly to time) were measured. Before solving a series of multiplication problems, participants were randomly assigned to either a prompting or control group. Findings suggested that self-efficacy and meta-cognitive prompting increased problem-solving performance and efficiency separately through activation of reflection and strategy knowledge. Educational implications and future research are suggested. Wei (2008) conducted a study based on the theories of meta-cognition and learner autonomy, and by analyzing the relationship between meta-cognitive awareness training and learner autonomy theoretically and statistically, the paper argued that in ELT (English Language Teaching) meta-cognitive awareness training should go before the training of meta-cognitive strategies, and only when students are conscious about meta-cognitive awareness can they strengthen their effort, motivation and persistence, seek assistance from peers and teachers when needed, and provide self-instruction while learning and take responsibility for their learning. Maghsudi and Talebi (2009) studied cognitive versus meta-cognitive strategies. The major aim of the study was to find out whether being mono or bilingual has any impact on the awareness and use of meta-cognitive, cognitive and total cognitive meta-cognitive strategies with respect to students' proficiency levels. The researchers found that mono and bilingual students differed significantly in their cognitive, meta-cognitive as well as total cognitive meta-cognitive strategy scores, meaning that bilinguals had significantly higher scores than monolingual students. Further, students with high proficiency had significantly higher scores than students with low proficiency in their cognitive, meta-cognitive and also total cognitive/meta-cognitive strategies. Jadhav (2012) studied meta-cognition in areas of school success. Jayaprabha (2013) conducted a study aimed at examining the effects of inquiry based learning and co-operative learning on meta-cognitive awareness in science class room. A quasi experimental design involving three groups namely, two treatment groups- inquiry based learning and co-operative learning and control group was adopted. Standardized tool developed by Schraw and Dennison (1994) was used to measure meta-cognitive awareness in three groups. Results revealed that students in co-operative learning received higher meta-cognitive awareness compared to other groups. Aurah, Cassady & McConnell (2014) studied predicting problem solving ability from meta-cognition and self-efficacy beliefs on a cross validated sample. Grounded in social cognitive theory of self-efficacy and self-regulation, this study examined the influence of meta-cognition and self-efficacy beliefs on genetics problem solving ability among high school students in Kenya using a quasi-experimental research design. The study was conducted in Western Province, Kenya. A total of 2,138 high school students were purposively sampled. Findings revealed that meta-cognition and self-efficacy significantly predicted genetics problem-solving ability. Furthermore, self-efficacy moderated the relationship between meta-cognition and genetics problem-solving ability.

Need of the Study

Meta-cognition enables students to benefit from instruction (Carr, Kurtz, Schneider, Turner & Borkowski, 1989) and influences the use and maintenance of cognitive strategies. While there are several approaches to meta-cognitive instruction, the most effective involve providing the learner with both knowledge of cognitive processes and strategies (to be used as meta-cognitive knowledge), and experience or practice in using both cognitive and meta-cognitive strategies and evaluating the outcomes of their efforts (develops meta-cognitive regulation). Landine and Stewart (1998) showed that a positive relationship existed between meta-cognition, self-efficacy, and motivation. Downing (2009) found that meta-cognition was used as coping strategy and that when an individual failed in their coping it led to decreased self-efficacy, which ultimately had a negative effect on learning.

Operational Definitions of the Terms

Meta-cognition: Meta-cognition refers to a learner's awareness of his/her own knowledge and cognitive processes and ability to understand, control and manipulate his/her own cognitive processes.

Meta-cognitive Strategies: Meta-cognitive strategies refers to methods used to help students understand the way they learn and refers to the processes designed for students to manage, monitor and evaluate their learning and 'think' about their 'thinking'.

Meta-cognition Awareness: Meta-cognition awareness is ability of a student's knowledge concerning one's own cognitive processes.

Self- Efficacy: Self-efficacy is the measure of one's own ability to complete tasks and reach goals.

Statement of the Problem: Interactive Effect of Meta-cognitive Strategies-based Instruction in Mathematics and Self-Efficacy of Students on their Meta-cognition Awareness

Scope and Delimitations of the Study

In the present study, English medium schools from the Greater Mumbai affiliated to the SSC board have been included. It excludes schools with other media of instruction such as Marathi, Hindi, Urdu, Gujarati etc. The present study includes eighth standard students from English medium schools situated in Greater Mumbai. Students from other primary and secondary classes have been excluded. It also excludes schools affiliated to ICSE or CBSE boards.

The present research studies interactive effect of meta-cognitive strategies-based instructional mathematics and self-efficacy on meta-cognition awareness of students. It has adopted the quantitative approach to the study rather than the qualitative approach.

Aim of the Study

To ascertain the interactive effect of the intervention programme and self-efficacy of students on their meta-cognitive awareness.

Objectives of the Study

1. To ascertain the interactive effect of the intervention programme and self-efficacy on meta-cognitive awareness of students.
2. To compute the effect size of the intervention programme and self-efficacy on meta-cognitive awareness of students.

Research & Null Hypothesis of the Study

H_1: There is a significant the interactive effect of the intervention programme and self-efficacy on meta-cognitive awareness of students.

H_o: There is no significant the interactive effect of the intervention programme and self-efficacy on meta-cognitive awareness of students.

METHODOLOGY OF THE PRESENT STUDY

The study has adopted the quasi- experimental method. In the present research, the quasi-experimental design of the pre- test post-test, non-equivalent group type was used. It can be described as follows:

The pre-test-post-test non-equivalent groups design:

$O_1 X O_2 \quad O_3 C O_4$

Where,

O_1 and O_3: Pre-test Scores & O_2 and O_4: Post- test Scores

X: Experimental Group & C: Control Group

Sample of the Study

In the present study, the sample has been selected consisting of one intact class each of standard eighth from two different schools situated in the Greater Mumbai. The experimental and the control groups included 62 and 60 students respectively. The schools were selected using simple random sampling technique (lottery method) from a list obtained from Department of Education Mumbai.

Tool of the Study

In the present study following tools was used by the researcher to collect data:

1. Self-Efficacy (Muris, 2001)

2. Meta-cognitive Awareness Inventory (Schraw & Dennison, 1994).

Intervention Programme

The duration of the intervention programme is 35 hours. The control group was taught using the traditional method. The experimental group was taught using intervention programme, which was divided into two levels. The first level included knowledge about cognition, which was ascertained through KWL chart and the second level included regulation about cognition which consisted of three steps, namely, planning (understanding the problem, devising a plan, carrying out the plan and looking back), monitoring (self-awareness of one’s thought processes), control (self-monitoring of one’s thought processes, beliefs and intuitions about one’s cognition) and evaluation (problems on the topic and self -reflection sheet). The three step process is explained further using the following questions: (a) **Planning:** What is the nature of the task? What is my goal? What kind of information and strategies do I need? How much time and resources do I need? (b) **Monitoring:** Do I have a clear understanding of what I am doing? Does the task make sense to me? Am I reaching my goals? Do I need to make changes? and (c) **Evaluating:** Have I reached my goal? What worked? What didn’t work? Would I do things differently the next time? The meta-cognitive strategies included in the study were (a) Knowledge about cognition, (b) Regulation about cognition, (c) Ask questions, (d) Foster Self-reflection, (e) Encourage self-questioning, (f) Think aloud and (g) Self-explanation. The teaching units were selected from the syllabus prescribed for the schools affiliated to the SSC board for the state of Maharashtra and included the topics on Cube, Indices, Construction of Quadrilateral, Joint Bar Graph and Discount and Commission.

TECHNIQUES OF DATA ANALYSIS

The present research used statistical techniques of ANOVA and Wolf’s formula.

Data Analyses

Null Hypothesis 1: There is no significant the interactive effect of the intervention programme and self-efficacy on meta-cognitive awareness of students.

This hypothesis was tested using two-way ANOVA in which the pre-test scores of students is controlled. The following table shows the relevant statistics of meta-cognitive awareness of students by treatment and self-efficacy.

	Self-Efficacy			
Group	LAW SEff (LSEff)	MODERATE SEff (MSEff)	HIGH SEff (HSEff)	Total
	N	N	N	N
CG	13	31	16	60
EG	16	28	18	62
	Mean	Mean	Mean	Mean
CG	34.61	38.38	40.12	38.03
EG	36.93	42.25	44.66	41.58
Total	35.89	40.22	42.52	39.83

Table 1: Adjusted mean of MCAS by treatment and SEff

Table 2 shows the ANOVA for meta-cognitive awareness of students by intervention programme and SEff after partialling out the effect of the pre-test MCAS of students.

Source	SS	df	MS	F	P
Rows (T)	383.69	1	383.69	12.57	0.0006
Column (SEff)	705.43	2	352.72	11.56	<.0001
Interaction (TxSEff)	49.23	2	24.62	0.81	0.4474
Error	3540.37	116	30.52		
Total	4678.72	121			

Table 2: ANOVA for MAI of students by treatment (T) and self-efficacy (SEf)

Since the F-ratios for SEf effect is significant, the t-test is applied for further analysis as shown in table 3.

No.	Groups	Mean	N	t	l.o.s.
1	H-SEf	42.52	34	1.93	NS
	M-SEf	40.22	59		
2	H-SEf	42.52	34	4.75	0.01
	L-SEf	35.89	29		
3	M-SEf	40.22	59	3.46	0.01
	L-SEf	35.89	29		

Table 3: Mean differences of MCAS between treatment and SEf

The preceding table shows that (a) the F-ratio for rows i.e. intervention programme is significant at <0.0001. Hence it may be concluded that the Mean Score on MAI of the experimental group is significantly greater than that of the control group. (b) The F-ratio for columns i.e. self-efficacy is significant at 0.05. Hence it may be concluded that the Mean Scores on MAI do differ significantly on the basis of self-efficacy. (c) The F-ratio for interaction effect of intervention programme and self-efficacy is not significant at 0.447 level. Hence it may be concluded that the Mean Score on MAI of students differ on the basis of the interaction between intervention programme and self-efficacy.

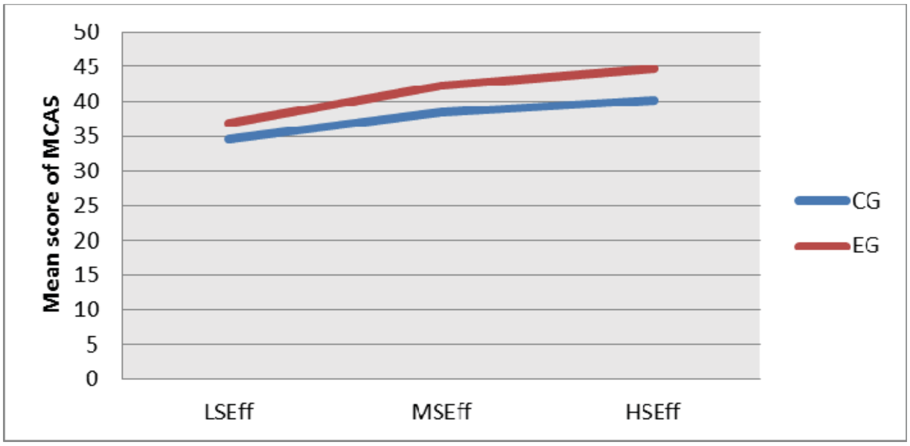

Figure 1: Interactive effect of treatment and Sef on MCAS

DISCUSSION

The treatment i.e. the intervention programme developed by the researcher is effective for enhancing meta-cognitive awareness of students. Moreover, the intervention programme is found to be more effective for students with high self-efficacy as compared to those with moderate and low self-efficacy. KWL chart, think aloud method of teaching and various meta-cognitive strategies may help to improve students Bandura and Schunk (1981) found that students' mathematical self-efficacy beliefs were predictive of their choice of engaging in subtraction problems rather than in a different type of task. The higher the children's sense of efficacy, the greater their choice of the arithmetic activity.

Experimental group students have high self-efficacy as compare to control group because self-efficacy also called perceived ability, refers to the confidence people have in their abilities for success in a given task (Bandura, 1997) which might be increase by the meta-cognitive strategies and meta-cognitive awareness.

Students with high self-efficacy is have more awareness about their own thinking process because student plan, monitor and evaluate their learning in a way that directly improve performance. Unrealistically low self-efficacy, not lack of capability or skill, can be responsible for maladaptive academic behaviours, avoidance of courses and careers, and diminishing school interest and achievement.

Students who have a low sense of efficacy for acquiring cognitive skills may attempt to avoid tasks, whereas those who judge themselves more efficacious should participate more eagerly.

References

Aurah, C., Cassady, J., & McConnell, T. (2014). Predicting problem solving ability from meta-cognition and self-efficacy beliefs on a cross validated sample. *British Journal of Education 2*(1), 49-72.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Bandura, A. (2000). Exercise of human agency through collective efficacy. *Current Directions in Psychological Science, 9*, 75-78.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology, 41*, 586-598.

Carr, M., Kurtz, B. E., Schneider, W., Turner, L. A., & Borkowski, J. G. (1989). Strategy acquisition and transfer among German and American children: Environmental influences on meta-cognitive development. *Developmental Psychology*, *25*, 765-771.

Downing, K. J. (2009). Self-efficacy and meta-cognitive development. *The International Journal of Learning, 16,* 185-199.

Efklides, A. (2001). Metacognitive experiences in problem solving: Metacognition, motivation, and self-regulation. In A. Efklides, J. Kuhl, & R. M. Sorrentino (Eds.), *Trends and prospects in motivation research* (pp. 297–323). Dordrecht, The Netherlands: Kluwer.

Hoffman, B., & Spatariu, A. (2008). The influence of self-efficacy and metacognitive prompting on math problem-solving efficiency. *Contemporary Educational Psychology, 33*(4), 875-893.

Hoffman, B., & Schraw, G. (2009). The influence of self-efficacy and working memory capacity on problem-solving efficiency. *Learning and Individual Differences*, *19*, 91–100.

Jadhav, V. (2012).Construction and standardization of a meta-cognition inventory for the students of secondary schools. *Voice of Research 1*(2).

Jayaprabha, G. (2013). Meta-cognitive awareness in science classroom of higher secondary students. *International Journal on New Trends in Education and their Implications, 4*(3), 49- 56.

Landine, J., & Stewart, J. (1998). Relationship between metacognition, motivation, locus of control, self-efficacy, and academic achievement. *Canadian Journal of Counselling*, *32*, 200-212.

Maghsudi, M., & Talebi, S. (2009). The Impact of lingualuity on the cognitive and metacognitive reading strategies awareness and reading comprehension ability. *Journal of Social Science 18*(2). 119-126.

Muris, P. (2001). A brief questionnaire for measuring self-efficacy in youths. *Journal of Psychopathology and Behavioural Assessment, 23*(3), 145-149.

Schraw, G. (1998). Promoting general meta-cognitive awareness. *Instructional Science, 26*(1), 113-125.

Schraw, G., & Dennison, R. S. (1994*). Assessing metacognitive awareness. Contemporary Educational Psychology, 19*, 460-475.

Tobias, S., & Everson, H. (2002). Knowledge monitoring and its relationship to learning from instruction. Retrieved from http://research.collegeboard.org/publications/content/2012/05/knowing-what-you-know-and-what-you-dont-further-research-metacognitive

Wei, C. (2008). Meta-cognition and learner autonomy. *CELEA Journal 31*(4), 110-120.

Young, A., & Fry, J. D. (2008). Meta-cognitive awareness and academic achievement in college students *Journal of the Scholarship of Teaching and Learning, 8*(2), 1-10.

MULTIPLYING INTEGERS: MATHEMATISING TO MAKE SENSE

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This paper presents a trajectory for teaching multiplication of integers using the context of assets and loans. This context provides an experiential basis to understand all the sign rules, including 'minus times minus' without having to resort to distributive property. The paper also extends the argument for making a distinction between operation and number to multiplication of integers, in order to support sense-making by children.

INTRODUCTION

If the sign rules for operating with integers have been for many the point when mathematics stopped making sense, the rules for multiplication have been the apogee. Many different real-life or otherwise contexts such as temperature, debt-asset, distance and micro-worlds and didactical tools such as tiles and number lines are used to help children make sense of negative numbers or integers. Usually they are successful in giving an intuitive sense to the idea of negative numbers and for addition involving negative numbers. Subtraction is usually not that intuitive or obvious. The real difficulty emerges with multiplication.

A review done by Arcavi and Bruckheimer a few decades ago, categorized the different strategies used to teach the sign rules of multiplication into five – rote, induction, deduction, models and axiomatic presentation (Arcavi & Bruckheimer, 1981). He suggested that no contexts have been found which could model convincingly all the aspects of integers including that of multiplication. This absence of an adequate context to model integers and integer multiplication appears to continue even now. In the case of multiplication, usually researchers resort to the use of distributive property and consistency with the laws of arithmetic to make sense of the sign rules (Hayes & Stacey, 1999, Sfard, 2007). This difficulty with making sense of the sign rules for multiplication have led many to even advocate the abandonment of the efforts to develop an adequate model for making sense of negative numbers as a whole itself (Fischbein, 2002). The fact that efforts continue to find an effective real life context for teaching integers, can be considered to indicate the felt need of real-life contexts for making sense to children.

Making Sense

The use of contexts and activities to help children make sense of a mathematical concept can be divided into two broad classes. In one type, which we can call as rule focused method, the context is used to explain the basis for the sign rules – in this case the starting point of the activities are the sign rules. In the other type which we can call as situation-based sense-making method, a problem is presented within a particular context or situation which makes sense to children and the sign rules emerge from a visualization of the new mathematical object of negative number and its relationships within a system.

The method which we have chosen belongs to the second type and has been influenced by insights from Activity Theory of Leontyev and Vygotsky as well as from Freudenthal. In

Activity Theory human activities are analyzed in terms of motives, objectives and operations. Sense-making happens when connections are established with the motive of an activity. Motives are objectives of an activity that fulfil a need – the need can be biological, emotional, intellectual or aesthetic.

One of the way in which sense connections are established is when the operations and tools of an activity which were unconscious earlier becomes the focus of attention.

Vygotksy and Leontyev consider that the meaning structures of society emerge through historical time, through the linkages objectively (in actual practice) established between different practices (Leontyev, 1981). We can consider that for example, the meaning structures for the concept of number have developed historically when the unconscious operations in one action/activity became the conscious object for investigations. This process of reification has been commented upon by many others also (Sfard, 1991). The challenge for the teacher in this perspective becomes finding ways of establishing sense connections that approach the meaning structures of society for a concept, through designed range of activities according to the learner's motivational structure.

Vygotsky has pointed out the role that words used with a **functional purpose**, ('function in communication, reasoning, understanding, or problem solving' (Vygotksy, 1987, p 123)) can play in this process of making sense and concept formation. To begin with, the word is not a concept for the child, but later through its function of 'directing and mastering mental processes' it supports the development of the concept and then becomes its sign.

This general sense-making approach to concept formation has considerable resonations with the RME approach of mathematisation, which considers how conceptual understanding is reached through a series of level-raisings (Treffers, 1991; Gravemeijer, 1997). One of the important areas of agreement which distinguish them from constructivist approaches is the role of the teacher in the process of didactisation (Menon, 2013). According to Treffers (1991), apart from providing a concrete orientation basis 'the provision of models, schemes and symbols' from the outside are also part of the task of the teacher. This is on the same lines as the method of double stimulation suggested by Vygotsky where the tools for problem solving are also made available to the children.

Integer Trajectory Development

In this paper we present the approach taken in a curriculum intervention going on for the last few years, in which the multiplication of integers was built on the activities used for making sense of negative numbers and addition and subtraction. The first steps for the trajectory for teaching integers involving loan and asset emerged between 2005 and 2007 and the first part of the trajectory was implemented in 2009 with children of Grade 6 (11 year olds) by sharing it with the teachers. This was followed in 2011 by a series of 15 classes which I took with the children. Outline of this developmental work and approach were shared during ICME-12 and this paper builds on that (Menon, 2012).

During July 2012 the earlier context used for addition was extended to multiplication and it was consolidated during 2014, both while working with children of Class VII.

Key Features of the Trajectory

1. Activities embedded within a narrative with a central character called Bunty/Baiju involving loan and assets.

2. Combining the opposites of loan and assets with the number line through the use of the arithmetic string or specially designed *Ganit Mala*
3. Most importantly establishing a clear demarcation between operations and numbers by using raised notation to indicate numbers along with the use of the language of ‘positive’ and ‘negative’ for number and plus and minus for operations.
4. Use of the words ‘bigger’ and ‘smaller’ to indicate only size or absolute value relationships and the words ‘greater’ and ‘lesser’ to indicate order or value relationships among numbers.
5. Establishment of numbers as reflecting the status (or net worth) of the character, balancing the amount of cash and loan and therefore orderable in terms of the net position of wealth (value).
6. A strong focus on activities to help children visualize movements along the number line.

TOWARDS MULTIPLICATION

Multiplication of integers was built on the same context as what was used for addition and subtraction. It involved a story of a boy who started a small vegetable business to support his mother by buying Rs.200 worth of vegetables every day. He decided to collect Rs.100 before giving it to his mother and puts a clip on a bead string to show how much money he has in the box. Through a series of events the clip on the string is seen to represent the net amount of cash in the box and loan from *samosewale* uncle who supports him (See Menon 2012 for details of the trajectory).

We had found that children responded very easily to addition and subtraction through activities within this context which also used number line extensively. The method also made a distinction between operations and numbers. Thus for example, a question such as ‘+2 - −5’ was mostly answered by children by saying ‘It is +7 because subtracting a loan is the same as adding cash’. Strong identification with Baiju and participating in classroom discussions and activities about where Baiju should put the clip to show his current situation can be considered to have led to this understanding. The problem during an incident in the narrative about where Baiju should put the clip to show his position, when Baiju had a loan of Rs.80 and was at position −80 and *samosewale* uncle forgave (माफ़ किया) half the loan, was easily solved by the children.

Other Explorations

While children were quite comfortable with addition and subtraction which made sense to them, the challenge was about how to go further to include multiplication. Earlier, before using this context for teaching integers, I had tried out another story context involving movement along a line with the sign and the number representing direction and magnitude respectively, as has been also done by various others. But the new trajectory based on loans and assets was much more satisfactory, both based on the response of children and the fact that it combined both quantity and number line aspects (See Menon, 2012).

Normally when people consider multiplication, all the four instances do not pose the same level of difficulty in making sense. Let us for example, consider multiplication involving the following

A. 3 x 2 = 6

B. 3 x -2 = - 6

C. -2 x 3 = - 6

D. -2 x -3 = 6

Of these, the first two do not generally create any difficulties. B is usually interpreted to say that 3 times -2 is -6 using the idea of repeated addition. Normally for C, the same argument is used while invoking commutativity to find the answer as – 6. The real problem lies with D, and often it is assumed that this can be only solved by using distributive property and using the laws of arithmetic with the tacit assumption that they would apply. In fact this 'permanence principle' was used in the nineteenth century to finally establish the sign rules.

The Problem and a Solution from History

The challenge within the context we had chosen was to find a plausible method by which all the sign rules could be derived consistent with the framework used for addition and subtraction. The children, with whom the classes were being taken, had learnt multiplication with Jodo Gyan curriculum and were used to thinking about multiplication as multiplier times multiplicand. In this format A and B would be presented as

$3 \times {}^{+}2 = {}^{+}6$ (spoken as 3 times positive 2 equal to positive 6)

$3 \times {}^{-}2 = {}^{-}6$ (spoken as 3 times negative 2 equal to negative 6)

So far, as in other approaches, there was no problem. The problem arose when the multiplier was a negative number. One did not want to resort to the logic of commutativity (although that was kept as a last resort) but to build it within the situational logic itself. At that stage, there was also lack of clarity about how the multiplier should be presented, whether with the raised or unraised sign. It was at this juncture that I happened to read the words of John Wallis from his Treatise on Algebra written in 1685. There he wrote

> But in case the Multiplier be a Deficit or Negative quantity: suppose −1; then instead of Putting the Multiplicand so many times, it will signify so many times to Take away the Multiplicand…so that + by − makes −; But to Multiply –A by −2 is twice to take away a Defect or Negative. Now to take away a Defect is the same as to supply it; and twice to take away the Defect of A is the same as twice to add A or to put 2A …: So that – by – (as well as + by +) makes +. (Quoted in Mumford, 2010, p 137.)

Suddenly there was in front of me the solution that I had been searching for years!

Repeated Addition?

Questions have been raised in the last few decades about considering multiplication as repeated addition. It has been argued that the metaphor of dilation and shrinking is better for teaching multiplication, especially in order to prevent the development of the misconception related to 'multiplication makes bigger'. It has been our experience, even before dealing with integers that multiplication is better taught first through the experience of repeated addition. Although space does not permit for details, it is important to mention that the response of children made us change the earlier approach and take to a trajectory using repeated addition. The approach taken during the teaching of fractions seems to have taken care of the problem of thinking that 'multiplication makes bigger'.

THE TRANSACTION

We present here the core instructional sequences of the trajectory for multiplication of integers which is based on the teaching experiences. It follows broadly the class as it happened with some modifications.

The teacher revisits the context of Baiju and is happy to note that children still remember the context after a lapse of one year. She continues and says that Baiju meets an old friend…pauses and asks the children what the name of the friend should be and the suggestion Suraj comes in. The teacher goes on to say that Suraj tells Baiju of new work that he can do to earn money to support his mother. He talks of the shop keeper who buys cloth bags with embroidery. This job has more flexibility and less risk – no need to be afraid of cows eating vegetables or rain spoiling them! Baiju agrees and is happy to be introduced to the shop keeper who sells the raw materials for making embroidery on the bags. The shopkeeper also provides the material for bags on loan. Baiju decides to take material for four bags on loan.

At this stage, the teacher draws an empty number line (ENL) on the blackboard and represents the transaction as shown here, pausing to interact with the children, recalling the convention that since it is an addition we shall show it above the number line. Children concur that since he has taken a loan, his wealth position would worsen and that it would move towards the left. A separate jump is shown for the loan for each bag taken and children say that his wealth position would be now at -160. (The wealth position is a net position reflecting the cash in the box and the outstanding loans).

Figure 1: First representation

Then the teacher takes a new step and in conversation with the children writes what happened as 'added 4 times −40' saying as she writes 'four times negative 40'. The class agrees that this is the same as adding a loan of 160 or adding negative 160, which is written as = +−160. Similarly the sale of the embroidered bags is shown on the number line, showing movements to the right from -160 to reach +80. This time a child comes forward to do it and also writes in words 'added 4 times +60 which is the same as adding positive 240 = ++240.

The same format of representation is used for the transaction later when Baiju goes to buy material for making 6 bags. But in this case there are two types of transactions. First Baiju spends Rs.40 for the materials for two bags and then takes loan for the material for the other 4 bags. Children do not have much difficulty in showing these transactions on the ENL as well as in words. The first part involves subtracting two times +40 and the second part 4 times taking a loan of −40.

Short Form and Two Types of Multiplication

The next major step is that of writing these events in a short form. To begin with teacher goes on to write the transaction in a 'short form'. The first two transactions involve addition and are written easily and without any sign before the multiplier. The teacher writes the first transaction in conversation with the children and the second one could be written by a student who volunteers.

Before writing the third one involving subtraction, the teacher pauses with the question, “How shall we write this in short form?”, sharing the dilemma that “if we write simply 2 x −40, then it would look as if we added 2 times negative 40. But we did not add negative 40. We subtracted!” It was seen in the class that children readily saw the point that we cannot just write 2 x −40. When the teacher suggested they distinguish between these two ways of multiplying, the children agreed. A new norm was being established in the classroom. The class agrees that when we repeatedly add, we will write a ‘plus’ + before the number (multiplier) and when we repeatedly subtract we will write a ‘minus’ −, before the number. This introduction went much smoother than I anticipated. It was as if children and John Wallis were on the same plane! Table 1 gives the final short form after this convention was introduced and also the later abbreviated form.

Incident and change in net wealth position	Long form	Short form final	First Abbreviated short form*
1.Took loan for 4 bag materials 	Added 4 times $^{-}40 = +^{-}160$ $= -^{+}160$	$+4 \times {}^{-}40 =+^{-}160$ $= -^{+}160$	$4 \times {}^{-}40 = {}^{-}160$
 2.Got cash for 4 bags	Added 4 times $^{+}60 =+ {}^{+}240$ $=-^{-}240$	$+4 \times {}^{+}60=+ {}^{+}240$ $=-^{-}240$	$4 \times {}^{+}60 = {}^{+}240$
3. Bought 6 bag materials paying for two with cash and taking 4 on loan 	Subtracted 2 times $^{+}40 = -^{+}80$ $= +^{-}80$ Also added 4 times $^{-}40$ (similar to earlier transaction)	$-2 \times {}^{+}40 = +^{-}80$ $= -^{+}80$	$-2 \times {}^{+}40 = {}^{-}80$

Table 1: Level-raising in representations 1

Minus Times Minus?

The next situation was a little unusual but in fact it dealt with the ill-famed ‘minus times minus’. Baiju had taken on loan material for ten bags. But a jug of water fell on the embroidered bags before he could sell them. The shopkeeper refused to take the bags since the colours of the thread had spread. The shopkeeper who had given the bag material on loan said, “It is your mistake! Who asked you to pour a bucket of water over the embroidered bags?” But after some time the shopkeeper felt bad. He felt that he was also a little responsible for the accident. He told Baiju that he will reduce the loan for 5 bags. Children responded to this incident very comfortably and were able to use the different formats.

Figure 2: Short form - subtracting 5 times a negative

Incident and change in net wealth position	Long form	Short form final	First Abbreviated short form*
4.Reduced loan for 5 bags 	Subtracted 5 times $^{-}40 = -^{-}200$ $= +^{+}200$	$-5 \text{ x } ^{-}40 = -^{-}200$ $= +^{+}200$	$-5 \text{ x } ^{-}40 = ^{+}200$

Table 2: Level-raising in representations

*In this first abbreviated short form only addition based answer is presented. Also the addition or plus symbol is not shown. In the second abbreviated short form the symbol for positive number (raised + symbol) would not also be shown. This second form becomes the same as the normal conventional practice.

We can also see that in fact when we talk about ‘minus times minus is plus’, we are in fact ignoring the signs for positive numbers and for addition operation and ignoring the two different meanings for the negative sign. It has been argued that this conflation might contribute to the difficulties that children have with algebra. (Vlassis, 2004)

The classroom interventions and follow-up assessments were done essentially as part of an ongoing programme of curriculum support to teachers. The responses of children to questions about integers indicate a very good sense of the order of numbers. While there is more data on the response of children to addition and subtraction, multiplication as such was not a focal point on these assessments. Yet the results of one question indicate that children have an understanding of the sign rules which they are able to combine with their sense of direction on the number line to compare numbers. About 5 months after the classroom intervention children were given a series of numbers to compare. One set involved comparing the following to identify the greater number.

$-17 \text{ x } ^{-}19$ and $-179 \text{ x } ^{+}25$

Of the 172 children, 153 children or 89 % answered correctly.

SENSE MAKING AND MATHEMATISATION

All along this trajectory, we see the engagement of children with a situation and a problem which emerges from the situation, which gets resolved with the means at hand. Later the means used or the operation which was not the focus of conscious attention itself becomes the focus. This also happens through a word or sign being used with functional purpose to solve the problem. To begin with, in the earlier part of the trajectory the objective for children was to support Baiju (I found that children remembered Baiju even years later) and participate to distinguish between two types of situations in which Baiju finds himself which leads to the use of the integer *Ganitmala* (Menon, 2012). Later while reflecting on the operations done using this tool, the words ‘positive number’ and ‘negative number’ get used with the functional purpose of organising that experience.

These processes are also evident in the case of multiplication. Subtracting two times a cash amount of Rs.40 is easily solved by children in the context, where the motive is connected to the story context. When attention is focused on the nature of the operation that was used, the need emerges to distinguish between two types of multiplication and leads to the use of a new sign with a functional purpose. This in turn leads to different equivalence relationships involving the usage of minus sign in different ways. The concepts that develop evolve further. When children have started solving problems using the distinction between numbers and operations for some time, later by reflecting on the relationships, they can reach the standard format of the mathematics community which now makes sense to the children. This process of sense-making also concurs with the process of mathematisation that Freudenthal put forward which involves organising a field of experience.

This approach differs from learning through association and programmed instruction of components of a concept or through the use of examples and non-examples for concept attainment. Rather than the components, even at the outset a sense of the concept is grasped although rooted in a situation which then further evolves.

TO CONCLUDE

The experiences with this trajectory have indicated that it is possible to continue the effort to make sense of integers by continuing along the same lines as what was done in the case of addition and subtraction, also in the case of multiplication. We see that the representational tools get used for problem solving and as the trajectory develops the attention shifts to the tools itself through various stages of level-raisings. Some happen within the same period while some happen over the grades.

It is proposed that we need to extend the approach of making a distinction between operations and numbers to multiplication also. An evolutionary approach to concept development with the signs also evolving would give the possibility of supporting the sense-making efforts of children. There are also intimations that the separation between quantity and number which was established in the nineteenth century need to be reviewed, at least in the case of school mathematics.

References

Arcavi, A., & Bruckheimer, M. (1981). How shall we teach the multiplication of negative numbers? *Mathematics in School, 10*(5), 31-33.

Fischbein, E. (2002). *Intuition in science and mathematics – An educational approach*. New York: Kluwer Academic.

Gravemeijer, K (1997). Instructional design for reform in mathematics education. In. M. Beishuizen, K. P. E. Gravemeijer and E. C. D. M. van Lieshout (Eds.), *The role of contexts and models in the development of mathematical strategies and procedures* (pp. 13-34). Utrecht: Freudenthal Institute.

Hayes, B., & Stacey (1999, July). Teaching negative number using integer tiles. In *Proceedings of the 22nd Annual Conference of the Mathematics Education Research Group of Australasia (MERGA)*. Adelaide, Australia.

Leontyev, A. N. (1981). *Problems of the development of the mind.* Moscow: Progress Publishers.

Menon, U. (2012). Extending numbers with number sense. *Paper presented at ICME12*. Seoul, Korea Retrieved from available at http://www.icme12.org/upload/UpFile2/TSG/1244.pdf

Menon, U. (2013). Mathematisation- vertical and horizontal. In Nagarjuna et.al. (Eds.), *epiSTEME -5, Proceedings - International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 260-267). Delhi: Macmillan.

Mumford, D. (2010). What's so baffling about negative numbers? – A cross-cultural comparison. In. C. S. Seshadri (Ed.), *Studies in the history of Indian mathematics* (pp 113-143). New Delhi: Hindustan Book Agency.

Sfard, A. (1991). On the dual nature of mathematical conceptions: Reflections on processes and objects as different sides of the same coin. *Educational Studies in Mathematics 22*(1), 1-36.

Sfard, A. (2007). When the rules discourse change, but nobody tells you: Making sense of mathematics learning from a commognitive standpoint. *The Journal of the Learning Sciences*, *16*(4), 567-615.

Treffers, A. (1991). Didactical background of a mathematics program for primary education. In. L. Streefland (Ed.) *Realistic Mathematics education in Primary School* (pp. 21-56). Utrecht: CD beta Press.

Vlassis, J. (2004). Making sense of the minus sign or becoming flexible in 'negativity'. *Learning and Instruction*, *14*(5), 469-484.

Vygotsky, L. (1987/1934). Thinking and speech. In R. W. Rieber and A. S. Carton, *The collected works of L.S. Vygotsky - Volume 1* (pp. 39-285). New York: Plenum.

HOW EXPERTS AND NOVICES NAVIGATE CHEMISTRY REPRESENTATIONS – AN EYE-TRACKING INVESTIGATION

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Experts are known to form more sophisticated conceptual associations between multiple external representations (MERs) than novices, however, the cognitive mechanisms underlying this ability in chemistry is not well understood. We attempt to characterize expert-novice differences in terms of the way they mentally process chemistry MERs. In this study, chemistry professors (experts) & undergrads (novices) view & categorize MERs. Using eye-tracking, we capture fine-grained data about participants' gaze patterns while they view given MERs, which we then correlate with the quality of categories they generate as well as justifications they provide for those categories. The professors tend to form chemically meaningful relationships between MERs than do undergrads. Eye-tracking data reveal differences between the two groups, in navigating chemical equations.

INTRODUCTION

Chemistry deals with complex systems, entities & phenomena that often cannot be directly perceived (e.g. atoms, chemical reactions, etc.) These imperceptible systems are understood at multiple levels of detail (electronic configuration, stereo-chemistry, stoichiometric ratios etc.), using multiple external representations (MERs), such as reaction mechanisms, molecular diagrams, graphs & equations, at each level. The ability to generate & use these MERs in an integrated fashion (for conceptualization, discovery & communication) is indicative of expertise in chemistry. This skill-set is collectively known as representational competence (abbreviated as RC, Kozma & Russell, 1997). Developing RC (expertise over MERs) is an important goal of chemistry education. Problems & difficulties in teaching/learning chemistry are attributed to difficulties in understanding the MERs in chemistry (Johnstone, 1991 & 1993; Kozma & Russell, 1997; Gilbert & Treagust, 2009).

A significant strand of research in chemistry education reports descriptions of students' use of multiple representations, transformations of these representations, and the difficulties students face while doing both of the above. Studies show that students fail to associate the symbols and numbers with substances and phenomena (in other words relate MERs and the information they convey; Herron & Greenbowe, 1986; Nurrenbern & Pickering, 1987; Sanger & Phelps, 2007), primarily due to a lack of clarity on basic concepts such as oxidation numbers, ionic charge, atoms and atomic structure, formal rules for writing molecular formulae, as well as meaning of subscript numbers and brackets and coefficients (Savoy, 1988). Ben-Zvi, Eylon and Silberstein, (1988) propose that students' thinking about phenomena relies primarily on perceptual/sensory information but since current pedagogical practices hardly provide perceptual/sensory assistance, students do not understand chemical symbols in terms of their macro and micro-level instantiations. Johnstone's model of three thinking levels (Johnstone, 1982) and versions thereof, describe three different levels of chemistry MERs: (a) macro level, where one sees and handles materials, observes and describes phenomena and their properties, such as color, flammability, solubility, (b) symbolic level, where one represents chemical substances and phenomena using symbols, formulas, equations and conventions, and (c) submicro level, at which one explains the nature of chemical substances, mechanisms of reactions, and the underlying molecular/atomic interactions. Johnstone (1991) attributes students' difficulties in learning chemistry to the difficulty in simultaneously handling MERs distributed across these three levels as a result of the limited capacity of the human working memory (Ben-Zvi, Eylon & Silberstein, 1988; Justi & Gilbert, 2002; Kozma & Russell, 1997; Mayer, 2002; Sirhan, 2007).

Another strand of research attempts to characterize and examine RC, and describes expert-novice differences in terms of use of MERs. For instance, researchers demonstrate using eye-tracking, that students mainly concentrate on graphical and model representations in animations and often ignore equations, when interacting with a multi-representational molecular mechanics animation (Stieff, Hegarty & Deslongchamps, 2011). While students face difficulties in producing static representations (e.g. sketches; Madden, Jones & Rahm, 2011) of the (imagined) dynamic particulate interactions, experts, on the other hand, seem to better transform between static (such as equation & graphs) and dynamic representations (such as reaction mechanisms; Wu & Shah, 2004; Nakhleh & Postek, 2008). Kozma and Russell (2005), identify specific skills among chemistry experts, viz., (a) using representations to describe chemical phenomena, (b) generating and/or selecting appropriate MERs according to specific needs, (c) identifying and analyzing different features of MERs, (d) comparing and contrasting different MERs, (e) making connections across different representations, relating/mapping features between MERs, (f) understanding that the MERs correspond to phenomena but are distinct from them, and (g) using MERs to support claims, draw inferences, and make predictions. Levy and Wilensky (2009) suggest that understanding chemical phenomena involves building of internal (mental) models that simulate the behaviors of many individual molecules/atoms, their collective behaviors and properties, and effects of various parameters on such behaviors.

Current characterizations of student difficulties and/or RC in chemistry can summarily be categorized into – cognitive load based explanations (expert is better able to handle the cognitive load by employing cognitive strategies such as information chunking, whereas novices lack such skills, Cook, 2006; Johnstone, 1982), context & practice based accounts (students lack exposure to these while experts have had ample exposure, Ben-Zvi, Eylon & Silberstein, 1988; Nelson, 2002; Tsaparlis, 2009), and conceptual understanding/prior-knowledge based explanations (which say that students have superficial understanding and low prior knowledge making it difficult for them to understand MERs; Cook, 2006; Nitz & Tippett, 2012). Ultimately, all these accounts boil down to the classical information processing framework emphasizing cognitive load and strategies to lower/handle it. Such accounts do not seek to provide a detailed understanding of the cognitive mechanisms underlying the processing of MERs, and thus offer only a rather superficial account of MER integration.

Our research attempts to characterize RC by developing models of the cognitive mechanisms underlying the processing of MERs, particularly integration of MERs (which is how we define RC), and suggest design principles for interventions. In this study, chemistry professors (experts) & undergrads (novices) view & categorize MERs. Using eye-tracking, we capture fine-grained data about participants' gaze patterns while they view given MERs, which we then correlate with the quality of categories they generate as well as justifications they provide for those categories.

We used Tobii X2-60 static eye-tracker to capture fine-grained data on student eye-movement and gaze patterns across MERs presented to (and handled by) them. Our preliminary analysis confirms earlier reports on novices' surface-feature-based exploration of MERs, but adds details of eye-gaze patterns.

EXPERIMENTAL SETUP

An MER categorization task (from Kozma & Russell, 1997) was conducted with six chemistry undergrad students (3 girls). We describe below the two phases of the study.

Preparing Task Material

Materials for the categorization experiment included different representations for five pre-determined general chemical reactions. There were four representations corresponding to each reaction – a chemical equation, a graph (except for the precipitation reaction), a video of laboratory personnel performing the reaction in a laboratory, and a bare 3D molecular animation (that depicted only the reaction mechanism at molecular level). We developed bare 3D molecular animations for the five chemical reactions. Each animation depicts only the molecular dynamics of that reaction, and does not have any other embedded representations, such as text, narrative, graphs or equations; thus, only one kind of representation. Free videos of the five chemical reactions (being performed in laboratories) from on-line sources were used. Chemical equations and approximate graphs for each reaction (except for the precipitation reaction that had no graph) were generated. This resulted in 19 representations corresponding to five different chemical phenomena. To make these representations more convenient for physical handling, the image of each representation (for animation and video, snapshot of an important moment as an image) was color printed and pasted on a 3x4 inch cardboard, generating 19 cards. Figure 1 depicts preparation and execution of the experiment in detail.

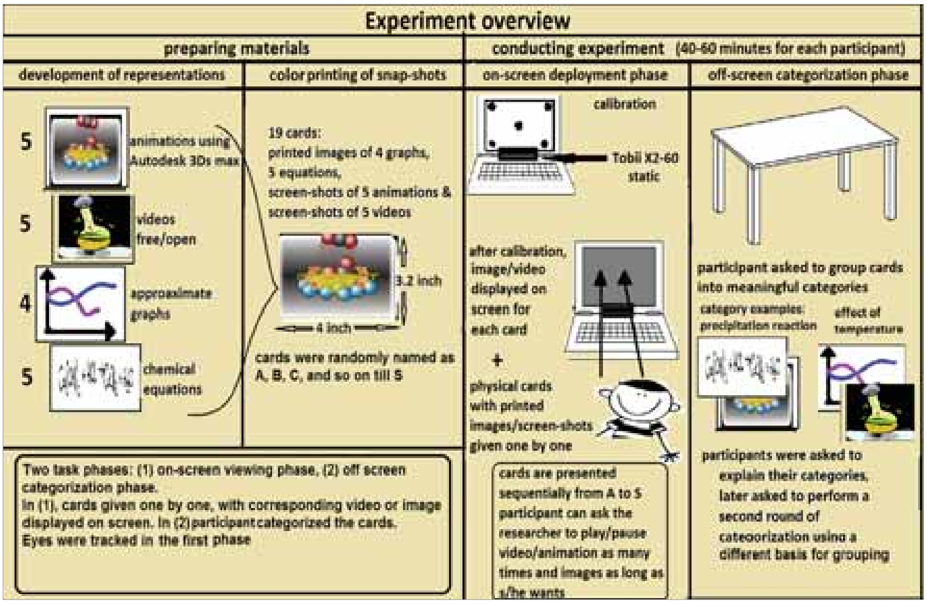

Figure 1: Material development and experimental design details

Running the Experiment

Six chemistry undergrads (3 females) as novices and seven chemistry faculty (4 females) as experts from different university colleges in the city of Mumbai participated in the categorization experiment. Each participant performed the experiment individually. The experiment had two phases:

On-screen phase

Participant was given each of the 19 cards (one after the other, in a pre-determined random order maintained for all participants), and was shown the corresponding image/video on a laptop screen. The participant could observe the images as long, and videos/animation as many times as he/she wanted. Going back to a previously shown representation was not allowed.

Off-screen phase

Once the participant viewed all the 19 representations and had all the cards, he/she was asked to group the cards into meaningful categories. There was no time limit to this phase. They were also asked to explain the different categories made and the basis of categorization (relationship between the cards/representations). The researcher then asked the participant to perform another round of categorization using a different grouping scheme, and explain the grouping criteria.

Data Collection

We used eye-tracking (Tobii X2-60, a static eye-tracker) during the on-screen phase of the task, to obtain fine-grained data about participants' eye-movements and gazes when they viewed the representations (See Pande & Chandrasekharan, 2014, for details eye-tracker setups).

Sources of data collection: (a) for on-screen phase – dynamic eye-movement and fixation data superimposed on the screen-capture video, (b) for off-screen phase – categories made by the participants, their verbal justifications, and side-view video recording of the categorization and justification sessions. The entire session ranged from 40-60 minutes for each participant.

RESEARCH QUESTIONS

1. Do experts make more chemically meaningful associations between MERs than novices?
2. Are there any gaze-pattern differences between experts & novices over static representations? If yes, what differences? How are they related to categorization?

HYPOTHESES

1. In graphs, the total fixation duration for experts would be higher for curves than the axes, as the shape of the curves conveys dynamic information about the phenomena (e.g. sigmoid behavior with time). Instead, novices are likely to spend more time on the axes than curves, as they might find numerical information more relevant to adhere to.
2. On equations, experts' total fixation duration would be more distributed across reactants, arrow, and products, as they would systematically look through each part of the equation and transit between the sub-scripts, super-scripts and coefficients.

Novices would either move randomly or tend to focus either on reactants or products more.

3. Experts would make more long-distance transitions over different parts of the equations, than novices, who would tend to move between closely located elements.

FINDINGS

We report preliminary results on (a) the nature of categories experts and novices make in the first trial of categorization, and the justifications they provide for those categories, (b) statistical analysis of the fixation data on static representations (graphs and equations), and (c) fine-grained process data on how the two groups differ in the way they navigate chemical equations during the viewing phase.

Nature of Categories

We coded the categories of representations participants generated, based on the chemical meaningfulness of relations/connections participants established between different representations, into following five types. (1) Conceptual categories: Chemically meaningful combinations of cards supplemented with correct conceptual description of grouping criteria (e.g. associations of cards depicting equilibrium phenomena, precipitation reaction). (2) Mixed categories: Categories with correct/plausible combinations of cards, with some associations and/or representations explained using chemical concepts while others explained using visual features (e.g. a category made with, say 4 cards depicting equilibrium reaction, of which two cards are explained using the concept of equilibrium while the other two explained based on similarity in features such as heating, or temperature-concentration axes of a graph). (3) Categories based on similarity in visual-features between the representations: Associations of cards explained purely on the basis of visual features of the representations grouped together (e.g. animation showing settling of molecules and a laboratory demonstration exhibiting precipitation; association explained in words such as, 'both settling down'.) (4) Media-based categories: Complete media-based combinations of cards (e.g. all molecular animations/simulations as a category, all graphs as another, etc.), and (5) Non-sense categories: Incorrect or meaningless combinations of cards not employing falling under any of the above category types (e.g. an association between a precipitation reaction equation with a video showing effect of temperature on a chemical equilibrium.

Experts tend to form more number of mixed as well as conceptual (chemically meaningful) categories than do novices, who tend to associate MERs more often based on their visual features and their medium of representation. This confirms the results from a previous study by Kozma and Russell (1997). The two groups do not seem to differ from each other in terms of the number of non-sense and media-based categories they made. Figure 2 depicts the mean percentage for each type of category generated by experts and novices, during the first round of categorization. A similar trend is observed over second round of categorization.

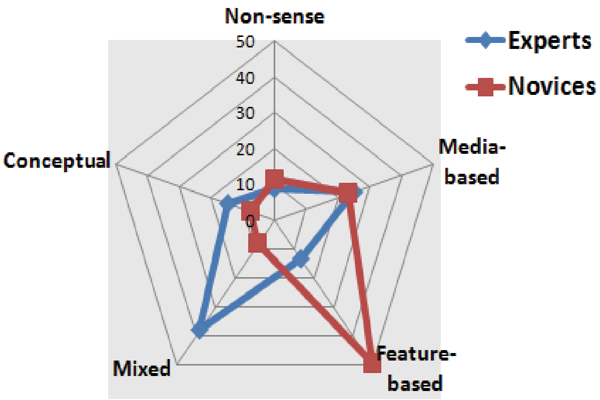

Figure 2: Distribution of participants' categories across different types

Fixation/Visit Duration Analysis

Fixation duration is a useful statistic to understand the total time spent by a participant viewing a given area of interest (AOI) or part of the representation while viewing it. We found no expected differences between experts and novices. They seem to spend their time viewing the different AOIs roughly similarly, thus rejecting hypotheses (i) and (ii). Both the groups seem to fixate slightly longer on the axes in the graphs, and reactants in the equations.

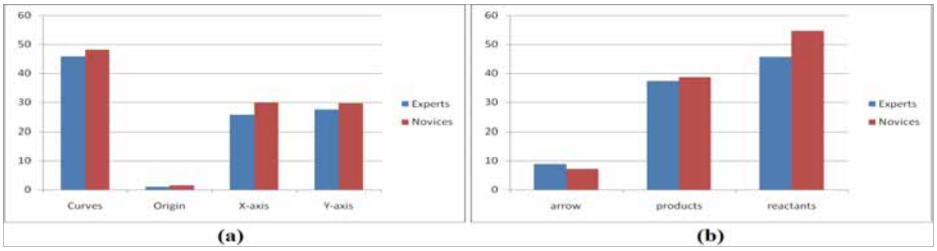

Figure 3: (a) Percent fixation duration on different parts (areas of interest - AOIs) across all four graphs presented, (b) Percent fixation duration on different AOIs across all the five equations.

Since nothing conclusive can be said through the fixation duration statistics, we decided to delve further into the viewing/thought process data. Below we report one aspect of such qualitative data – nature of fixation transitions (jumps).

Nature of Gaze Transitions

Here we report transition data only for equations. We characterized two kinds of transitions viz. long jumps (gaze transitions occurring within two distantly situated AOIs in the space) and short jumps (gaze transitions happening over two closely situated AOIs). For instance, in figure 4, any direct transition between the two reactants (R1 and R2) or between the two products (P1 and P2) would be counted as short jumps, whereas, transitions between the reactant and the product side would be long jumps.

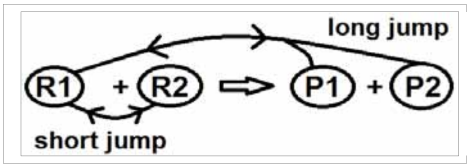

Figure 4: Long and short jumps

Experts performed more number of long jumps than novices on an average, while novices tended to perform more number of shorter jumps than longer jumps in comparison to the experts (results can be considered as partially significant at $p = 0.05$, as the extreme deviations from both groups overlap slightly, apparent in the box plots in figure 5).

Figure 6 depicts a normalized distribution of long jumps performed by experts and novices across all the equations. Experts make significantly higher number of longer jumps than novices. Conversely, they make significantly less number of short jumps than the novices.

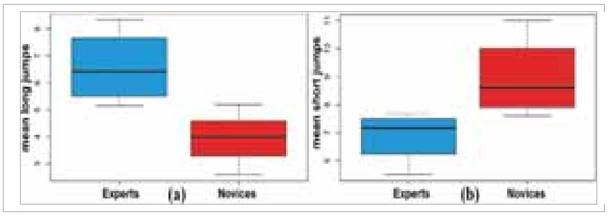

Figure 5: Box plots capturing (a) mean number of long jumps across all equations, (b) mean number of short jumps across all equations.

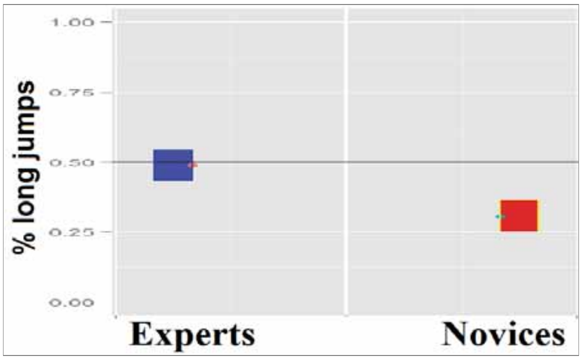

Figure 6: Percentage long jumps performed by experts and novices across all the equations, an inverse would be percent short jumps performed.

CONCLUSION

Our findings confirmed some results from previous literature, and added further details about how experts and novices move their eyes as they navigate (through) the MERs. Experts tend to make chemically meaningful as well as mixed groups of MERs in the categorization task more often than do novices, who tend to relate MERs based on their surface features. The eye tracking data suggests that RC and expertise can be characterized in terms of eye movements and gaze patterns across MERs (behavioral/cognitive markers). Significant differences between experts and novices in the proportion of gaze transitions between distant AOIs (reactants and products) suggest differences in the way they understand the dynamic relationship between reaction components. Experts may be said to imagine the reaction dynamics better, by relating elements between reactants and products, and understanding the points of chemical/substance-level transformations. Novices, on the other hand, seem to look at the chemical equation more linearly.

Further analysis is required to (i) isolate eye movement and navigation patterns related to RC, as well as (ii) comment specifically on the nature of internal/mental representation.

References

Ben-Zvi, R., Eylon, B., & Silberstein, J. (1988). Theories, principles and laws. *Education in Chemistry*, *25*(3), 89-92.

Cook, M. P. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education*, *90*(6), 1073-1091.

Gilbert, J. K., & Treagust, D. (2009). Towards a coherent model for macro, submicro and symbolic representations in chemical education. In J. K. Gilbert & D. Treagust (Eds.), *Multiple representations in chemical education* (pp. 333–350). The Netherlands: Springer.

Herron, J. D., & Greenbowe, T. J. (1986). What can we do about sue: A case study of competence. *Journal of Chemical Education*, *63*(6), 528.

Johnstone, A. H. (1982). Macro and microchemistry. *School Science Review*, *64*(227), 377-379.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75-83.

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing demand. *Journal of Chemical Education, 70*(9), 701–705.

Justi R. S., & Gilbert, J. K. (2002). Models and modelling in chemical education. In J. Gilbert, O. De Jong, R. Justi, D. F. Treagust and J. H. Van Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 213-234). Dordrecht: Kluwer Academic Publishers.

Kozma, R. B., & Russell, J. (1997). Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching*, *34*(9), 949-968.

Kozma, R., & Russell, J. (2005). Students becoming chemists: Developing representational competence. In J. K. Gilbert (Ed.), *Visualization in science education* (pp. 121-145). Dordrecht: Springer.

Levy, S. T., & Wilensky, U. (2009). Crossing levels and representations: The connected chemistry (CC1) curriculum. *Journal of Science Education and Technology*, *18*(3), 224–242.

Madden, S. P., Jones, L. L., & Rahm, J. (2011). The role of multiple representations in the understanding of ideal gas problems. *Chemistry Education Research & Practice.*, *12*(3), 283-293.

Mayer, R. E. (2002). Multimedia learning. *Psychology of Learning and Motivation*, *41*, 85-139.

Nakhleh, M. B., & Postek B. (2008). Learning chemistry using multiple external representations. In J. K. Gilbert et al., (Eds.), *Visualization: Theory and practice in science education*, (pp. 209–231). NY: Springer.

Nelson, P. G. (2002). Teaching chemistry progressively: From substances, to atoms and molecules, to electrons and nuclei. *Chemistry Education Research & Practice*, *3*(2), 215-228.

Nitz, S., & Tippett, C. D. (2012). Measuring representational competence in science. In E. de Vries & K. Scheiter (Eds.), *Proceedings EARLI special interest group text and graphics: Staging knowledge and* experience: How to take an advantage of representational technologies in education and training (pp. 163-165). Grenoble, France: Université Pierre-Mendès-France.

Nurrenbern, S. C., & Pickering, M. (1987) Concept learning versus problem solving: Is there a difference? *Journal of Chemical Education, 64*(6), 508.

Pande, P., & Chandrasekharan, S. (2014) Eye-tracking in STEM education research: limitations, experiences and possible extensions, In Kinshuk & Murthy, S. (Eds.), *Proceedings of the 6th IEEE International Conference on Technology for Education* (pp. 116-119), Amrita University, Kerala: IEEE Conference Publications/ Conference Publishing Services.

Sanger, M. J., & Phelps, A. J. (2007). What are students thinking when they pick their answer? A content analysis of students' explanations of gas properties. *Journal of Chemical Education, 84*(5), 870–874.

Savoy, L. G. (1988). Balancing chemical equations. *School Science Review*, *69*(249), 713-720.

Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish Science Education, 4*(2), 2-20.

Stieff, M., Hegarty, M., & Deslongchamps, G. (2011). Identifying representational competence with multi-representational displays. *Cognition and Instruction*, *29*(1), 123-145.

Tsaparlis, G. (2009). Learning at the macro level: The role of practical work. In J. K. Gilbert & D. Treagust (Eds.), *Multiple representations in chemical education* (pp. 109-136). Dordrecht: Springer.

Wu, H. K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education*, *88*(3), 465–492.

DOES INTERACTIVE VISUALIZATION AFFECT MOTOR COGNITION AND LEARNING OUTCOMES OF STUDENTS?

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Interactivity in e-learning environment is an innovative approach in teaching-learning. Predominantly theoretical justification of interactive learning environment has been discussed on the basis of the process of visual and auditory information in our memory system. However, by definition interactive is described as 'to act'. In this view point the present research attempts to explore the effectiveness of interactive visualization when compared with only visual animation. To do so total 360 student have been selected to conduct the study with different matching criteria. Participants are randomly assigned to two different instructional condition (interactive and animation condition). Analysis are conducted in two different phase; a prior knowledge test to find out the significant difference in students existent knowledge regarding the subject matter (Human Heart) and MANOVA are conducted to find out group difference in different condition. Result has shown a momentous mean difference in different condition i.e., in interactive condition where student perform virtually in the on-screen object better than animated condition (observed action) in respect of various learning outcome. Result is discussed critically from several theoretical focal points.

Keywords: motor cognition, interactive visualization, multimedia in learning outcome, visualization

INTRODUCTION

E-learning environment, learning with computer based on-screen learning environment is a growing phenomenon since the use of computer as a mode of teaching learning. Nevertheless, researcher have been giving more focus on interactivity in visual instruction which is not less important than linear visual instruction such as video tape and static animation because learning is not simply a process of information transmission, rather students should become actively engaged for deep learning (Halder et al., 2015). However, predominantly theoretical justification of visual instruction specially on multimedia and interactive on screen instructional environment mainly focus on cognitive process of visual and audible sequence in our memory system, so to say a dual coding approach (Paivio, 2014), Cognitive Theory of Multimedia Learning (CTML) (Mayer & Chandler, 2001) and Integrated Theory of Text and Picture Comprehension (Schwan & Riempp, 2004). All mentioned theories have emphasized mainly on encoding of auditory and visual information with two separate channel help through specific process (selection, organization and integration) for meaningful learning. However, an interactive learning environment also requires the learner by definition act. In this view point, major contribution in this article is to explore the effectiveness of enactment (Motor encoding) in interactive onscreen learning material by adding virtual manipulation features with action phase.

Besides, present research illuminates the multimodal theory and enactment conception radiating a distinctively different domain such as incorporating virtual enactment in instructional visualization modeling as virtual manipulation. That is relatively unique contribution in this research especially in India where this research is conducted. Nevertheless, present research emphasizes over various kinds of knowledge domain (factual, conceptual, rules and principle) adding a new characteristics in the existing research.

ENACTMENT IN COGNITIVE PSYCHOLOGY AND INTERACTIVE MULTIMEDIA ENVIRONMENT: RESEARCH REVIEW

Many empirical studies incorporated various interactive features in on-screen learning environment but they have given major emphasis on outcome oriented perspective in the sense that they have given impotency of computer response to learner action rather than learner activity and engagement in computer programming (Trninic & Abrahamson, 2012). Notably, this study emphasized on design of instructional media (eg, object manipulates or not) ignored the learner activity and engagement. Only limited number of studies has described interactive instruction from the motor activity perspective. Study by Schwartz & Plass (2014) examined the effect of four different types of interactive (iconic, symbolic, look and listen) condition and have found that iconic (dragging) interactivity is superior than other three conditions in free recall and recognition tasks and describes this result from the enactment focal point. However, for meaningful learning there is need to emphasize different knowledge domain which is ignored in these researches. Nevertheless, previous research on enactment or participant performance has been conducted mainly on real situation and major emphases have been given on free recall and recognition task. However, we have gone step further to explore this theoretical assumption on virtual manipulation performance in computer based instructional environment and to enrich previous research on measuring effectiveness of this performance in factual, conceptual and rules and principal knowledge domain.

Objective of the Study

To investigate the effect of visual instruction (interactive visualization as compared with Animated instruction) on student achievement of learning objectives (factual, conceptual, and rules and principle knowledge).

Hypothesis

H0: There will be no significant difference with respect to various instructional visualizations (interactive visual and animation) of student achievement of different learning objective (Factual, Conceptual and Rules and principle knowledge).

Participant

Present study was conducted on Central Board of Secondary School (CBSC) in Kolkata. Most of the students belonged to lower-middle-class families. From 500 students, 360 students were strictly matched on the following criteria:

- Scored 10 or greater in computer proficiency test developed by researcher.
- Age ranged from 13-16 (mean age 15.02 years and SD= 2.36).

Measurement Instrument

General Information Schedule: General Information Schedule comprised of student demographic information and Socio economic status (Parental education, income and occupation).

Computer Proficiency Test: To match experimental and control group, a computer proficiency test was developed by the researchers. The main objective of this test was to measure how efficient they were to use different functions of the computer specially mouse, keyboard and computer screen. Reliability of this test was measured as 8.74.

Prior Knowledge Test (pre-test as covariate): The Prior knowledge test originally developed by the researchers Dwyer (1978), consisted of 36 multiple-choice questions on human physiology. For this study purpose the test was re-standardized and validated by Kuder-Richerdson (KR) estimation and by content validation. The objective of this test was to measure student's previous knowledge regarding human physiology. Reliability of the prior knowledge test was .89.

Criterion Measures Test (Post-Tests)

The three criterion tests used in this study was developed by the researchers (Dwyer, 1978). Each test consisted of twenty multiple-choice questions worth 1 point.

Identification test: The main objective of identification test was to measure student's factual knowledge about content material used for the present study. This test measured student ability to identify the names and positions of the parts. Students have to identify the parts of the heart indicated by the numbered arrows on a heart outline drawing.

Terminology test: The main objective of terminology test was to measure conceptual knowledge of student about content material used for the study. The terminology test measured student knowledge of specific facts, terminologies, and definitions. Students answered the multiple-choice questions selecting the answer that best described different parts of the heart.

Comprehension test: The main objective of comprehension test was to measure student's rules and principle knowledge about content material used for the study on the topic (human heart). Rules and principle knowledge learning of students on the given module (human heart) refers to those cause-and-effect or correlational relationships that are used to interpret events or circumstances.

Reliability and Validity of All Three Criterion Tests

The KR 20 results were all above 0.80, which is satisfactory level of reliability. Anastasi & Urbina (1997) indicating high reliability for the three criterion tests (0.86 for Identification test, 0.81 for Terminology test and 0.85 for Comprehension test).

All the tests (computer proficiency test, prior knowledge test and three criterion tests) have been validated by content validity with expert rating. Group of panel experts included a professional visual designer offering visual design classes and subject experts in Biology.

DEVELOPMENT OF INSTRUCTIONAL MODULE AND LEARNING MATERIAL

Instructional content material of this study is adapted from a color-coded, paper-based booklet developed by the researchers Dwyer (1978),on the topic 'human heart 'containing five units: 1) the heart's structure; 2) the veins and arteries; 3) the valves of the heart; 4) the blood flow through the heart; and 5) the phases of the heart cycle. This content was chosen as it allows the evaluation of different levels of learning objectives. This topic is selected after consultation with experts in the subject.

Illustration of Developed Instructional Module

For the purpose of the study following two separate instructional modules has been developed by the researchers:

Interactive Visualization Condition (Virtual Manipulation)

Under this condition the above mentioned instructional content was framed in 20 different slides. Each frame introduced the structure and function of human heart. Extreme left sides of each frame had text and the right side had a corresponding virtual manipulative graphical and programmed instruction elaborating the text. Over every manipulative graphic there were some action phases (instruction given). Student needs to read the text and work as per the given action phase. In each frame the user can hear an audio corresponding to the text and action phases.

Animated Condition

Akin to virtual manipulation condition there were instructional content framing 20 different slides. Each frame introduced the learner structure and function of human heart presented in animated video (function of human heart) along with some particular button (play, pause, and stop).

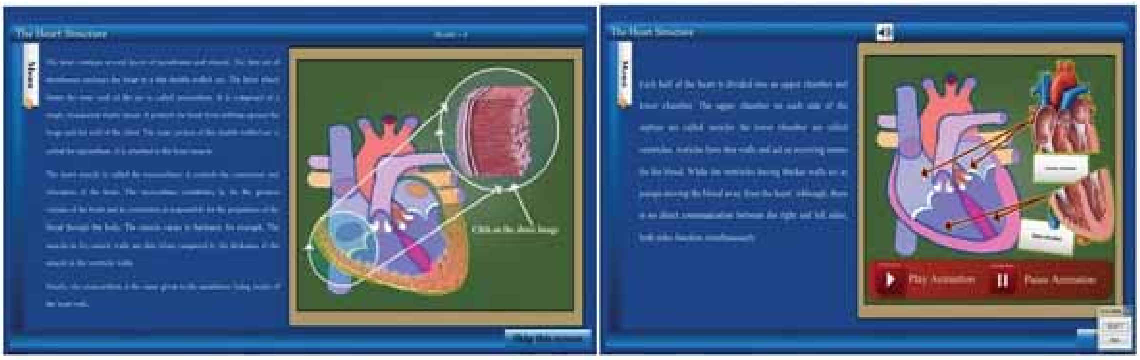

Figure 1: Left side image is the screen shot of interactive visual with action phase screen design and right side image is the screen short of continuous animated visual design.

RESULTS ANALYSES AND INTERPRETATION

The overall objective was to find out the effectiveness of various instructional visualization (virtual manipulation in interactivity and animation) conducted in two phases

First Phase, Covariate Data Analysis: Prior Knowledge Test on the Physiology

An analysis of variance was conducted on the physiology test scores to determine if there was a significant difference among the treatment groups on their prior knowledge regarding subject matter (Human heart).

Criterion Test	Sum of Squares	df	Mean Square	F	Sig.
Identification + Terminology + Comprehension	68.60	8	8.58	1.28	0.27
Each criterion test consist of 20 items					

Table 1: ANOVA result for tests of between-subjects effects (prior knowledge test and three criterion tests)

The result of the ANOVA analysis indicated that there is no significant differences among the treatment groups on the test (Table 1) score F (8/352) = 1.28, p= 0.27. Result indicated that the participants were approximately equal in their prior knowledge on the content material used in the study and therefore any results of treatment effects would not be attributed to the difference in participants' prior knowledge.

Second Phase: Results of MANOVA

As more than one dependent variable was used in conjunction with the independent variable, a multivariate analysis of variance (MANOVA) was conducted to analyse the effect of treatment material in instructional visualization in the student achievement of learning of educational objectives (overall effect i.e., factual, conceptual, and knowledge of rules and principles) through computer based instruction visualization method.

Effect	Tests	Value	F	Sig.	ηp^2
Instructional Visualization	Wilks' Lambda	0.75	38.39	0.00**	0.24
**Mean difference significance at 0.05 level and each of the criterion tests contains 20 items.					

Table 2: Represents analysis with all criterion test (Identification, Terminology & Comprehension test) indicating MANOVA results using Pallai's trace & Wilks' lambda.

From the above table we found that there was a significant main effect of instructional visualization (Wilks' Lambda = 0.75, F (3/357) =38.39 & ρ= 0.00>0.05) in the three criterion test (identification, terminology and comprehension) and the multivariate effect size was estimated at 0.24, which is large and implying that 24.0% of the variance in the canonically derived dependent variable was accounted by instructional visualization. This significance MANOVA result and percentage of partial eta square was sufficient to do univariate follow-up ANOVAs that helped to further isolate exactly where the significant and interesting mean differences were found (Table 3)

Experimental Group	Test by Treatment	df	F	Sig	ηp^2
Instructional Visualization	Identification	1	113.56	0.00**	0.24
	Terminology	1	11.84	0.00**	0.03

	Comprehension	1	5.63	0.01**	0.16
**Mean difference significance at 0.05 level in the three criterion tests (contains 20 items).					

Table 3: Test Between subject effect instructional visualization on three criterion test

Subsequent univariate tests or exploratory follow-up analysis using ANOVA (Table 3) result indicated significant differences in achievement among students who received different conditions of instructional visualization on the three criterion test (Identification test $F(1/358) = 113.56$ and $\rho = .00 < 0.05$, $\eta p^2 = 0.24$, Terminology test $F(1/358) = 11.84$, $\rho = 0.00 < 0.05$, $\eta p^2 = 0.03$, Comprehension test $F(1/358) = 5.63$, $\rho = 0.01 < 0.05$, $\eta p^2 = 0.16$). This significant ANOVA result on the three criterion test indicate the need to explore which of the specific groups of instructional visualization differed viz, virtual manipulation in interactive visualization, and animated visual. To further identify the differences (Table 4) adjusted means and standard errors for type of instructional visualization on three criterion test were done

Dependent Variable	Instructional Visualization	Mean	Std. Error	95% Confidence	
				Lower	Upper
Identification	Animation	9.672	.204	9.271	10.073
	Virtual Manipulation	12.744	.204	12.344	13.145
Terminology	Animation	11.911	.256	11.408	12.414
	Virtual Manipulation	13.156	.256	12.653	13.658
Comprehension	Animation	12.867	.238	12.398	13.335
	Virtual Manipulation	13.667	.238	13.198	14.135

Table 4: Presents the adjusted means and standard errors for different types of instructional visualization condition on three criterion test.

From (Table 4) we found that student who used virtual manipulation in interactive instructional visualization outperformed than the students who used animated visualization in identification (12.74), terminology (13.15) and comprehension (13.66) tests which measured factual, conceptual and rules and principal knowledge.

DISCUSSION

Superiority of virtual manipulation compared with animated condition establishes the fact that “enactment” positively affects achievement of students learning objective in a virtual computer based environment. Theoretically this finding concurs with previous researchers that noticed that various sensory and motor output systems get activated during enactment elevating richer encoding (Nilsson et al., 2000). More specifically one can discuss both motor and visual output encoding and decoding processes conjuncting in virtual manipulation condition, distinguishable with animated condition where only visual sensory information involves. This research result is also supported by previous research Schwartz & Plass (2014) revealing iconic interactivity (manipulation) superior in free call performance of the student than symbolic interactivity (click condition). The present research supports these findings. It is found that the virtual manipulation condition where student directly involves in drag and manipulation of screen object scores higher as compared with animation condition. Besides result also establishes the fact that virtual manipulation not only increases recognition power but also its positive effect has been found on participant conceptual and rules and principle knowledge domain.

SIGNIFICANCE OF THE STUDY

Present study extends and applies previous multimodal theory in instructional visual instruction. The result of this research introduces a theoretical approach to thinking more systematically regarding the different types of visual instruction and their impacts on learning outcomes from the enactment or motor activity focal point. This major contribution can be helpful for forthcoming researcher of educational technology and instructional designer to design an educational multimedia learning material.

Nevertheless, present study establishes the fact that enactment not only effect free recall but also various knowledge domains. This view can be helpful for willing future researchers to establish a theoretical assumption regarding visual instruction.

One of the major practical advantages is that in the classroom environment one is not able to produce various abstract concepts. By adding virtual manipulation features in instructional visualization one can produce all types of abstract and real world object in computer based laboratory environment by visual simulation.

On practical level, the present research finding provide a significant road map for instructional designer that virtual manipulation features in interactive visualization activating motor cortex rather than pre-programmed animation to enhance teaching-learning.

References

Dwyer, F. (1978). *Strategies for improving visual learning*. State College, Pa.: Learning Services.

Halder, S., Saha, S., & Das, S. (2015). Computer based self- pacing instructional design approach in learning with respect to gender as a variable. In Mandal et al. (Eds.), *Information systems design & intelligent applications, V. 340 Advances in intelligent systems & computing.* India: Springer.

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93*(2), 390–397.

Nilsson, L., Nyberg, L., Klingberg, T., Åberg, C., Persson, J., & Roland, P. E. (2000). Activity in motor areas while remembering action events. *NeuroReport, 11*(10), 2199-2201.

Paivio, A. (2014). Intelligence, dual coding theory, and the brain. *Intelligence*, *47*, 141-158.

Schwan, S., & Riempp, R. (2004). The cognitive benefits of interactive videos: Learning to tie nautical knots. *Learning and Instruction*, *14*(3), 293-305.

Schwartz, R., & Plass, J. (2014). Click versus drag: User-performed tasks and the enactment effect in an interactive multimedia environment. *Computers in Human Behaviour, 33*, 242-255.

Trninic, D., & Abrahamson, D. (2012). Body of knowledge: Rethinking mathematical concepts as signified embodied procedures. Paper presented at "*Rethinking Cognitive Development"—the 42nd Annual Meeting of the Jean Piaget Society*, Toronto, May 31 – June 2, 2012.

USING DIAGRAMS IN INCLUSIVE LEARNING SITUATIONS

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Diagrams and drawings are important tools for understanding science. However, these are often not given due importance in textbooks and specifically braille textbooks. Haptic perception through raised lined diagrams and use of colours give students with/without vision a better opportunity for visualization. Studies have also indicated that interactive peer support strategies help in the successful inclusion of students with disabilities in general education. The study focused on understanding questions raised by students while observing diagrams and how students with visual impairments represent their visualization. It used adapted diagrams with small groups of students to facilitate peer to peer interaction.

Keywords: inclusive education, diagrams, collaborative learning, disabilities, students' questions, science education

INTRODUCTION

With the current emphasis on educational inclusion, there is a dire need to develop and study effective pedagogies for inclusive science education (Sharma & Chunawala, 2013). Inclusive education along with its many other characteristics "*recognises and responds to the diversity of children's needs and abilities, including differences in their ways and paces of learning. It encourages the use of adapted curricula and teaching devices*" (Jonsson, 1994, p. 158).

In Indian middle school science scenario, learning opportunities that allow students to observe and handle specimens and models, are scarce. Thus, information about structures and functions of abstract entities are accessible to students only through diagrams. Diagrams are important tools for science learners to get access to complex information as these initiate visualization (Uttal & Doherty, 2008). Visual representations through diagrams have a motivating and cognitive role in science communication (Jones & Broadwell, 2008). Besides, development of science and technology depends on visuals *"such as diagrams, illustrations, maps, plots, and schematics."* (Mathewson, 2005, p. 530).

Moreover, drawing of diagrams by students is as important as learning through diagrams. It not only provides a medium to represent the visualization, but also helps them in *"manipulating complex concepts, expressing feelings, observations and perceptions"* (Hope, 2008, p. 170). According to some science educators, a pedagogy centered around diagrams does not require any special equipment to be integrated into normal classroom (Padalkar & Ramadas, 2011). However, a study on Indian textbooks (Vinisha & Ramadas, 2013) suggests that visuals are often not given due attention by textbook writers and publishers.

For students with visual impairments (SVI), the situation is even more problematic as they do not have access to visuals in textbooks. Most brailled textbooks do not have raised illustrations and have "*nothing but pages and pages of boring Braille dots"* (UNICEF, 2000). It is important to note that visualization is not only about vision; the processes of visualization are not disrupted due to vision impairment (Figueiras & Arcavi, 2012). Studies suggest that there is little difference in the perception of spatial relationships by SVI and other students. This may be because the semantic representations used by SVI and sighted students facilitate imagery (Zimler & Keenan, 1983) and knowledge construction by SVI is also supported by haptic perception and verbalization (Figueiras & Arcavi, 2012).

Hill (1995) has reported the use of raised line diagrams for SVI to give them nearly full access to diagrammatic aspects of science. Using multi-sensory approaches in education, such as, the combined use of haptic perception through raised lines, visual perception using colours and verbal descriptions can benefit all students (with vision, low vision or without vision). These help in developing a student centered classroom (Stoffers, 2011) and can enable learners with sensory disabilities to learn with the same resources as used by others (Jubran, 2012).

Heterogeneity exists in the classroom in many forms. Apart from differences of skills, interests and abilities, students also differ in the senses they use primarily for learning. Therefore, when planning pedagogic strategies or learning aids, the teacher must thoughtfully acknowledge such differences (Sapon-Shevin, 2005). One such pedagogic strategy is peer-to-peer interactions in groups (Mehrotra, 2008) which involves collaborative learning and caters to heterogeneous classrooms. Roschelle and Teasely (1995) define collaborative learning as a *"coordinated and synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of the problem"* (p. 70).

The Study

This study tries to understand the processes involved in the use of adapted diagrams in inclusive collaborative learning situations. Depictive diagrams ("that closely resemble the objects they represent", Mathai, 2013, p. 55) and static models were used to assist visualization and students represented these by drawing diagrams. The study was done in 3 parts; the first 2 parts involved using diagrams, while the third part, used models and verbal descriptions for evoking visualization. The study addresses the following research questions: 1) What do students observe in diagrams in inclusive collaborative learning situations? 2) What questions are raised by students while observing diagrams? 3) How do SVI represent their visualization?

Sample: Convenience sampling was used for sample selection for all three parts of the study. **Part 1:** 20 students (Grade 8, age range 13-18) from an inclusive school were selected. Five groups of four students each were formed. Group 1 (3 girls, 1 boy, all had orthopaedic disabilities); Group 2 (4 boys, 2 had orthopaedic disabilities, 1 had no vision, 1 had low vision); Group 3 (2 boys, 2 girls, 1 boy had a learning disability, others had no disabilities); Group 4 (4 girls, 2 had hearing disabilities, 1 had hearing & speech disability, 1 had no disability); Group 5 (4 boys, 2 had orthopaedic disabilities, 2 had no disabilities).

Tools and administration of Part 1: Students performed two tasks: A) unguided collaborative observation of 8 large, raised lined, coloured and labelled diagrams of micro-organisms. B) recognizing these diagrams and recalling the names of the micro-organisms the next day. During this recalling of names in task (B), unlabelled, miniaturised, colourless, raised lined, mirror image representations of diagrams in task A were presented to all the students individually.

For task A, an observation sheet was used; groups wrote their observations of the diagrams and questions. Any one member of the group did the writing. Students were allowed to take as much time as they needed to observe and discuss each diagram, and write on the given sheet. Since the session lasted only for 40 minutes, groups observed differing number of diagrams.

(Group 1= 6 diagrams, Group 2= 3 diagrams, Group 3= 4 diagrams, Group 4= 4 diagrams and Group 5= 2 diagrams). We focused on Group 2, which had 2 SVI, to find out if all information was transmitted effectively to them. Some of the responses and questions raised by the group regarding the diagrams of rhizopus and virus are given below.

 Rhizopus	**Student observations:** *There are some bacteria like dots in the three circles. (Sporangiospores in sporangia),* *There are some root like bushes at the lowest part. (Rhizoids),* *There is a (horizontal) green bamboo like wood. (Stolon).* **Questions:** *Where are they found? What are the harms and uses due to this? What are the causes of their spreading? What diseases can be caused by them?*
 Virus	**Student observations:** *It looks like an alien or robot. Legs are visible in it.* **Questions:** *What disease is caused by it? What is its colour? Where are they found?*

Table 1: Some of the responses of students in Group 2 to the diagrams of micro-organisms

Results of part 1: Collaborative observations of students could be attributed to analogies, such as, “looks like an alien or robot”. The questions raised by the students on the basis of these diagrams were non-trivial. The next day, all students including the SVI recognized the diagrams that had been observed by their group from the complete set of 8 diagrams. On the recall task, it was found that the name of Amoeba was recalled correctly by all students (8/8 students of the two groups who had viewed it) while *Aspergillus* and *Chlamydomonas* were recalled by none of the students (0/8 students of the two groups who had observed these).

Part 2: 18 students (Grade VII, age range 12-16) from the same school were selected. Students formed 4 groups of their own choice. Group 1 (4 girls, 1 had an orthopaedic disability, others had no disability); Group 2 (5 boys, 2 had hearing disability, 1 had learning disability, 2 had no disability); Group 3 (5 boys, 1 had hearing disability, 1 had learning disability and 3 had no disability); Group 4 (4 girls, 1 had no vision, 1 had orthopaedic disability, 1 had learning disability, 1 had severe skin related illness).

Tools and administration of part 2: Students were asked to write the names of different types of teeth and draw their diagrams; this was done to learn their previous knowledge. The SVI was given instructions on a braille sheet, where she could also write and draw. Each group of students were given a set of four different types of diagrams of teeth made by the researcher. Each type of teeth diagram (for example, incisors) was different from another type (canine, molar or pre-molar) in terms of colour, type of raised outline and raised or smooth inner space. Students had previous knowledge about the names and shapes of the four types of teeth through their science textbook, but the SVI had no exposure to the diagrams of teeth as her braille textbook did not have such diagrams.

Students recorded their unguided collaborative observations and questions related to the diagrams, and also drew the four observed diagrams of teeth on the observation sheet individually. The sheets for the SVI were brailled. A video of digestive system was screened in the interval between filling of observation sheet and the test sheet; the latter required students to name and draw all the observed four types of teeth based on recall. Next, students were presented 9 unlabelled raised line test diagrams with coloured outlines, among which four represented the types of teeth shown earlier, while the other five represented different types of cells namely nerve cell, unstriated muscle cells, human cheek cells, onion peel cells and red-blood cells. Students had to recognise the diagrams they had seen earlier.

Results of part 2: Only 2/18 students could draw the teeth-diagrams (partially correct) while 9 students could name all the types of teeth correctly. Students' observations of the diagrams often focused on the resemblance of the diagram with some known object. Some responses:

Student observations	Questions
Incisor: This shape seems to be like a carrot, -root part of tooth looks somewhat like a hand.	How is its root part (root) formed? Why don't these teeth prick in our mouth? How long is this teeth?
Canine: This seems to us like an ice-cream.	Why is it shaped so?
Pre-molar: The crown part looks like teeth itself, but the root looks like a chilli *(mirchi)*. - It looks like radish.	All these teeth look similar. Why is it so? - Why does it look so?
Molar: This looks like a World cup trophy. - It looks like an Octopus. - This is the biggest diagram among all. - This is helpful in chewing.	Why are they present (in mouth)?

Table 2: Some responses of students to teeth diagrams

Even when asked to draw while observing the diagrams, an average of 13-14 students drew each diagram correctly. Remaining students (5) either did not draw some diagrams or drew some of them incorrectly. The correctness of a diagram was decided by the presence of the differentiating features of the tooth, such as the outline of the teeth, inner contours, proportion of crown to root, etc. When asked to draw the teeth diagrams from memory after observation, 15 students drew the molar correctly but other teeth (incisors, canines and pre-molars) were drawn correctly on an average by 9-10 students. Reasons why more students drew the molar correctly could be as it was the last observed diagram; or the combination of colour, raised lines and raised inner space are effective aids; or both the above conditions together. Students' performance on recalling the names of teeth was better; the molar was named correctly by 17/18 students while the other three teeth were named correctly on an average by 14-15 students. In the recognition task, all the 18 students including the SVI could recognise the previously observed four diagrams correctly out of the given 9 test diagrams.

Drawings by the SVI: The SVI in part 2 stated that she had never drawn anything previously. Her first attempt to draw was by using the stylus and the braille sheet on a braille slate, as seen in (Fig.1 B), where she attempted to draw a canine tooth.

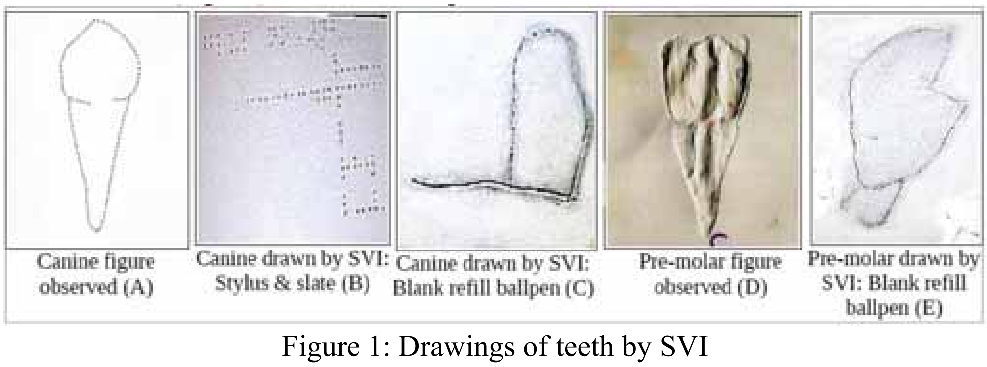

Figure 1: Drawings of teeth by SVI

It is to be noted that she herself was not satisfied with her efforts. Later, she attempted to draw the same on the braille sheet with a blank refill ball-pen. This attempt (Fig 1 C) had the crown part but not the root. Lastly her drawing of a pre-molar (Fig.1 E) with a blank refill ball-pen, on a braille sheet showed both the root and crown. The practice of drawing and the changes in the instrument she used, led to better diagrams. The SVI was helped by her group members in her efforts.

Part 3: This was done in a different inclusive setting with 7 students who were studying in different grades (P3 was from primary class; P1, P2, B and F1 were from Grade VIII; R was from Grade IX; F2 was from Grade X). Of these students, 2 (P1 & P2) had normal vision, 2 had no vision (R & F1) while 3 had low vision (B, P3, F2). The student F1 had no vision congenitally. Three days prior to this study, some activities were done with the students related to the basic concept of Atoms (as requested by students). Additionally, students were exposed to some tools that are helpful for SVI in drawing. In part 3, verbal descriptions and models of Rutherford's gold-leaf experiment and resulting atomic model were presented.

Students explored the models and asked questions to understand the experiment and the model for around an hour. The students were then asked to draw the diagram of the setup of the Rutherford's experiment and the model of atom, for which they took around 25 minutes. The model and the descriptions provided a context to ask questions and for discussion. Example of discussions while observing the model of Atom:

F1: ...like I have read in science that the planets revolve... then a question arises do they also collide, so we say that they do not collide as they revolve in their own orbits. Now you say that these (electron in Atoms on basis of Rutherford's experiment) revolve in the same orbit, then would they collide?

Res: This is a very good question... would anyone among you like to tell whether this would happen or not?

B: No they would not collide, they may go behind each other like this (moving finger in circular motion), and their speed would be the same.

R: They would have possibly maintained the distance.

Res: Ok. Is any other way possible?

F1: Sir, I feel that they would collide... because whatever distance they maintain, some misunderstanding is still possible.

Res: Ok. Can anybody else say what other possibilities exist?

F1: Yes... one thing is there, the merry-go-round that goes round-round, in the same manner as it rotates, that too rotates by keeping distance and does not collide. So maybe this is possible. (focusing on motion of the outer edge of merry-go-round)

Results of part 3: The SVI in this study along with other students asked some higher order questions related to science and could represent their visualization using diagrams. In Fig. 2, the diagrams of the two models explored and drawn by some students are depicted. The diagrams (B) and (E) were drawn by SVI (R) to represent the models (A) and (D). The student used a bangle to get the ring shape in both the diagrams. She has drawn the thread in diagram (E) which is not part of the atomic model but is part of the teaching aid. Her diagram (B) on the other hand had the essential features of the model except the gold foil which she drew outside the ring. Her drawing had some resemblance to the diagram (G) that was made by student P2 who had normal vision.

The SVI (F1) drew the drawings (C) and (F) to represent (A) and (D), but could draw only some features of the models and missed many details, such as, the 2 slits through which the alpha particle travels. However, he managed to properly orient the source of alpha particles and the gold foil (the alpha particles would hit upon the gold foil). Student R had exposure to drawings previously, but F1 stated that he had no such experience except the exposure he received three days prior to the study.

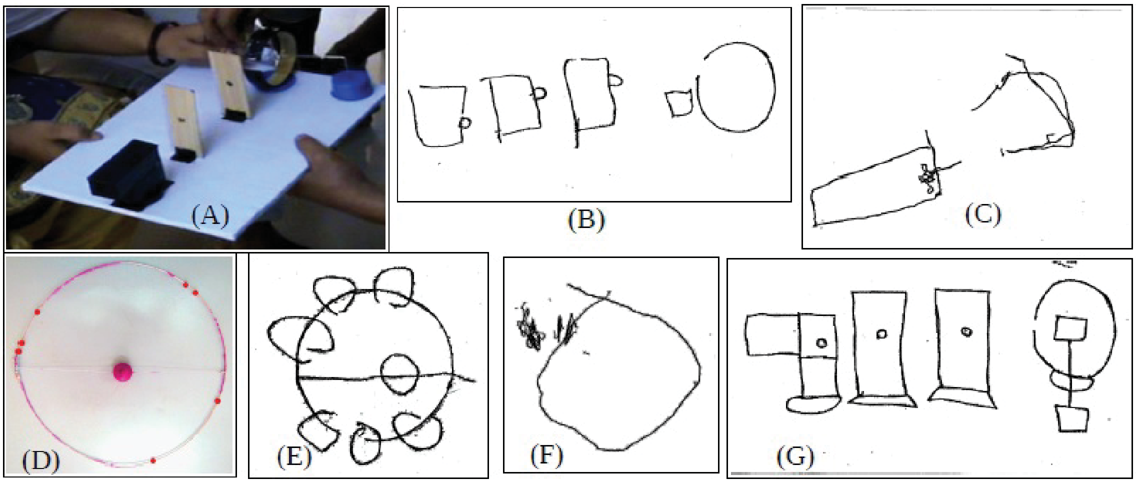

Figure.2: Models observed by students: (A), (D); Diagrams made by SVI-R: (B) and (E); Diagrams made by SVI- F1: (C) and (F); and drawing made by student P2: (G)

FINDINGS

Collaborative learning settings were found to be effective in the study. In part 1, the two SVI recalled the names of the observed diagrams after a day, despite those names being inaccessible to them in tactile form. They also recognized all the 3 miniaturized, mirror imaged, raised line diagrams from 8 diagrams through touch. A positive aspect of peer interaction and inclusion was seen in part 2 of the study, with peers helping the SVI to draw diagrams. Some findings related to the research questions are:

a) Students' observations in diagrams: Students made analogies of the given representation with common objects, such as, chilli, radish, carrot, world cup trophy, octopus, ice-cream cone (types of teeth), robot (bacteriophage virus), etc. This comparison may have helped students in remembering and recalling the diagrams.

b) Questions raised by students while observing diagrams: The study provided scope for students to raise questions. They spontaneously raised questions, such as; Why is this called so? What does the term mean? Why does it have this shape, colour? etc. Other questions were- does this harm or benefit humans; what are its uses; where are they found? Questions were also aimed at making comparisons between two objects, such as– why do all the teeth look similar? Students also asked questions regarding the materials used in making diagrams.

c) Representations by the SVI: The SVI in part 2 of the study was able to represent the pre-molar tooth by drawings, after using the available tools and with some practice. It is important to note that she had never drawn before. A similar experience was reported by another SVI (F1) in part 3 of the study. In part 3, SVIs also shared their visualizations through verbal descriptions and gestures. The two SVIs (no vision) also made representations with diagrams, one of which had a great deal of similarity with the represented object and also with the drawing made by a student with normal vision.

IMPLICATIONS

The study reports contexts of collaborative learning through diagrams and models which were successful in evoking higher order questions from students. It suggests that collaborative-inclusive settings are effective for SVIs to draw and learn through diagrams. The study also finds that SVIs manipulate mental images, both visual and/or spatial. Yet, teachers and society in general tend to have low expectations from SVIs (Sacks, Kekelis & Robert, 1992). It is important for teachers to not only recognise the specific learning needs of SVI but also have similar expectations from them, as they would have from their peers (Fraser & Maguvhe, 2008). In the Indian educational context, where SVIs are often not able to select science as a subject for further study due to various constraints, we feel that this ability to manipulate mental images can be tapped by the science curriculum (Sharma & Chunawala, 2013). Diagrams, important in all subjects need to be emphasized in textbooks but more so in the printing of braille textbooks where they are conspicuously absent. Embossed (coloured) diagrams could be effective in inclusive classes for visualization as well as for developing drawing skills in all children. Thus, diagrams can provide students a context to develop higher order thinking skills, to raise questions that are critical and facilitate dialogues with peers.

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References

Fraser, W. J., & Maguvhe, M. O. (2008). Teaching life sciences to blind and visually impaired learners. *Journal of Biological Education*, *42* (2), 84- 89.

Figueiras, L., & Arcavi, A. (2012). Learning to see: The viewpoint of the blind. *12th International Congress on Mathematical Education.* Seoul, Korea.

Hill, K. E. (1995). Blind students and practical science. *Future Reflections Fall, 14*(3). Retrieved on 10-5-2013, from https://nfb.org/images/nfb/publications/fr/fr14/issue3/f140308.html

Hope, G. (2008). *Thinking and learning through drawing in primary classrooms*. London: SAGE Publications Ltd.

Jones, M. G., & Broadwell, B. (2008). Visualizing without vision. In J. Gilbert, M. Nakhleh, and M. Reiner (Eds.), *Visualization: Theory and practice in science education* (pp. 283-294). Springer.

Jonsson, T. (1994). *Inclusive education: Interregional program for disabled people.* United Nations Development Program.

Jubran, S. (2012). Using multi-sensory approach for teaching English skills and its effect on students' achievement at Jordanian schools. *European Scientific Journal, 8*(22), 51- 61.

Mathai, S. (2013). Schematisation in biological diagrams: A historical analysis. *Proceedings epiSTEME- 5 International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 51-61). HBCSE, Mumbai: Cinnamonteal.

Mathewson, J. (2005). The visual core of science: Definition and applications to education. *International Journal of Science Education*, *27*, 529–548.

Mehrotra, S. (2008). Introducing Indian middle school students to collaboration and communication centred design and technology education: A focus on socio-cultural and gender aspects (Unpublished doctoral thesis). Homi Bhabha Centre for Science Education, Mumbai, India.

Padalkar, S., & Ramadas, J. (2011). Using diagrams as an effective pedagogic tool in elementary astronomy. In S. Chunawala & M. Kharatmal (Eds.). *Proceedings epiSTEME 4 International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 160-164). Homi Bhabha Centre for Science Education, TIFR, Mumbai, India.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley, (Ed.), *Computer supported collaborative learning* (pp. 67-97). Berlin, Germany: Springer.

Sacks, S., Kekelis, L. & Robert, J. G. (1992). *The development of social skills by blind and visually impaired students: Exploratory studies and strategies.* US: American Foundation of the Blind, AFB Press.

Sapon-Shevin, M. (2005). Ability differences in the classroom: Teaching and learning in inclusive classrooms. *Common bonds: Anti-bias teaching in a diverse society.* Olney, Maryland: Association for Childhood Education International.

Sharma, A., & Chunawala, S. (2013). Marching towards inclusive education: Are we prepared for inclusive science education? In G. Nagarjuna, A. Jamakhandi, & Sam, E (Eds.). *Proceedings epiSTEME 5: International Conference to Review Research on Science, Technology and Mathematics Education* (pp. 314 -320). HBCSE, Mumbai: Cinnamonteal.

Stoffers, M. A. (2011). *Using a multisensory teaching approach to impact learning and community in a second grade classroom.* Master's thesis, Rowan University, New Jersey, United States. Retrieved from http://dspace.rowan.edu/bitstream/handle/10927/187/stoffersm-t.pdf?sequence=1

UNICEF. (2000). Teaching visually impaired students in Poland. Teachers Forum. Retrieved on 14 Sep. 2013 from http://www.unicef.org/teachers/forum/0300.htm

Uttal, D. H., & Doherty, K. (2008). Comprehending and learning from 'visualizations': A developmental perspective. In J. K. Gilbert, M. Reiner & M. Nakhleh (Eds.). *Visualization: Theory and practice in science education*. NY: Springer.

Vinisha, K., & Ramadas, J. (2013). Visual representations of the water cycle in science textbooks. *Contemporary Education Dialogue, 10*(1), 7-36.

Zimler, J., & Keenan J. M. (1983). Imagery in the congenitally blind: How visual are visual images? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*(2), 269-282.

DIAGNOSING ALTERNATIVE CONCEPTIONS IN THE NATURE OF THERMODYNAMIC VARIABLES AND ENTROPY

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Alternative conceptions play a pivotal role in learning physics. Students either consciously or subconsciously construct their concepts by experience. For them it becomes difficult to accept new information, which contradicts their alternative conceptions. Knowledge of students' alternative conceptions can provide instructors a window into their students' thinking. To assess alternative conceptions, diagnostic tools such as concept inventories or survey, are often used. In this paper, the development of a tool based on two themes, thermodynamic state variables and entropy, which are encountered at undergraduate level, is discussed and further used for analysis. This tool discussed here is a subpart of the concept inventory developed by authors on statistical physics at undergraduate level. This analysis helped us to identify some of the alternative conceptions prevailing among students on these two themes.

Key words: statistical physics, concept inventory, alternative conceptions

INTRODUCTION

For the last two decades there has been a lot of focus on the implementation of new theories of learning and teaching in the field of science, engineering and technology, to increase students' knowledge and conceptual understanding of the subject matter and to make teaching learner centered, rather than teacher centered (Halloun & Hestens, 1985; Hake, 1987). To evaluate conceptual knowledge of learners, assessment or diagnostic tools such as concept inventories, usually built in a format to ensure that they can be readily administered in large classes, and scored in an objective manner have been designed (Anderson, Fisher & Norman, 2002; Martin, Mitchell & Newell, 2003; Midkiff, Litzinger & Evans, 2001). These inventories help the instructors to identify concepts, which students find hard to understand, and let them know alternative conceptions in their minds about those concepts. This also provides instructors an opportunity to know the learning gaps and assist in chalking out research-based strategies to bridge these gaps, enhance and measure learning (Adam & Wieman, 2010). A lot of work has already been done on the development of such concept inventories. The Force Concept Inventory (FCI), is one of the important and mostly used research based standard instrument for assessing the conceptual understanding and probing the alternative conceptions of basic mechanics (Hestenes, Wells & Schwackhammer, 1992).

Thermodynamic state variables and entropy are two important concept domains, which crop up in the study of statistical mechanics and solid-state physics as given in Table1. However, sometimes these concepts are considered very difficult and abstract by the students.

In this paper, the process of development of a concept inventory related to the above mentioned two basic concept domains, "thermodynamic state variables" and "entropy", needed in the study and understanding of statistical physics and solid state physics courses for undergraduate, Bachelor of Science (B.Sc.) three years degree course, have been discussed.

Further, the paper summarizes some general information about students' alternative conceptions emerging from this study. This knowledge of alternative conceptions can be helpful for instructors in deciding where to start and what to cover.

METHODOLOGY

The authors have developed a concept inventory on statistical physics. The complete methodology adopted for the development of concept inventory version 1.0 is shown in Figure1. The tool (consisting of two themes) discussed in this paper is a subpart of that concept inventory (Kaistha, 2014).

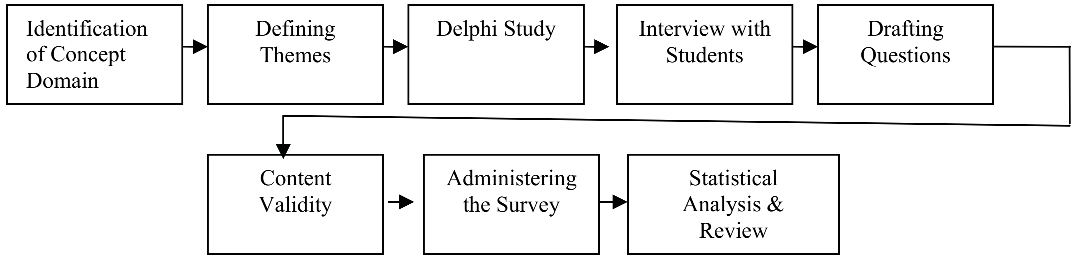

Figure 1: Algorithm used for the development of tool

Defining of Themes for the Development of Concept Inventory

Looking at the content of solid state physics course, the list of statistical physics concepts applied in different topics of this course was identified. Thermodynamic state variables and Entropy were two such identified themes in the statistical physics course as given in Table 1.

Themes	Concept Profile	Topics of Solid State Physics course in which concept(s) is/are used
Theme 1	Thermodynamic state variables	Provides a macroscopic backdrop for innate understanding. e.g. Superconductivity; Critical field of superconductors, Variation of specific heat, entropy and thermal conductivity of superconductors with temperature.
Theme 2	Entropy	Superconductivity

Table1: Concept profile of themes-thermodynamic state variables and entropy

Delphi Study

After identifying, the concept profile of these two themes (thermodynamic state variables and entropy), a widely used research technique called Delphi Study was carried out. This technique provides an interactive communication between researcher and experts in a field to develop themes and directions about a particular topic. This method was followed, to reach a consensus among a group of experienced teaching faculty of physics involved in teaching undergraduate B.Sc. physics courses about the difficulty and importance of these concepts. Peer group of teachers was drawn from faculty members of physics department of local undergraduate colleges in Shimla, University Institute of Information Technology, Summerhill, Shimla and Himachal Pradesh University, Shimla.

Interviews with Students

Delphi study was followed by an extensive brain storming session with the students who had gone through solid-state physics course and who conveyed a general dissatisfaction with the course with the responses like: Solid State Physics course is confusing; Solid State Physics expects an in depth understanding of concepts of both Statistical Physics and Quantum Mechanics etc.

These interviews helped us to understand the thinking process of the students, identification of the missing linkages or alternative conceptions and mental barriers, impeding the learning of solid-state physics. We observed that they were finding it difficult to articulate their experience or feelings in picking up and underlining the conceptual difficulties.

Drafting of Multi Choice Type Questions for Each Sub Theme

The question items for the present tool were developed by consulting widely used textbooks (Bhatia, 2002; Lal, Subrahmanyam & Hemne, 1994; Hugh & Roger, 2008) and web sites. To get structural validity a draft of concept inventory was sent to 15 experts all over the country to check mark and point out any

1. deviation from concept specificity of the question item
2. ambiguity as regards physical concept involved
3. ambiguity of wording and diagrams in the sent items
4. choices/alternative options which in their opinion are not good distracters etc.

After the content validity, statistical analysis was carried out for validity and reliability of the tool.

Validity (Item Analysis)

Validity tells how well the test is able to measure the things, which it is supposed to measure. To check that items of the test are functioning well, item analysis was performed. Item analysis is a set of three tests: *item discrimination test, item difficulty test and point biserial coefficient test.* This analysis, as the name suggests, was done for each individual item of the test developed and results are given in Table 2 and Table 3.

Reliability (Test Analysis)

Cronbach Alpha coefficient test to measure reliability, and Ferguson Delta test to measure the discriminatory power, were performed on the developed statistical physics concept inventory (present tool is a subpart of it). Some sources consider a test reliable if alpha value is 0.60-0.80 (Nunnally, 1978). The instrument developed on statistical physics was having Cronbach alpha value above 0.6 and Ferguson delta coefficient 0.9., which were reasonably good.

Mode Adopted

The tool consisting of five questions (refer Appendix A) based upon the themes thermodynamic state variables and entropy was administered to 152 students at the beginning of the course (pre-test), and to 134 students at the completion of the course (post-test). This provided us data of 134 common students (37 postgraduate (PG) and 97 undergraduate (UG)), from June 2010 to March 2011 for further study and statistical analysis. The test was also administered to 55 teachers teaching undergraduate physics in different colleges or universities all over the country. These teachers had come to attend a refresher course conducted by the Physics Department, Himachal Pradesh University, on Physics Education Research, at University Grants Commission Academic Staff College (ASC). Therefore, post test could not be conducted for them. Ten days advance intimation for administering the test was given to all the target group members. Both teachers and students took time between forty-five minutes to an hour to complete the test, stipulated time given was an hour.

DISCUSSION AND ANALYSIS

Research has shown that every individual holds some prior beliefs/alternative conceptions, and even greatest scientists like Galileo and Newton had some firm beliefs/alternative conceptions (Steinberg, Brown & Clement, 1990). The exploration and research of such alternative conceptions can help teachers and researchers to know how learners perceive particular knowledge and justify their inferences (Sharma & Ahluwalia, 2012).

For this purpose after the administration of the tool, interviews were conducted with B.Sc. students at one of the undergraduate colleges and students of M.Sc., at Physics Department, Himachal Pradesh University. The effort was made to know, how these students have arrived at the ticked options in their attempt of the question items of the inventory and what were the alternative conceptions occurring in their minds.

Theme 1: Thermodynamic State Variables

Thermodynamic state of a macroscopic substance is specified by the macroscopic variables like, temperature, pressure, entropy and do not immediately require knowledge of microscopic structure of the matter. However, one of the fundamental problems of Statistical Physics has been to relate these microscopic parameters to thermodynamics. This theme had three questions. Q1 and Q2 dealt with the difference in intensive and extensive parameters, Q3 dealt with relation between thermodynamic probability and entropy

Figure 2 gives the question wise response of students (pre-post) and teachers (pre) in this theme. Q1 and Q2 both were based on the concept of intensive and extensive parameters of thermodynamics. In Q1:

Consider a homogeneous system in equilibrium. Suppose the system is divided into two parts. If the macroscopic variable x of the system has the values x1 and x2 in each of these parts and $x = x1 + x2$, then x is said to be

(a) an extensive parameter

(b) an intensive parameter

(c) a local parameter

It was asked, whether the additive property of the variable given, points to it as being an extensive parameter or an intensive parameter. In pre test 49% of UG students gave the correct responses, which reduced to 46% in post test. 76% of PG students gave correct responses in pre-test, which reduced to 54% in posttest. 53% of teachers responded correctly in pre test and there was no post- test for teachers.

In Q2, students were supposed to identify the set of intensive parameters. Very less percentage of UG, PG students as well as teachers gave correct answer to this question. Most of the students were identifying even mass and volume as intensive parameters and temperature as an extensive quantity.

Since both the questions were based on the same concept, we were expecting some consistency in answers to these questions. However, the large difference in percentages shows that the students were not able to differentiate between the extensive and intensive parameters properly and most of them only tried a wild guess. Some of the students were having a misconception in mind that temperature is a property of the material from which a body is made. Majority of students and teachers could answer Q3, which was based upon the relation between thermodynamic probability and entropy. UG, PG students, as well as teachers scored less than 60% in Q1 and Q2, indicating that they also lack in conceptual understanding of the concept domain involved.

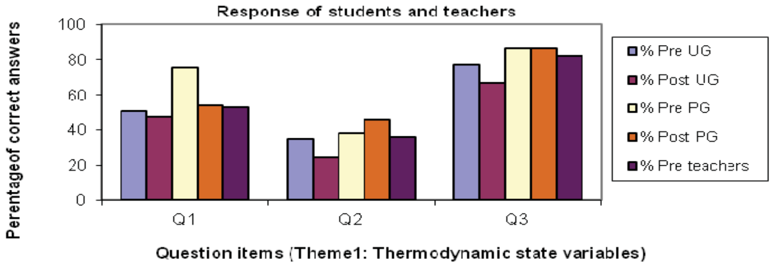

Figure 2: Response of UG, PG students and Teachers on theme 1 (thermodynamic state variables)

Table-2 gives the pre-post values of item discrimination index (D), item difficulty index(d), point biserial coefficient (r_{pb}) of each question item, and alternative conception occurring in the minds of students in that particular question item.

Q. No	Concept	Class	D			d			r_{pb}			Alternative conceptions identified
			Pre	Post	Avg.	Pre	Post	Avg.	Pre	Post	Avg.	
1	Extensive & intensive parameters	UG	0	0.08	0.04	0.51	0.47	0.49	0.41	0.39	0.4	No understanding of the fact that in which physical thermo dynamical quantities total is sum of parts and when not
		PG	0.42	0.67	0.55	0.76	0.54	0.65	0.44	0.47	0.46	
		Teachers	0.27	-	-	0.53	-	-	0.31	-	-	
2	Extensive & intensive parameters	UG	0.06	0.2	0.13	0.35	0.25	0.3	-0.1	-0.5	-0.3	Temperature is a property of the material from which a body is made
		PG	0.25	0.67	0.46	0.38	0.46	0.42	0.36	0.6	0.48	
		Teachers	0.23	-	-	0.36	-	-	0.22	-	-	
3	Thermodynamic Probability	UG	0.13	0.31	0.22	0.77	0.67	0.72	0.15	0.31	0.23	No alternative conception revealed
		PG	0.08	0.25	0.17	0.86	0.86	0.86	0.12	0.41	0.27	
		Teachers	0.23	-	-	0.82	-	-	0.2	-	-	

Table 2: Item analysis results and alternative conception identified in theme 1 (thermodynamic state variables)

Theme 2: Entropy

Any physical system consisting of large number of particles possesses macroscopic properties such as pressure, volume, and temperature, which are easily measurable, though its microscopic properties, such as positions and momenta of the constituent particles, cannot be measured. Statistical physics relates these microscopic properties to the macroscopic properties and acts as a bridged by providing a relationship between number of different microstates of a system, 'W' and a thermodynamic (macroscopic) quantity called entropy 'S'. Infact one of the biggest achievements of the Statistical Physics has been to provide a physical picture of the value of entropy dependent on the actual macroscopic state enumerated in terms of the count of microstates of the system.

The theme on entropy involved two questions (Questions 4, 5). Figure 3 gives the question wise response of students in this theme.

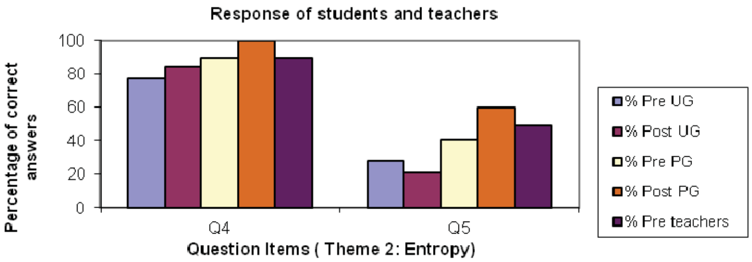

Figure 3: Response of UG, PG students and teachers on theme 2 (entropy)

Q4 was designed to check whether students are able to establish a connection between entropy and the meaning of order and disorder as enunciated in the second law of thermodynamics and thermodynamic processes. More than 70% of UG, PG students as well as teachers ticked the correct option showing that learners have a feeling of a link between the meaning of order /disorder and entropy. Q5 was designed to further probe the link between meaning of order/ disorder with entropy in terms of number of microscopic and macroscopic states.

For any system, the most probable macroscopic state is one with the greatest number of corresponding microscopic states, it is also the macroscopic state with the

(a) least disorder and the greatest entropy

(b) least disorder and the least entropy

(c) greatest disorder and the least entropy

(d) greatest disorder and the greatest entropy

In this question students were supposed to consider entropy as a statistical quantity and were expected to know that entropy is a measure of accessible microstates of system and thus most probable macroscopic state will have greater disorder and hence entropy. Very less percentage of students as well as teachers could give correct answer.

Again, here since both the questions were based upon same concept, we were expecting consistency in the answers of the learners. Instead, we found inconsistency in answers of Q4 and Q5. We noticed that students were able to recall definition of entropy but they found it difficult to relate entropy with the microstates of a given macro state the very basis of the development of Statistical Physics. On further probing during interviews, students were unable to relate that thermal equilibrium means all parts of system are at the same temperature and this is the state of maximum probability. Instead, they were interpreting equilibrium state as a state of minimum entropy. There was an alternative conception that thermal equilibrium means thermodynamical stability and thermodynamical stability automatically implies order i.e. they interpreted the question that in equilibrium, system should have least disorder, and thus least entropy. All UG, PG students and teachers scored less than 60% in Q5 of this theme. This situation clearly marks the fact that important properties of entropy have been completely missed and indicates general confusion, which learners bring with them in the classroom about a much, talked but least understood concept. Table 3 gives the pre-post values of item discrimination index (D), item difficulty index (d), point biserial coefficient (rpb) of each question item, and alternative conception identified thereafter.

<table>
<tr><th rowspan="2">Q.no</th><th rowspan="2">Concept</th><th rowspan="2">Class</th><th colspan="3">D</th><th colspan="3">d</th><th colspan="3">r_{pb}</th><th rowspan="2">Alternative conception(s) identified</th></tr>
<tr><th>Pre</th><th>Post</th><th>Avg.</th><th>Pre</th><th>Post</th><th>Avg.</th><th>Pre</th><th>Post</th><th>Avg.</th></tr>
<tr><td rowspan="3">4</td><td rowspan="3">Entropy</td><td>UG</td><td>0.19</td><td>0</td><td>0.1</td><td>0.77</td><td>0.84</td><td>0.81</td><td>0.17</td><td>0.08</td><td>0.13</td><td rowspan="3">No alternative conceptions was revealed</td></tr>
<tr><td>PG</td><td>0.08</td><td>0</td><td>0.04</td><td>0.89</td><td>1</td><td>0.95</td><td>0.1</td><td>0</td><td>0.05</td></tr>
<tr><td>Teachers</td><td>0.27</td><td>-</td><td>-</td><td>0.89</td><td>-</td><td>-</td><td>0.36</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">Entropy</td><td>UG</td><td>0.13</td><td>0.22</td><td>0.18</td><td>0.28</td><td>0.20</td><td>0.24</td><td>0.19</td><td>0.29</td><td>0.24</td><td rowspan="3">In thermos dynamical equilibrium
system should have least disorder and hence least entropy, hence belief is equilibrium means order</td></tr>
<tr><td>PG</td><td>0.25</td><td>0.17</td><td>0.21</td><td>0.41</td><td>0.59</td><td>0.5</td><td>0.2</td><td>0.07</td><td>0.2</td></tr>
<tr><td>Teachers</td><td>0.44</td><td>-</td><td>-</td><td>0.49</td><td>-</td><td>-</td><td>0.47</td><td>-</td><td>-</td></tr>
</table>

Table 3: Item analysis results and alternative conceptions identified in theme 2 (entropy)

CONCLUSIONS

One of the best ways to check the learning of various concepts is, to use the concept inventory or survey. We have developed research based diagnostic tool, which should access the knowledge of two basic concepts used in Statistical Physics: thermodynamic state variables and entropy taught to students at undergraduate level.

The alpha version (1.0) of tool was administered to UG students (pre-post), PG students (pre-post) and teachers (pre). The responses were analyzed for both test analysis and item analysis to check the reliability and validity of the tool. The values of discrimination index, difficulty index of some of the items do not fall in the prescribed range. However, we think that it does not necessarily mean that these items are not satisfactory to a certain extent. We intend to work on item response curves in future to get detailed information of quality of this tool.

Looking at the responses given we could identify some alternative conceptions prevailing in the minds of students which need to be changed from the target group and prepare it for the better understanding of the topics/subjects.

One can conclude that the developed concept inventory can indeed help to see the student's performance vis-à-vis their understanding of basic concepts. It can also give us insights into desirable changes in teaching and remedial measures, which needed to set the learning in the right direction. The identified alternative conceptions can also be used to design improved Statistical Physics curriculum, which takes care of these conceptions.

References

Adam, W. K., & Wieman, C. E. (2010). Development and validation of instruments to measure learning of expert-like thinking. *International Journal of Science Education*, *33*, 1-24.

Anderson, D. L., Fisher, K. M., & Norman, G. J. (2002), Development and evaluation of the conceptual inventory of natural selection. *Journal of Research in Science Teaching, 39*(10) 952-978.

Bhatia, V. S. (2002). *Statistical physics thermodynamics & kinetic theory*. Jalandhar: Shobin Lal Nagin Chand & Co.

Hake, R. (1987). Interactive –engagement Vs traditional methods: A six thousand student survey of mechanics test data for introductory physics courses, *American Journal of Physics, 55*, 878.

Halloun, A., & Hestens, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics, 5*3(11), 1043.

Hestenes, D., Wells, M., & Schwackhammer, G. (1992). Force concept inventory. *Physics Teacher, 30*, 141.

Hugh, D. Y. & Roger, A. F. (2008). *University physics with modern physics* (12th edition). India: Pearson Publication.

Kaistha, S. (2014). Development of concept inventories for statistical physics and quantum mechanics to enhance learning of solid state physics. Ph. D. thesis, H. P. University.

Lal, B., Subrahmanyam, N., & Hemne, P. S. (1994). *Heat thermodynamics & statistical physics.* India: S. Chand & Company Ltd.

Martin, J., Mitchell, J., & Newell. T. (2003). Development of a concept inventory for fluid mechanics. *Proceedings of the 33rd ASEE/IEEE Frontiers in Education Conference*. Session T3D-6.

Midkiff, K. C., Litzinger, T. A. & Evans, D. L. (2001). Development of engineering thermodynamics concept inventory instruments. *Proceedings of the 31st ASEE/IEE Frontiers in Education Conference.* Session F2A-3.

Nunnally, J. (1978). *Psychometric theory.* New York: McGraw-Hill.

Sharma, S., & Ahluwalia, P. K. (2012). Diagnosing alternative conceptions of fermi energy among undergraduate students. *European Journal of Physics, 33,* 883.

Steinberg, M., Brown, D. E. & Clement, J. (1990). Genius is not immune to persistent misconceptions, conceptual difficulties impeding Isaac Newton. *International Journal of Science Education, 12,* 265.

Appendix A

1. Consider a homogeneous system in equilibrium. Suppose the system is divided into two parts. If the macroscopic variable x of the system has the values x_1 and x_2 in each of these parts and $x = x_1 + x_2$, then x is said to be:

   (a) an extensive parameter (b) an intensive parameter (c) local parameter

2. Out of these given parameters choose the set of intensive parameters:

   (a) S,T,F (b) M,P,S (c) M,V,T (d) P,T,F

   (where P,T,F,M,S,V represent respectively pressure, temperature, surface tension, mass, entropy and volume of the system).

3. Suppose there is an isolated system consisting of large number of particles. It neither gains nor loses energy and is also in thermal equilibrium, so it has maximum probability W_m. Hence change in Its entropy ΔS is:

   (a) zero (b) less than zero (c) cannot be defined

4. Entropy is a measure of :

   (a) chemical potential and number of particles (b) order and disorder (c) pressure and volume

5. For any system, the most probable macroscopic state is one with the greatest number of corresponding microscopic states, it is also the macroscopic state with the :

(a) least disorder and the greatest entropy (b) least disorder and the least entropy

(c) greatest disorder and the least entropy (d) greatest disorder and the greatest entropy

USE OF MULTIPLE REPRESENTATIONS TO PROMOTE STUDENTS' UNDERSTANDING OF PHASE CHANGES

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The research in this paper examines the effect of multiple external representations in the promotion of senior school students' understandings about changes in the physical state of matter. Static pictures and dynamic visual representations, as well as students' self generated diagrams were embedded into constructivist pedagogy to challenge students' alternative conceptions of phase changes in molecular substances. Students' change in conceptions and retention was determined through a pre test- post test- delayed post test research design. Data included student generated molecular level diagrams, written explanations, responses to conceptual interviews and researcher's field notes. This paper presents a qualitative analysis of change in students' conceptions and discusses the implications for pedagogy.

INTRODUCTION

Phase change or change in the physical state of a substance is an observable macroscopic property of matter whose scientific explanations are at abstract molecular level. In order to generate scientifically accepted explanations of phase changes, learners need to visualize and imagine entities and processes at molecular level. Learners also need to apply concepts related to bonding, molecular structure and intermolecular forces in order to formulate explanations of phase changes. This paper presents a part of the study in which a series of intervention sessions were conducted by the first author to promote senior secondary school students' understanding of phase changes.

THEORETICAL BACKGROUND

This study is based on the theoretical perspectives of constructivism, both individual and social constructivism. Individual constructivism asserts that learning is the construction of knowledge by the individual through his/ her interaction with the environment. Learner's existing ideas too effect the further construction of knowledge (Taber, 2006). Hence, there can be multiple interpretations of the same event.

Social constructivism emphasises the supporting activity of teachers and more informed peers in learning who communicate ideas through different modes, talk, gestures, visual images etc. to promote individual understanding (Scott, Asoko & Leach, 2008).

The past two decades have seen a large number of studies in the constructivist paradigm exploring students' conceptions in various domains of science. In the recent past, researchers have moved from exploring students' conceptions to addressing students' misconceptions. Calik et al. (2007) used a four step strategy, incorporating the following elements of constructivist pedagogy: eliciting student's prior ideas, focusing on the target concept through small group activities, challenging the idea thorough discussion with peers and teacher, and applying newly constructed ideas to other similar situations, to promote students' scientific understanding of phenomena. According to Baviskar et al. (2009) reflection by the learner on the learning which has taken place, is also an essential feature of constructivist pedagogy. The use of multiple modes of representations (visual, textual etc.) and collaboration in learning was recommended by Driscoll (2000) as important constructivist conditions of learning.

Pictures, concrete models, text etc. are commonly used as instructional materials in the science classroom. These are external representations that are used to communicate scientific ideas. The benefits of using multiple external representations in science learning have been documented in literature (Corrandi et al., 2014; Wu & Puntambekar, 2012). Theories in the information processing approach have explained the learning though multiple representations. According to Mayer's theory, learners select and organize the information from text and visuals, and then build referential connections between the verbal mental representations and visual mental representations (Adadan, 2013; Goldman, 2003; Kozma, 2003).

Wu and Puntambekar (2012) have emphasized the active engagement of students to integrate representations. Group discussions around multiple representations where students share their understanding of representations and concepts, can encourage students to form connections between the different representations and integrate representations with their prior knowledge (Goldman, 2003, Kozma, 2003, Wu and Puntambekar, 2012).

Adadan, Trundle and Irving (2010) used multi representational instruction, with focus on student generated diagrams and reflection on learning, to promote Grade 11 students' learning of particulate nature of matter. Hilton and Nichols (2011) used instructional strategies like animations and simulations using Molecular workbench, and static visual representations along with small group activities to address students' alternative conceptions of bonding.

Wu and Puntambekar (2012) have pointed out the need for further studies on how MER's can be effectively used in the classroom, by embedding MER's in different teaching approaches.

Use of multiple representations is especially significant in the context of phase changes due to the sub microscopic level of explanations.

Students' misconceptions about phase changes reported in literature (Tsai, 1999) are related to change in size of particle, the relative distance between particles and the motion of particles during phase change. Another misconception reported in literature is the conception that intramolecular covalent bonds are broken during phase changes of covalent molecular substances (Treagust et al., 2011).

Successful attempts to promote conceptual understanding of phase changes and related concepts amongst students, through use of different strategies, have also been reported in literature. These include use of representations like concrete models, diagrams and texts (Prain et al., 2009) for evaporation, demonstrations followed by discussion (Treagust et al., 2011) on effect of intermolecular forces on states of matter, and technology enhanced dynamic visualizations (Levy, 2013) for phase changes.

More studies are required, especially in the Indian classroom context, to examine the effects of students' engagement with multiple representations on their understanding of sub - microscopic level processes like phase changes.

THE STUDY

In this study, multiple representations primarily static pictures and dynamic visuals (accompanied by text), were embedded in constructivist pedagogy, to address senior secondary school students' conceptions of phase changes. The participants were 35 Class XI students (21 boys and 14 girls) from an urban private school. The school follows English as the medium of instruction. The students in this school belong to upper middle class families. All participants during the time of the study were of age 16-17 years.

The Research Questions

The research questions which are addressed in this paper are:

What are students' explanations and conceptions of phase changes two months after regular formal instruction (prior to the intervention)?

What are the changes in students' conceptions as they engage with the learning sessions of the intervention based on constructivist approach?

What is the short term and long term impact of intervention sessions based on multiple representations and constructivist pedagogy on students' conceptions of phase changes?

THE METHODOLOGY

The study incorporated a single group quasi experimental (pre test- post test- delayed post test) design. A set of ten conceptual questions (of which four had subparts) was prepared to elicit students' prior conceptions of phase changes in molecular substances, and their conceptions of intermolecular forces. The questions were predominantly open ended and included questions for which students were required to make pictorial representations or diagrams of phenomena at molecular level, along with written explanations. The purpose of the questions was to explore students' conceptions of changes in physical state of substance: melting, vaporization and condensation processes and to understand how students used the concept of 'forces' of attraction between atoms/ molecules, to explain phase changes.

While some of the questions were adapted from previous studies, others were designed by the researcher. The questions were validated by a six chemistry experts, teaching the chemistry courses at the undergraduate level, and a chemistry teacher educator. Two chemistry teachers teaching at the senior secondary school level also validated the questions for their appropriateness to the cognitive level of the participants. The same set of questions served as the pre test and post test.

Students' pre intervention conceptions were determined by administration of the pre-test two months after regular formal instruction in the classroom on phase changes. Semi structured interviews were then conducted with those students who gave their consent to be interviewed. Students' responses to the pre test and conceptual interviews, was examined for their conceptions and their difficulties in understanding phase changes.

A series of seven intervention sessions, each of one hour duration, were designed and conducted with the objective of promoting a more scientific understanding of bonding concepts, intermolecular forces and phase changes. The last two sessions had the specific objective of remediating the most common alternative conception of students about phase changes, that is, 'covalent bonds are broken during phase change in molecular substances'.

These two sessions aimed at developing the understanding that,

i) Change of state is an interplay between thermal energy and strength of intermolecular forces.

ii) When temperature is increased and the state of a substance changes from liquid to gas, weak forces between molecules are overcome and not the strong forces of covalent bond within the molecule.

iii) During condensation of gas at low temperatures the kinetic energy of particles decreases and the intermolecular forces are able to bring the slow moving molecules together, leading to condensation.

External representations that were used in the sessions included static diagrams of processes at macroscopic and molecular level, accompanied by a text, and dynamic visualizations. According to Ploetzner and Lowe (2004), static visuals demand lesser processing requirements than dynamic visualizations. Static visuals are preferred for students who are new or less familiar in dealing with visualizations. Sequencing of MER's also needs to take into account learners' prior competencies with multiple representations (Wu & Putambekar, 2012). In this study, students were first presented with static visuals, accompanied by text. Static visuals selected were depictions of substances in the three states or processes of phase change at atomic/ molecular level. Animations were then used to facilitate the idea of increased motion of particles and its role in changing states of matter.

Static pictures from internationally well-known books were selected and included as a part of the learning experiences of the sessions. An example of a static picture used is that of boiling of pentane, macroscopic view and molecular level representations (from the book Chemistry; the molecular nature of matter and change, fifth edition by M.S. Silberberg et al., 2006). The dynamic visuals were taken from the free resources available on you tube, on the world wide web and also the resources available with the school. These included an animation on the changing states of matter, depicting the increased motion of particles and the increase in distance between the particles on heating. These external representations were also validated by experts for their appropriateness to the learning goals.

In the intervention sessions, the multiple representations were embedded in a *constructivist teaching learning strategy.* The steps of the teaching- learning strategy were *elicitation of prior conceptions, restructuring of ideas, application of new ideas and reflection on learning*. A worksheet was also designed to facilitate the learning process.

For restructuring of ideas, group discussions were woven around the multiple representations. This allowed the students to exchange their perceptions of the static and dynamic representations, listen to others ideas and justify their own. This was followed by whole class discussion. Students were also encouraged to maintain a reflective journal where they recorded their new learning. The first author, that is the researcher who was also the facilitator, recorded her observations and reflections of the classroom interactions immediately after each session.

The post test was administered a day later after the intervention sessions were conducted, and the delayed post test was administered three months later. Both the tests were followed by semi-structured interviews of students who were willing to be interviewed. In all there were 11 students who appeared for all the three interviews at each stage, pre intervention, post intervention and delayed post intervention. While a qualitative analysis of the development of students' understanding was carried out for the whole group, the change in the conceptions of the students who participated in the interviews could be studied in greater depth.

DATA ANALYSIS AND FINDINGS

Prior to the intervention, analysis of the expressed constructs of students in the form of their written responses and molecular level diagrams revealed that none of the students had sound understanding of processes of phase change.

Students' prior conceptions of the change of state during the boiling of water: Most of the students gave partial explanations, mentioning either the increase in KE of water molecules or the overcoming of intermolecular forces, but not the relation between the two to explain the change of state of physical state of water.

The explanations of eight students were limited to the conceptions of change of state learnt in junior classes, that is, the simple explanation that the distance between the molecules increases, with no mention of the role of KE of molecules or intermolecular forces.

Alternative conceptions were noted in seven students, that is twenty percent of students, which was that the covalent bond in liquid water breaks to give H and O atoms, or H_2 and O_2 molecules, when it changes to gaseous state.

Students' prior ideas of the liquefaction of Chlorine gas: Most students gave the simple explanation that the particles would come closer in the liquid state. Amongst these five(about 14 percent of students) had the alternative conception that individual atoms of chlorine and not diatomic molecules are present in both the liquid and gaseous state. One student, S-10 expressed the scientifically unacceptable idea that additional covalent bonds are formed between the atoms of chlorine. He wrote in his explanation,

"Chlorine in gaseous state has weak bond order but long bond length, whereas in liquid chlorine the atoms come closer to each other and form short bond lengths but strong bond order.'

Three students had the notion that chlorine gas cannot be condensed (it had something to do with critical temperatures, they said).

Overall in their explanations, it was found that almost all students were aware of the change in distance between particles in the three states. However, none of the students could give detailed, clear as well as consistent scientific explanations of the phase change processes in molecular substances, in terms of intermolecular forces, kinetic energy and motion of molecules. Even those students, for example, S-26, S-8, who gave partially scientifically accepted explanations in situations like phase change in water and chlorine, expressed alternative ideas in another context that N_2 would have a higher boiling point than Br_2 because the triple bond is N_2 is more difficult to break than the single bond in Br_2.

During the intervention sessions: Students' perceptions of the static pictures and animations included the colour of substances and the relative distance between the molecules in the three states, and the motion of the molecules. S-7 mentioned that the molecules in liquid phase are closer than he thought them to be. For some of the students, the new learning also included other aspects like knowledge of scientific terms like 'deposition'.

S-28, after the session which had static pictures of molecular level representations of bromine in the three states and sublimation of iodine, wrote as his new learning in his reflective journal,

> "Covalent bond is not broken during change of state.
>
> The colour of bromine is orange.
>
> Iodine can easily sublime, it's colour is magenta'.
>
> S-16 wrote in her new learning: "Iodine sublimes to vapours and then condenses and deposits.

Intermolecular and not intramolecular forces have to be compared to find which compound will have more boiling point."

It was evident from their worksheets and their reflective journals that all students could reconstruct or strengthen their idea that the intermolecular forces are involved and not the covalent bonds during the phase change of covalent molecular substances.

During the post test, most students could give consistent scientifically accepted explanations of phase changes in different contexts.

However, in the delayed post test a regression was observed in few students. These students gave explanations in terms of intermolecular forces for liquefaction of X_2 gas, and boiling of water. But while comparing substances for their boiling points, their spontaneous idea was that O_2 will have higher boiling point than Br_2 because the double bond is more difficult to break. Even in such students, when they were asked to make a pictorial representation, they made molecules of O_2 separating from each other. While making the diagram, they connected their ideas to the visual representations that they had seen during the sessions. Most of these students then corrected themselves and said that the intermolecular forces between O_2 molecules would be overcome.

The efficacy of the external representations can be judged in terms of students' reflections about their learning and their feedback about the sessions.

S-14: Earlier I was not knowing the correct procedure of solid changing into liquid. In solid I thought that the particles are at rest. The animation helped me that know that they are vibrating at their mean positions....though the randomness is less but it is still there.

S-16: "Next time when we will read about anything which explains the process at atomic level we will be able to make a picture in our mind. This will enhance our ability to build concepts."

IMPLICATIONS FOR PEDAGOGY AND TEXTBOOK

Molecular level representations related to phase changes need to be included in the current national level textbook, to help students visualise the processes of phase change. However, just incorporating the pictures in the textbook or the animations in the classroom teaching is not enough. Students should be given an opportunity to express their conceptions in different ways, writing, speaking and through their self generated molecular level representations. The nature of questions in our assessments tasks as used currently also needs to undergo a change. Classroom environment should also encourage students to freely express and justify their ideas, to enable them to reconstruct their ideas, and promote meaningful learning.

It was found in the study that prior to the intervention students did not give consistent scientific explanations of phase changes of molecular substances in all situations. Both the scientific framework as well as the alternative conception coexisted in their cognitive structures. While the alternative conception was successfully tackled for the short term, a regression was observed in a few students in the delayed post intervention stage. There was spontaneous use of the alternative framework of breaking of covalent bonds in the phase changes of molecular substances, which shows that this idea is highly resistant to change. This finding stresses the need to practice and revisit the scientific explanations using sub-microscopic level representations various times in the course of the study of physical properties of inorganic as well as organic molecular substances, in order to remediate this strongly held alternative conception.

The molecular level diagrams of a few learners were representations of the scientifically accepted ideas, but were in contradiction of their verbal representations of ideas. This shows that these learners were not able to form a coherent mental model of phase change. Further studies are required on how to help students actively integrate the multiple representations, and how to optimize the results of the integration to promote retention.

References

Adadan, E., Trundle, K. C., & Irving, K. E. (2010). Exploring grade 11 students' conceptual pathways of the particulate nature of matter in the context of multirepresentational instruction. *Journal of Research in Science Teaching, 47*(8), 1004–1035.

Adadan, E. (2013). Using multiple representations to promote grade 11students' scientific understanding of the particle theory of matter. *Research in Science Education, 43*, 1079-1105.

Baviskar, S. N., Hartle, R. T., & Whitney, T. (2009). Essential criteria to characterize constructivist teaching; derived from a review of literature and applied to five constructivist teaching method articles. *International Journal of Science Education, 31*, 541-550.

Calık, M., Ayas, A., Coll, R. K., U¨nal, S., & Costu, B. (2007). Investigating the effectiveness of a constructivist-based teaching model on student understanding of the dissolution of gases in liquids. *Journal of Science Education and Technology, 16*(3), 257-270.

Corrandi, M. J. D., Elan, J., Schraepen, B., & Clarebout, G. (2014). Understanding possibilities and limitations of abstract chemical representations for achieving conceptual understanding. *International Journal of Science Education, 36*(5), 715-734.

Driscoll, M. D. (2000*). Psychology for learning for instruction.* MA: Allyn and Becon.

Goldman, R. S. (2003). Learning in complex domains: When and why do multiple representations help*? Learning and Instruction, 13*, 239-244.

Hilton, A., & Nichols, K. (2011). Representational classroom practices that contribute to students' conceptual and representational understanding of chemical bonding. *International Journal of Science Education, 33*(16), 2215-2246.

Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction, 13*(2), 205–226.

Levy, D. (2013). How dynamic visualization technology can support molecular reasoning? *Journal of Science education and Technology, 22*, 702-717.

Ploetzner, R., & Lowe, R. (2004). Dynamic visualizations and learning. *Learning and Instruction, 14*(3), 235-240.

Prain, V., Tytler, R., & Peterson, S. (2009). Multiple representation in learning about evaporation. *International Journal of Science Education, 31*(6), 787–808.

Silberberg, M. S., Duran, R., Haas, C. G., & Norman, A. D. (2006). *Chemistry: The molecular nature of matter and change*. New York: McGraw-Hill.

Scott, P., Asoko, H., & Leach, J. (2008). Students' conceptions and conceptual learning in science. In S. K. A. Bell and N. G. Lederman (Eds.), *Handbook of research on science education* (pp 31-54), New Jersey : Lawrence Earlbaum Associates.

Taber, K. S. (2006). Beyond constructivism: The progressive research programme into learning science. *Studies in Science Education, 42*(1), 125-184.

Treagust, D. F., Chandrasegaran, A. L., Zain, A. N., Ong, E. T., Karpudewan, M., & Halim, L. (2011). Evaluation of an intervention instructional program to facilitate understanding of basic particle concepts among students enrolled in several levels of study. *Chemistry Education Research and Practice, 12*(2), 251-261.

Tsai Chin-Chung (1999). Overcoming junior high school students' misconceptions about microscopic views of phase change: A study of an analogical activity. *Journal of Science Education and Technology, 8*(1), 83-91.

Wu, H., & Puatambekar, S. (2012). Pedagogical Affordances of multiple external representations in scientific processes. *Journal of Science and Educational Technology, 21*, 754-767.

EXPLORING STUDENTS'THOUGHT PROCESSES INVOLVED IN THE INTERPRETATION OF ELECTRIC FIELD AND FIELD LINES

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The study concerns exploration of students' deficiency in interpreting the concept of electric field and field lines. A diagnostic test comprising four questions on basic aspects of electric field and field lines has been administered to higher secondary (CBSE) and undergraduate level students. The test requires paper pencil drawings of field lines and interpretation of the same in given situations. Test was followed by a structured interview with appropriate scaffolding accompanied by think aloud protocol. Students' inadequacies in interpreting the concept of field and interlinking the thought processes have been identified through detailed analysis of their field mapping diagrams. Important learning difficulty of students reveals poor visualization of physical concept related to electric field lines even when mathematical cognition of the same seems to be satisfactory. Few possible causes of these difficulties of students with reference to instructional strategies of teachers and text materials have been identified.

INTRODUCTION

Physics is an important subject in higher secondary level science and many students have learning difficulties in it. Further, our instruction is often far less effective than we realise. Indeed, recent investigations have revealed that many students, even after solving many quantitative problems and scoring good grades in examinations, emerge from their basic physics courses with significant conceptual difficulties (Kim & Pak, 2002; Sabella & Redish, 2007; Pradhan & Mody, 2009) and inability to apply their knowledge in further learning. In short, students' acquired physics knowledge is often largely nominal rather than functional. This may be one of the reasons why most of the students do not opt for a profession with physics. Broadly speaking, teaching is what a teacher does and learning is what a student does, and the result may be unsatisfactory without a consonance between the two. Hence, significance of both text and teacher mediated instructions need to be studied to realise better the thought processes underlying the various aspects of physics. The ability to interpret a scientific concept is clearly an essential prerequisite for using the concept to make complex inferences. In this context the concept of 'field' is a key one to investigate the conceptual understanding and higher order thinking process of students. The concept of field is abstract in nature, first introduced by Farady through field lines to represent electromagnetic interaction. Most of the earlier studies (Greca & Moreira, 1997; Viennot & Rainson, 1992; Rainson et. al., 1994) pertaining to electric field and superposition of electric fields have been carried out on college/ university and engineering level students. Literature survey shows that not much pedagogical studies have been carried out on Indian school/undergraduate students on the concept of field. But higher secondary level Indian physics syllabus devotes almost one volume of its text book (Physics, Part-I, Textbook for Class XII, NCERT, 2007) dealing with electric field ,magnetic field and electromagnetic field. So it is imperative to investigate the hierarchical learning difficulties of students in electric field and field lines from which they begin the concept of field.

OUR STUDY

In the present paper we have made an attempt to study the features of the understanding as well as representation skill of the higher secondary and undergraduate students on electric field and electric field line mapping. We have tried to find the genesis of their effective and ineffective representation skills post the instructions provided by textbooks and practicing teacher. The concept of 'field' is a significant one which usually starts at higher secondary level and goes a long way as prelude to many branches of physics like particle physics, plasma physics, electrodynamics, astrophysics etc. This concept is usually taught (Physics Part I, Textbook Class-XII, Chapter-1, Electric Charges and Fields) through a bunch of formulas and a few field line drawings. We have analyzed the instructional implications on students learning as well as the interpretation difficulty in extending the concept of electrostatic field. While constructing knowledge it is not sufficient to know the reasons for one's belief, it is also necessary to know the reasons why alternative conceptions are not credible. Hence, demerits of alternative conceptions have been weighed by us and a rational judgement has been made between competing ideas. While analyzing the learning and interpretation difficulties of students the concept specific instructional strategies provided by practicing teacher and text books have been discussed. In the following sections we present the test design followed by the detailed analysis of question-wise responses and conclusion. We expect the findings will help students, teachers and teacher educators in this abstract domain of physics.

TEST DESIGN

The diagnostic test comprises four questions on basic aspects of electric field and electric field line drawings. Before administration these questions were ratified by the physics faculty members of NISER Bhubaneswar, post-graduate teachers of DM School (RIE, Bhubaneswar) and Jawahar Navodaya Vidyalaya (JNV), Munduli, Cuttack, Odisha, and the physics faculty of the Regional Institute of Education (RIEB), Bhubaneswar. All the four questions are designed to probe the understanding of the students on electric field through electric field line drawings. The test requires paper pencil drawings of field lines and interpretation of the same. The test was administered to 39 higher secondary students of Class XII, JNV, Munduli, Cuttack; 47 higher secondary students of Class XII, DM School, Bhubaneswar, 18 undergraduate students of NISER, Bhubaneswar, and 32 undergraduate students of the integrated B.Sc.B.Ed. semester-4 students of RIE, Bhubaneswar. Immediately after the test a structured interview was conducted with eight randomly selected students from each school/institute. One of the authors (MG) recently spent three months at a stretch at JNV, Munduli, Dist. Cuttack, Odisha as a school experience program of NCERT, New Delhi and observed mostly the higher secondary classes engaged by single physics PGT of the school. The higher secondary classes of DM school, which is the laboratory school of RIE, Bhubaneswar have also been observed by the authors. The rationale of selecting such schools/institute lies on the fact that JNV is a rural residential school, DM School is an urban non- residential school, NISER is a premium national level institute, and RIE is a regional (eastern) teacher training institute. The maximum time given for the test was half an hour and time for interview was not fixed. The interview protocol has been designed with appropriate scaffolding so as to bring out students' microstructure of knowledge presentation.

The interviews were recorded using a video camera and the drawings and formulas etc. written during interviews were collected. The transcripts of the interviews, students' written answers, and the steps followed in scaffolding were analyzed subsequently.

ANALYSIS OF RESPONSES

The responses, both in drawing and oral forms, have been analyzed question-wise below. This analysis will be equally beneficial for students as well as teachers/teacher educators. The genesis of students' deficiency in interpreting the concepts has been discussed in detail to design more effective instructional materials.

Q1. Two point charges +Q and +4Q are fixed at a distance of 12 cm from each other. Sketch the field lines and locate the neutral point.

The following diagrams reproduce three sample sketches of the field lines (Fig 1.1, Fig 1.2, Fig 1.3), Fig 1.1 being the most appropriate mapping.

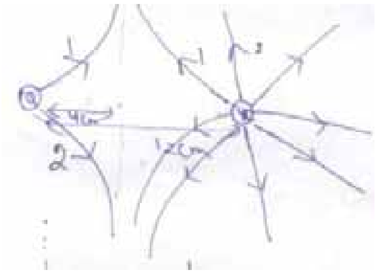
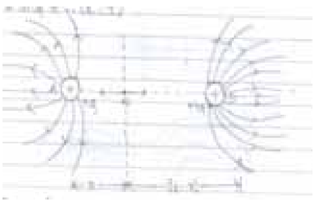
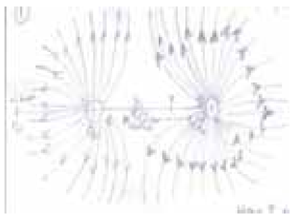

Figure 1.1 Figure 1.2 Figure 1.3

For locating the neutral point numerically, 79% of higher secondary students and 30% undergraduate students have correctly worked out the problem using Coulomb's inverse square law. However, only one higher secondary level and one undergraduate level student have drawn the field lines correctly. This is a very unusual but interesting finding that students even if good at solving numerical problems to locate a neutral point of an electrostatic field are very poor in mapping the field lines. One typical answer in connection with neutral point (Fig 1.3) has revealed the fact that students put much importance to mathematical forms of representation rather than physical phenomenon. While solving the above numerical problem using Coulomb's law and Newton's third law of motion for locating the neutral point where resultant force on a positive test charge due to both +Q and +4Q charge is zero we get a quadratic equation whose solutions are +4 and -12. Most of the students without stating any reason have discarded -12 cm option and has accepted +4cm as neutral point which lies between +Q and +4Q. However, one student assuming +Q charge as reference point has marked -12cm left to the +Q charge as one neutral point and +4cm right to the reference +Q charge as another neutral point. With guided scaffolding the students were first directed to grasp the meaning of neutral point to realise that at neutral point two forces balance each other and their directions are opposite and hence +4cm is the appropriate neutral point, which must lie within two similar charges. Using scaffolding in the reverse order students were made to assume -12cm left to +Q charge as neutral point. Then they were hinted to explore that the directions of two forces due to both +Q and +4Q charges on a +ve test charge at that point will be in the same direction and this does not qualify the concept of a balance force. This shows students have not been alert to the direction of force. Here students were given a chance to weigh their competing ideas and arrive at right scientific conclusion. This finding seems to be very similar to the finding of Rainson et. al. (1994) where students do not recognize field lines as a set of curves representing a vector property of that space. No discussion about the neutral point in an electrostatic field has found a place in the NCERT text book. Practicing teachers were also found to be silent about it during classroom instructions. But neutral point is a very essential field element to understand the configuration of both electric and magnetic field.

The drawing also shows that students have not understood that for mapping the field lines for charges of different magnitude the number of field lines per unit area emerging from each source charge should be proportional to the amount of charge. For charge Q, if for example 6 field lines are drawn, then for charge 4Q, 24 field lines are to be drawn. The amount of curvature/bending of the field lines according to the magnitude of charges have not been taken into consideration and symmetry of the mapping have not been maintained. During interview most of the students could draw the field lines of isolated charges correctly. But when two similar or two dissimilar charges are brought near each other why the field lines bend in a particular pattern they could not answer. The scaffolding to construct the field lines for two similar and two dissimilar charges by referring to calculation of resultant was provided through ICT based diagram Fig 2.4 to Fig 2.6. During interview it was also diagnosed that even if students have solved the numerical problem correctly for locating the neutral point using Coulomb's law they do not relate this inverse square law in the spacing of field lines. This shows that success in numerical problem is not a reliable measure of conceptual development.

Q2. Draw electric field lines between two charges +20 C and -50 C placed 30 cm apart.

This question is similar to Q1. The attractive nature of the field between two dissimilar charges of different magnitude needs to be used for drawing field lines. Unfortunately, not a single higher secondary level student has drawn it correctly. No doubt they have joined the positive charge to the negative charge correctly with arrow sign. But here also they have not paid any attention to the magnitude of charges. Their thought process has not been driven towards the fact that the direction of resultant field on a positive test charge near the positive charge of the lower magnitude will be different than near the negative charge of higher magnitude. Three typical mappings of the field lines are reproduced below, where Fig 2.3 is most appropriate.

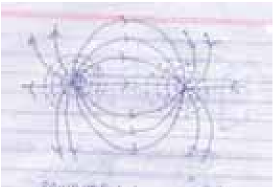

Figure 2.1

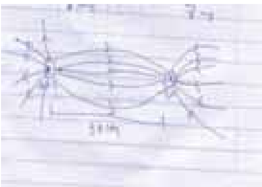

Figure 2.2

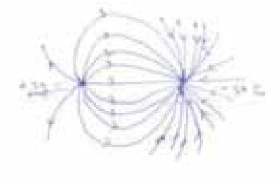

Figure 2.3

During interview one higher secondary School student first joined the two charges with a straight line and, when asked, she pointed that it is the axis, but said that it is not a field line. She thinks field line needs to be curved always. She was convinced about the incorrectness of her answer using the following diagrams and guided scaffolding.

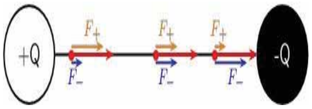

Figure 2.4

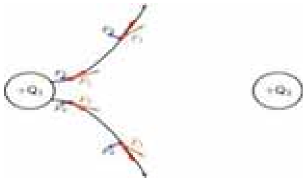

Figure 2.6

Figure 2.5

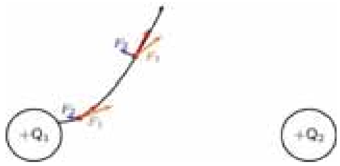

Figure 2.7

Students were hinted to recall the law of parallelogram of addition of forces and apply that for computation of field lines. If we put a +ve test charge near +Q (say on the line joining +Q &-Q) then it is pushed/repelled by +Q (shown by F_+) and pulled/attracted by –Q (shown by F_-) in Fig 2.4 (everything maths.co.za/ science/Grade11). Indeed repulsive force being larger than attractive force at that space point has been shown by longer arrow, F_+ than F_-. The resultant of F_+ and F_- obtained by parallelogram of forces is shown by longest arrow. At the mid-point of the line joining the two charges both attractive and repulsive forces are of equal magnitude and resultant also points from +ve charge towards –ve charge. As the +ve test charge gets nearer to –Q charge the attraction due it is more than the repulsion due to -Q charge as depicted by longer vector F_- than shorter vector F_+. The resultant vector obtained by parallelogram of forces is shown by longest vector. When +ve test charge is placed slightly higher than the line joining the two dissimilar charges of equal magnitude the similar discussion as illustrated above follows and direction of field takes the shape as shown in Fig 2.5. The discussion was extended for two dissimilar charges of unequal magnitude (Fig 2.3). The students were hinted with same principles to realise the curving of the field lines in case of two similar charges of equal magnitude (Fig 2.6 and Fig 2.7). These ICT based diagrams and few “youtube videos” in this concept were also utilized during scaffolding in Q1. The absence of these self- explanatory diagrams in the text books and lack of guided illustrations by the practicing teachers using ICT seems to be an instructional deficiency which might have led students to such pictorial comprehension problems.

Q3. A charge +Q is fixed at a distance ‘d’ in front of an infinite metal plate. Draw the field lines indicating the direction clearly.

This question is open for free interpretation by the students. The question does not explicitly mention whether the infinite metal plate is grounded or not. So, we do not remark their drawings as correct or incorrect rather we try to trace their thought processes. Some respondents have assumed the metal plate to be earthed and have drawn the field lines as shown in Fig 3.1, Fig 3.3 and Fig 3.4. Assuming the metal plate as not being earthed other respondents have shown the polarization or separation of charges inside the metal plate and have utilized those bound positive and negative charges to draw the field lines Fig 3.2.

Maximum number of students of a particular school, 66.7 % have drawn as Fig 3.1. They have correctly shown the induced negative charge only on the upper edge of the infinite plate and utilized those to draw field lines. Moreover, as expected they have directed all field lines towards the plate but none of them have shown pictorially the grounding of the plate. 10.6 % of higher secondary level school students and 22% of undergraduate students have drawn like Fig 3.1.

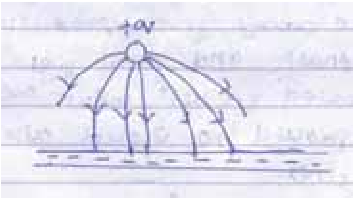

Figure 3.1

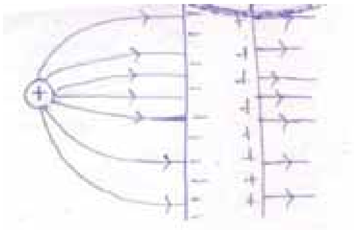

Figure 3.2

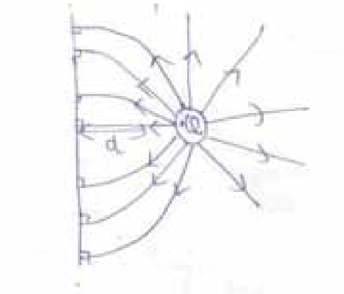

Figure 3.3

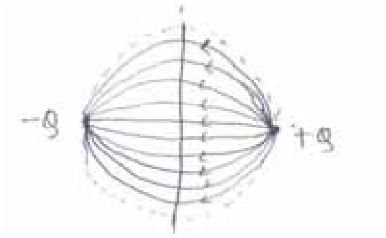

Figure 3.4

Maximum % of mapping by higher secondary level students of a particular school is like Fig 3.3. Two main learning difficulties of these students which are well visualized in their drawings are (i) the induced negative charges are not shown on the metal plate (ii) the number of field lines emerging from +Q charge should be the same entering into the infinite metal plate in consistence with gauss law. The students have never thought that +Q amount of charge in front of a grounded metal plate induces exactly –Q amount of charge. But during interview with scaffolding most of the students were found to be aware of this principle but they do not think of it during mapping. Moreover, in some of the mappings of undergraduate students (Fig 3.3) the concept of equipotential surface being perpendicular to the field lines has been correctly depicted. Other respondents even if aware of this concept do not realise the accuracy of the drawings and have casually drawn the mapping. It was interesting to find different drawings of undergraduate students. They have used 'method of electrical Images' for grounded metal plate. Some student simply through drawing assumed the plane plate as a plane mirror and put a fictitious charge -Q on the other side of the mirror and completed the field lines. They could not explain why abruptly one should take a fictitious charge on the other side of the metal plate. However, the other students could continue their arguments by explaining the basis of method of images using 'Uniqueness Theorem'. Of course we do not expect this higher order learning from school students, but teachers are expected to understand the existing diversity of interpretation skill among various grade students.

Q4. Draw equipotential surfaces for a uniform electric field.

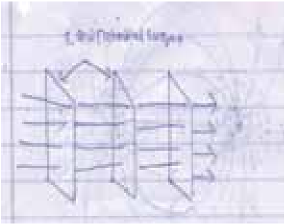

Figure 4.1

Figure 4.2

We mainly found two above varieties of answer. Maximum numbers of higher secondary students have answered correctly (Fig 4.1) as it is a text book based question. However, during interview the students who had drawn correctly could not explain the reason for equipotential surface to be a plane for uniform electric field. Those students who have drawn like Fig 4.2 have not understood the difference between uniform and non- uniform electric field, but have understood the meaning of equipotential surface. The 36% of students who have drawn it like Fig 4.1 argued properly that the work done in moving a test charge in the plane of equipotential surface is zero and mathematically derived that the angle between direction of electric field and equipotential surface is 90^0 . But he could not extend this interpretation to equipotential surface of a non- uniform electric field. As diagnosed in the Q1 most of the higher secondary students do not recognize the field around an isolated point charge as non- uniform field and hence face the difficulties to answer. Moreover, the equipotential surface in case of a non- uniform electric field as shown in Fig 4.2 are concentric spheres, not circles as shown in two dimensional diagram. Except few undergraduate students the higher secondary school students are not very clear about the fact work done on a test charge in moving it from one point to another on an equipotential surface is zero. The scaffolding hinted the students to relate work done to potential difference. This interpretation difficulties could have been avoided if the practicing teacher had interpreted it by showing mathematically, F.dl=dw=dv=0, on an equipotential surface and subsequently interpreting the field lines to be always perpendicular to the equipotential surface. Fig 4.1 is an appropriate three dimensional representation which depicts that for a uniform electric field in X-direction the YZ pane ought to be an equipotential surface. Then the students would have been facilitated to realise that for non-uniform electric field of the type shown in Fig 4.2 direction of field line is perpendicular to the equipotential surface because radius of a sphere always makes a right angle to its surface. The interview was extended to explore the students understanding about uniform and non- uniform electric field. Most of the students recognized the field between two finite plates capacitors as uniform field. But field inside a finite plate parallel capacitor is nearly uniform whereas field at both the edges of a finite plate capacitor is non- uniform as field lines bulge out at the edges due to edge effect. Students were reluctant to realise that electric field exists beyond the dimension of a capacitor. A similar finding is reported by Viennot & Rainson (1992) where students were reluctant to recognize the penetration of electric field into and out of an insulator.

OVERVIEW OF THE FINDINGS

The question wise analysis and discussion has definitely revealed some common inadequacies of students' interpretation skill and initial abilities. The most significant inadequacy is to identify the direction of field lines at different points of the field in various specific cases such as in Q1 and Q4. Many students deem it obvious that field lines are any convex curves those start from positive charge and end at negative charge. They do not realise that field lines are imaginary lines, a continuous locus that are guided by the resultant direction of the electric field vectors. The amount of curving and consequently the directions of tangent on every point of the curve (Fig 2.5 to Fig 2.7) depend upon the magnitude as well as the type of charge. The charge configuration for uniform and non-uniform electric field has not been grasped properly by the students. Field mapping hardly finds any place either in text book exercises or in routine test items. Hence, students are not skilled enough to organize their knowledge of field while representing through diagrams. Interviews reveal that the thought processes of most of the students are not consistent. What they think does not seem to be in consonance with what they show in diagram. Apparently the learning difficulties identified here have not been successfully addressed by the standard presentation of materials in the text books. Moreover, the best instructional material may not help if it does not foster the active mental participation of students in the learning process. For ensuring this a composite strategy based on pedagogy and subject matter needs to be adopted.

CONCLUSION

In this paper we have identified a common learning difficulty of the students' namely poor visualization of physical concept pertaining to electric field lines even when the mathematical cognition of the same seems to be satisfactory. The students need to realize that field lines basically are field vectors at a given point. In most of the cases students have not paid attention to the direction of resultant of force while dealing with the representational aspect of field lines. The convention regarding presentation of various electrostatic field lines pictorially has not been illustrated in instructional materials. The finding of this paper may throw light on this particular aspect of teaching which usually gets neglected during instruction.

References

Greca, I. M., & Moreira, M. A. (1997). The kind of mental representations- models, propositions and images- used by college physics students regarding the concept of field. *Int.J.Sci.Educ*, *19*(6), 711-724.

Kim, E., & Pak. S. J. (2002). Students do not overcome conceptual difficulties after solving 1000 traditional problems. *American Journal of Physics*, *70*(7), 759-765.

NCERT (2007). Physics, Part I, *Textbook for Class XII*. New Delhi: NCERT.

Pradhan, H. C., & Mody, A. K. (2009). Physics teaching and learning through problems. *Bulletin of Indian Association of Physics Teachers 1*(12).

Rainson, S., Transtommer, G., & Viennot, L.(1994). Students' understanding of superposition of electric fields. *American Journal of Physics*, *62*(11), 1026.

Sabella, M., & Redish, R. F. (2007). Knowledge organization and activation in physics problem solving, *American Journal of Physics, 75*(11), 1017-1029.

Viennot, L., & Rainson, S. (1992). Students reasoning about superposition of electric fields. *Int.J.Sc.Education, 14*(4), 475-487.

EXPLORING THE EFFECTIVENESS OF CONSTRUCTIVIST APPROACH ON ACADEMIC ACHIEVEMENT IN BIOLOGY AT HIGHER SECONDARY LEVEL

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A quasi-experimental study was conducted to explore whether constructivist approach could promote perception of nature of biology among higher secondary students. Close-ended questionnaires were administered before and after the treatment. Analysis of covariance test was performed to control the initial variance. The findings revealed that students taught through constructivist approach had higher scores on the concepts of digestion and absorption in the post-test compared to those exposed to conventional (traditional) method of teaching. The results confirm research supporting the positive effect of constructivist learning practices and view that constructivist approach to teach biology is a viable alternative to traditional modes of teaching.

Keywords: constructivist approach; (conventional) traditional approach; academic achievement; physiology of digestion.

INTRODUCTION

Classroom teaching practice is likely to be more effective when it is informed by an understanding of how students learn. Unfortunately traditional teaching approach (lecture method) is prevailing at all levels of education. Traditional teaching and learning is the process of the transmission of knowledge from teacher to student. It is essentially a one-way process. It involves coverage of the context and rote memorization without involving creative thinking and participation in the creative activities. Thomas Lord (1998) stated that students face difficulty while making connection between concepts that they had learned before, or when they are applying their knowledge to problem solving situations. He thought that these problems might be a consequence of the traditional way of teaching science, because this method does not provide time for discussion, or engagement of students on inquiry-base exercise. It is a kind of 'mug and jug approach' to education. The students represent empty mugs to be filled up with knowledge from the teachers' jugs. Most of the time, during teaching learning process, instruction remain unilateral which is consider to be orthodox activity.

The upcoming trends changed the present scenario and adopted the constructivist approach which is moral, focuses on innovative activities and knowledge acquisition. Constructivism is basically a theory about how students learn. This theory has been one of the latest catchwords in educational circles during recent years (Crowther, 1997). The perspectives of constructivism on learning and teaching have been strongly advocated by science educators and researchers. Pedagogical research has demonstrated that constructivism can help teachers to become successful in the class room (Carlin & Ciaccio, 1997; Deeds & Allen, 2000; Emmer & Gerwels, 2002; Vaughan, 2002). Inspite of the criticism made by *Phillips* (1995), Gil-Perez et al. (2002) and Mathews (2002), the perspectives of constructivism on learning have profound influences in contemporary science education (Staver, 1998; Niaz et al., 2003). The theory of constructivism is about "knowing" and "learning" (Bettencourt, 1993; Fosnot, 1996) asserting that knowledge cannot be directly transmitted but must be actively constructed by the learners. It is based on the idea that children learns better by actively constructing knowledge and by reconciling new information with previous knowledge (Smerdon, Burkam & Lee, 1999). Bischoff and Anderson (2001) highlighted the significance of the prior knowledge of individual learners in subsequent learning. According to Richardson (1997) when information is acquired through transmission models, it is not always well integrated with prior knowledge and is often accessed and articulated only for formal academic occasions such as examinations. Constructivist approaches, in contrast, are regarded as producing greater internalization and deeper understanding than traditional methods. This approach encourages students to confront real world problems which are within their everyday experience. The characteristics of constructivist teaching models include: prompting students to observe and formulate their own questions; allowing multiple interpretations and expressions of learning; encouraging students to work in groups; and in the use of their peers as resources to learning.

In India, National Curriculum Framework – 2005 (NCF – 2005) developed by National Council of Educational Research and Training for school education has put importance upon the constructivist understanding of teaching and learning. The NCF – 2005, recommends that children's life at school must be linked to their life outside the school/or classroom, because bookish knowledge or learning creates a gap between school, community and home. The objective of this study was to explore the effectiveness of constructivist teaching approach for meaningful learning in biological science in comparison to traditional teaching methods.

Hypothesis

There will be a significant difference in academic achievement between the senior secondary students taught through constructivist teaching-learning process and those taught through traditional approach on the chapter Digestion and Absorption.

METHODOLOGY

Quasi experimental research was used to achieve the purpose of this study. The study was conducted in Demonstration Multipurpose School of Regional Institute of Education, Bhubaneswar. Forty senior secondary school (standard XI) students participated in the study. Randomly one section was selected for transaction through constructivist approach (experimental group) and one through conventional or traditional approach (control group). Two variables were taken into consideration: (1) Independent variable - Constructivist approach (5E model) and traditional approach and (2) Dependent variable - Academic achievement of students under the chapter Digestion and Absorption.

Out of two sections of class XI, randomly one section was selected for teaching through constructivist approach consisting of 21 students of which 11 were boys and 10 were girls and the other section comprising of 19 students of which 10 were boys and 9 were girls were taught through traditional approach. Two different tools were used in the study: (a) Instructional tools: The constructivist teaching 5E model (Engage, Explore, Explain, Elaborate and Evaluate) developed by Bybee (1993) was employed. The traditional teaching approach included following steps: introduction, development and review and (b) Measuring tools: Two different types of closed ended questionnaires were developed to assess the effectiveness of the constructivist approach: multiple choice questionnaire and statement based questionnaire.

1. *Multiple choice questionnaires (MCQ):* Two separate sets of MCQs were developed, one for pre-test and the other for post-test consisting of 35 questions and each question with four alternative answers. The NCERT textbook, supplementary materials and lab manual formed the basis for developing items for the questionnaire. The questions developed were based on knowledge, understanding, creative thinking and application skills. For MCQ questions, two marks will be awarded for correct answer of each question while the questions left un-attempted, questions for which more than one answer if ticked and the incorrect answers will be awarded zero marks.

2. *Statement based questionnaires (SBQs):* Two sets of SBQs were developed, one set for pre-test and the other for post-test. Each set comprises of total of 20 statements and each with three alternative answers i.e. true, false and not sure. It consisted of both true and false statements randomly interspersed. The purpose of preparing this questionnaire in this way was to avoid guessing by the students. Statement based questions were in a 3 point scale. For correct statements, choice true will be given two marks while false and not sure choices will be awarded zero marks. For false statements, choice false will be awarded two marks while true and not sure choices will be awarded zero marks.

Concept number	Concept	No. of MCQ questions under each concept	No. of SBQ questions under each concept
1	Nutrition	7	3
2	Alimentary canal	7	5
3	Digestive glands	8	3
4	Physiology of digestion	8	5
5	Hormonal regulation of digestion	2	2
6	Digestive disorders	3	2

Table 1: Distribution of MCQs and SBQs under different concepts

The MCQs and SBQs were based on six concepts: nutrition, alimentary canal, digestive glands, physiology of digestion, hormonal regulation of digestion and digestive disorders. The validity of the questionnaire was established by experts from the field of life science and education in view of the objective of the study.

Instructional materials and lesson plans were developed for the chapter based on traditional method and constructivist method. MC questionnaire and SB questionnaire of 70 and 40 marks respectively were used for pre-test. After the pre-test, the two groups were intervened by two different methods of teaching separately for a period of 6 weeks. The constructivist group was taught by 5E constructivist model of teaching while control group was taught by traditional lecture method. During the transaction of the topic in the experimental (constructivist) group, the researcher conducted various activities involving students like activities on peristalsis, action of enzymes (salivary amylase, pepsin etc.), and action of HCl etc. The researchers also used necessary aids like pictures, handmade models, chart papers, power point presentations, audio-videos related to particular concept of the topic. An effective class room environment was created by the researchers by which students were motivated towards active participation and interaction. In the traditional group, the researchers transacted the topic by lecture method using black board, charts and interacted with students by asking questions in between.

After the completion of intervention, post-test was administered by using different set of questionnaires developed on same concepts as in pre-test. A comparison was made on the basis of scores of students of constructivist and traditional groups of students to find out the effectiveness of constructivist approach in terms of academic achievement. Inferential statistics like 't' test and ANCOVA were applied to find out the result and inference.

RESULT AND ANALYSIS

To explore the effectiveness of constructivist approach on student's academic achievement on the topic Digestion and Absorption a comparison of mean scores of constructivist group and traditional group under each concept was done through 't' test. The result obtained is graphically presented in figure.

MCQ Questionnaire

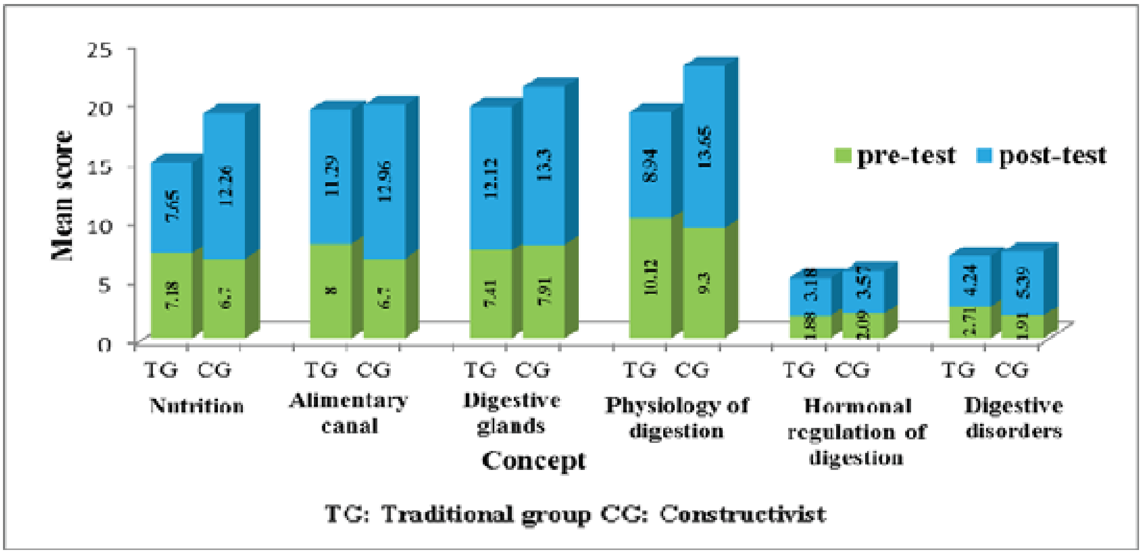

Figure 1: Differences of mean pre-test and post-test scores of multiple choice questions on various concepts between constructivist and traditional groups.

The results of the study showed that before intervention the mean difference in't'- value was not significant between constructivist and traditional or conventional group students but on the other hand after intervention the mean difference in 't'-value was highly significant with df 38 except for concept hormonal regulation of digestion. Therefore, it showed that there was no significant difference between the mean academic achievement of constructivist and traditional group before intervention but after applying constructivist approach there was significant difference in academic achievement of both the groups.

Analysis of Covariance (ANCOVA)

To increase the reliability and validity of the hypothesis analysis of co-variance (ANCOVA) has been done. Application of ANCOVA equates both the groups prior to the treatment and thus helps in valid conclusion. Here ANCOVA is performed by taking pre-test score of each concept of constructivist and traditional group as co-variate and post-test score of each concept of both the groups as dependent variable. The summary of ANCOVA is shown in the following tables.

The obtained 'F' values of co-variate showed significant difference between both the groups for concepts nutrition and alimentary canal while the obtained 'F' values of dependent variable demonstrated highly significant difference between both the groups for concepts nutrition, alimentary canal, digestion and disorder. This interprets that there was significant difference between the post-test score of constructivist and traditional group for most of the concepts. Consequently, constructivist teaching appeared to be influential in regard to academic achievements in comparison to traditional approach.

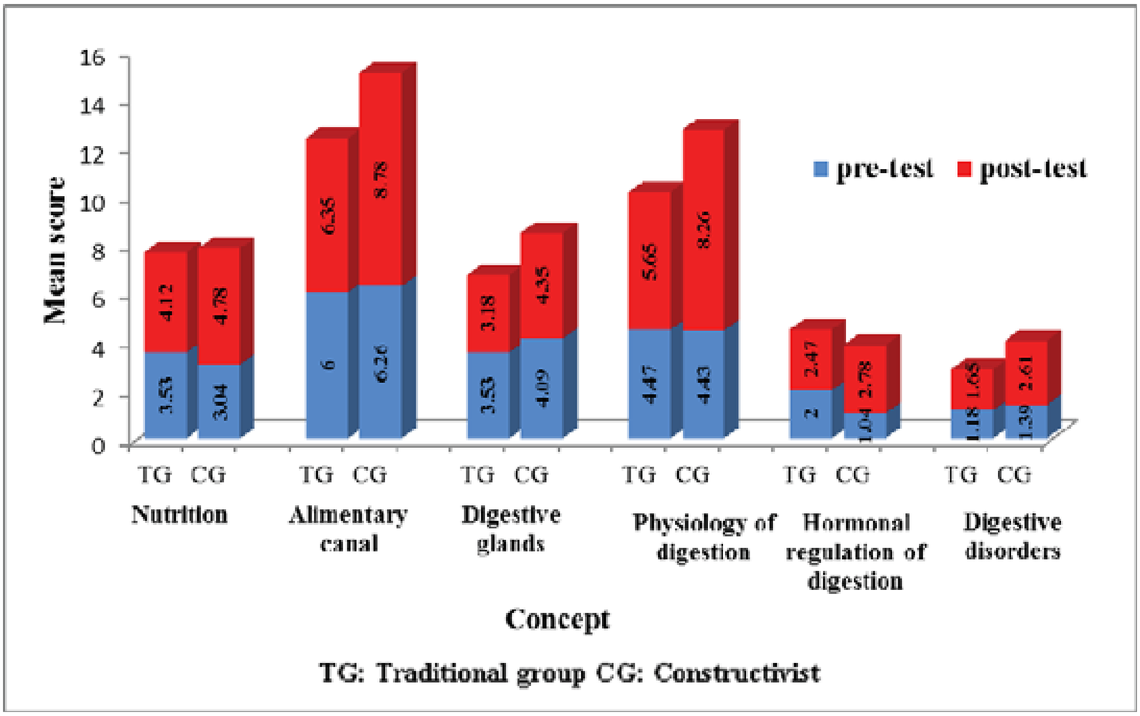

Figure 2: Differences of mean pre-test and post-test scores of statement based questions on various concepts between constructivist and traditional groups

Statement Based Questionnaire

The response to statement based questions clearly showed that before intervention the mean difference in 't'- value was not significant between constructivist and traditional or conventional group students but after intervention the mean difference in 't'-value was highly significant with df 38 except for concept nutrition between the two groups of students. Therefore, it showed that there was no significant difference between the mean academic achievement of constructivist and traditional group before intervention but after applying constructivist approach there was significant difference in academic achievement of both the groups.

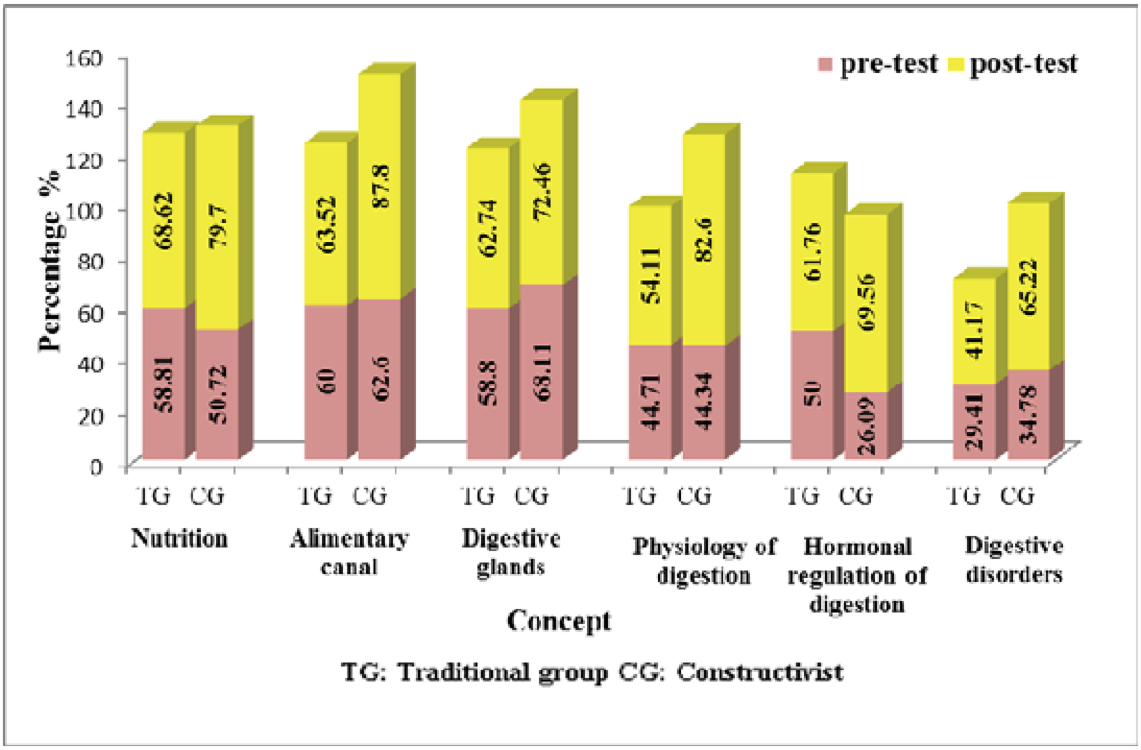

Figure 3: Differences in pre-test and post-test average percentages of various concepts between constructivist and traditional groups.

Analysis of Covariance (ANCOVA)

The average percentage of pre-test and post-test results clearly showed that both the groups have different levels of conceptual clarity for different concepts (Figure 3). Therefore, to increase the reliability and validity of the hypothesis, analysis of co-variance (ANCOVA) has been done. Application of ANCOVA equates both the groups prior to the treatment and thus helps in valid conclusion. Here ANCOVA is performed by taking pre-test score of each concept of constructivist and traditional group as co-variate and post-test score of each concept of both the groups as dependent variable.

There was no significant difference between both the groups for various concepts as indicated by 'F' values of co-variate while the obtained 'F' values of dependent variable demonstrated highly significant difference between both the groups for concepts alimentary canal, digestive glands, digestion and disorders. The results that there was highly significant difference between the post-test score of constructivist and traditional group for concepts alimentary canal, glands, digestion and disorders. Consequently, constructivist teaching appears to be effective in regard to academic achievements for all the concepts in comparison to traditional approach.

DISCUSSION

The statistical analyses of the concept wise results of the pre-test and post-test of the topic digestion and absorption clearly showed that constructivist approach had a significant effect on the students' achievement in the experimental (constructivist) group. There was no statistical significant difference in the average scores and standard deviation of the students in the conventional group and experimental group in respect to multiple choice questions on different concepts suggesting that the students had the same entry level before the treatment. Contrary, there was high significant difference in the average scores and standard deviation of the students in the conventional lecture group and experimental suggesting that the students in the experimental group gained significantly after treatment compared to their friends in the conventional group. In order to determine the effectiveness of constructivist teaching on academic achievement, pre-test and post-test scores were statistically analyzed by teaching methods as the independent variable, academic achievement of the students on various concepts as dependant variable, Covariance analyses were performed. The analysis of the results of the concepts showed that there is a significant difference found between the constructivist teaching group and the conventional teaching group. Therefore, the students of experimental group out-performed the students of conventional group in academic achievement.

The findings of the present study indicates that constructivist based teaching strategy is more effective than conventional lecture method. Similar observations have also been stated by Balci et al. (2006) and; Ceylan and Geban (2009) while studying the effectiveness of constructivist approach. In view of the afore-mentioned findings, this study has been able to establish that the hypothesis is acceptable because there was a statistically significant difference between the pre-test and post-test scores for all concepts between the students taught by constructivist method and the students taught by conventional lecture method. The findings of the present study are in line with the research findings of Saigo (1999); White (1999) and Brad (2000).

The investigator of the present study observed that in control group where conventional (lecture) teaching method was used, students were busy in taking notes to internalize the information and only 30 to 40% students retained what was discussed after the lecture in a period. In a study carried out by Colbum (2000) found that only 15% of the students were paying attention after the lecture had passed ten minutes and only few students could retain what was discussed in the lecture. Several researchers identified serious repercussions on the quality of science education acquired by students due to traditional way of teaching (Adams & Slater, 1998; Anderson, 1997; Rice, 1996; Yager, 1991). Thomas Lord (1998) reported that because of conventional approach students had difficulty in connecting concepts and while applying their knowledge to problem solving situations. He thought that these might be due to conventional lecture method for teaching science as this method has little room for student-initiated questions, independent thought or interaction between students. Traditional science teaching mainly relies upon lecturing facts, forcing students to memorize resulting in lack of motivation, poor content retention and does not effectively help children to use their knowledge (Burrowes, 2003; Leonard et al., 2001; Papadimitriou, 2004). This teaching method hinders the development of individual students' creative abilities.

In this study, the investigators observed that there was active participation of students in performing activities and interaction among themselves of experimental group. They showed higher level of understanding and retention of concepts with high confidence level than students of conventional group. During the post-test, students of the experimental group commented that they enjoyed the lesson much more than their earlier chalk and talk classes and learned more easily. This clearly indicates that constructivist approach is much superior to conventional approach. Researchers like Bimbola and Daniel (2010), Brad (2000), Kim (2005), Kurt and Somachai (2004) and Saigo (1999) in their studies found that students in the constructivist instruction exhibited higher degree of academic achievements than students in the traditional (lecture) instruction.

CONCLUSION

In the constructive learning, orderly arranged ambient as well as positive attitude generates advantageous for the learning process and enable the students to learn better. The students maintain their eagerness for longer period of time and participate effectively in group activities. Teachers play a crucial role in creating such ambient. This study provides ample evidence that constructivist approach of teaching creates active learning environment which is more effective than conventional lecture method for promoting academic achievement, enhancing conceptual understanding, higher order thinking skills and developing a more positive attitude towards biology.

Acknowledgement

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References

Adams, J. P., & Slater, T. F. (1998) Using action research to bring the large class down to size. *Journal of College Science Teaching, 28*(2), 87-90.

Anderson, E. (1997). Active learning in the lecture hall. *Journal of College Science teaching, 26*(6), 428-429.

Balci, S., Çakiroglu, J., & Tekkaya, C. (2006). Engagement, exploration, explanation, extension, and evaluation (5E) Learning cycle and conceptual change text as learning tools. *Biochemistry and Molecular Biology Education, 34*(3), 199-203.

Bettencourt, A. (1993). The construction of knowledge: A radical constructivist view. In K. Tobin (ed). *The practice of constructivism in science education* (pp. 39-50). Hillsdale NJ: LEA.

Bimbola, O., & Daniel, O. I. (2010) Effect of constructivist- based teaching strategy on academic performance of students in integrated science at the junior secondary level. *Educational Research and Reviews, 5*(7), 347-353.

Bischoff, P. J., & Anderson, O. R. (2001). Development of knowledge frameworks and higher order cognitive operations among secondary school students who studied a unit on ecology. *Journal of Biological Education, 35*(2), 81-88.

Brad, H. (2000). Teacher-centered instruction versus student-centered instruction. *Am. Sch. Board J,* 1-5.

Burrowes, P. A. (2003). A student-centered approach to teaching general biology that really works. *The American Biology Teacher, 65*(7), 491-502.

Bybee, R. (1993). *Instructional model for science education, in developing biological literacy. Colorado Springs.* CO: Biological Sciences Curriculum Studies.

Carlin, M. B., & Ciaccio, L. (1997). Improving high school students' performance via discovery learning, collaboration and technology. *THE Journal, 24*(10), 62-66.

Ceylan, E., & Geban, Ö. (2009). Facilitating conceptual change in understanding state of matter and solubility concepts by using 5E learning cycle model. *Hacettepe University Journal of Education, 36*, 41-50.

Colbum, A. (2000). Constructivist: Science education's "Grand Unifying Theory". *The Clearing house, 74*(1), 1-6.

Crowther, D. T. (1997). The constructivist zone: Editorial. *Electronic Journal of Science Education, 2* (2). http:/unr.edu/homepage/jcannon/ejse/ejsev2n2ed.html.

Deeds, D., & Allen, C. S. (2000). A new paradigm in integrated math and science courses. *Journal of College Science Teaching, 30*(3), 178-184.

Emmer, E. T., & Gerwels, M. C. (2002). Cooperative learning in elementary classrooms: Teaching practices and lesson characteristics. *The Elementary School Journal, 10.3*(1), 75-91.

Fosnott, C. T. (1996). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.). *Constructivism: Theory, perspectives and practice.* (pp. 3 – 7). New York: Teachers College Press.

Gil – Perz, D., Guisasola, J., Moreno, A., Cachapuz, A., Carvalho, M., Torregrosa, J. M., Salinas, J., Valdes, P., Gonzalez, E., Gene Duch, A., Dumas-Carre, A., Tricarico, H., & Gallepo, R. (2002). Defending constructivism in science education. *Science and Education, 11*(96), 557 – 571.

Kim, J. S. (2005). The effects of a constructivist teaching approach on student academic achievement, self-concept and learning strategies. *Asia Pacific Education Review, 6*(1), 7-19.

Kurt, H., & Becker, S. M. (2004). A comparison of student's achievement and attitude between constructivist and traditional classroom environments in Thailand vocational electronics programmes. *J. Vocational Educ. Res., 29*(2), 1-10.

Leonard, W. H., Speziale, B. J., & Penick, J. (2001). Performance assessment of a standard-based high school biology curriculum. *The American Biology Teacher, 63*(5), 310-316.

Lord, T. (1998). Cooperative learning that really works in biology teaching. Using constructivist-based activities to challenge student teams. *The American Biology Teacher, 60*(8), 580 – 588.

Mathews, M. R. (2002).Constructivism and science education: A further appraisal. *Journal of Science Education and Technology, 11*(2), 121–134.

Niaz, M., Abd-El-Khalick, F., Benarroch, A., Cardellini, L., Laburu, C. E., Marin, N., Montes, L. A., Nola, R., Orlik, Y., Scharmann, L. C., Tsai, C. and Tsaprlis, G. (2003). Constructivism: Defense or a continual critical appraisal. *Science and Education, 12*(8), 787-797.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology, 13*(2), 299-307.

Phillips, D. C. (1995). The good, the bad and the ugly: The many faces of constructivism. *Educational Researcher, 24*(7), 5-12.

Rice, R. E. (1996). *Making a place for the new American scholar.* Washington DC: American Association for Higher Education.

Richardson, V. (1997). Constructivist teaching and teacher education: Theory and practice. In V. Richardson (Ed.), *Constructivist teacher education: Building new understandings* (pp. 3-14). Washington, DC: Falmer Press.

Saigo, B. W. (1999). *A study to compare traditional and constructivism based instruction of a high school biology unit on biosystematics*. Unpublished Doctoral Dissertation. IOWA City: University of IOWA.

Smerdon, B. A., Burkam, D. T., & Lee, V.J. (1999). Access to constructivist and didactic teaching; who gets it? Where is it practiced? *Teachers College Record*, *101*(1), 5-34.

Staver, J. R. (1998). Constructivism: Sound theory for explicating the practice of science learning. *Journal of Research in Science Teaching, 35*(5), 510-520.

Vaughan, W. (2002). Effects of cooperative learning on achievement and attitude among students of color. *The Journal of Educational Research, 95*(6), 359-364.

White, J. H. (1999). *Constructivism in a college biology classroom: Effects on content achievement, cognitive growth, and science attitude of act-Risk students.* Unpublished Doctoral Dissertation, North Carolina State University, Raleigh.

Yager, R. (1991). The constructivist learning model: Toward real reform in science education. *The Science Teacher,* September, 53-57.

HOW CONSTRUCTION OF DIAGRAM EFFECT ADOLESCENT STUDENT PERFORMANCE IN SCIENCE EDUCATION?

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In class room environment, complex ideas are commonly represented through diagrams, images and models used in every day situation. However effective use of pictorial presentation is a complex process. Research establishes that pictorial diagram presentation leads to heavy cognitive load on an individual to perceive or conceive when ideas are represented through pictorial diagram presentation based learning. This article investigates which pictorial presentation (pre-constructed diagrams versus self-constructing diagrams) effects one's cognitive overload and learning outcome. This study also finds how different levels of prior knowledge effects learning outcome. The result of this study indicates that students learned better in self-constructing diagram condition than the pre-constructed diagram condition. This study explores how two kind of visual representation affects cognitive overload of the individual and subsequently, influence their achievement and performance.

Keywords: visual representation, prior knowledge, mental effort, achievement

INTRODUCTION

Learning is the process of gaining new, or modifying and reinforcing, existing knowledge, behaviors, skills, values, or preferences and may involve synthesizing different types of information. Human learns from the process of education, personal development and in life activities (Schacter, Gilbert & Wegner, 2011). Pedagogy, learning theory, educational psychology describes the process of learning. Cognitive psychology defines cognitive load is the total quantity of mental endeavor being used in the working memory. Researchers Paas and Van Merriënboer (1994) have proved heavy cognitive load can have negative effects on task completion, and it is important to note that the experience of cognitive load is not the same in everyone. Mayer and Moreno (2003) introduce nine methods for reducing cognitive load. They are Off-loading, Segmenting, Pre- training, Weeding, Signaling, Aligning, Eliminating redundancy, Synchronizing, Individualizing. Using diagrams are important in a few of above mentioned methods. Such as Synchronizing, Eliminating redundancy, Signaling, Weeding etc. Because diagram can enlarge the parts of the objects, provides helpful views by reducing two dimensional descriptions and removing unnecessary details.

After diagram, learners' prior knowledge is influenced by material for cognitive load. From the studies on visual representation it is proved that prior knowledge has an important role on perception and attention. Learner uses prior knowledge to get relevant information from graphics, add information from their prior knowledge and construct a mental model. According to the perspective of cognitive load, if schemas are sophisticated and automated, working memory is not overburdened and therefore learning may take place. For this reason in last few decades researchers have felt the importance of research on the using of diagrams for reducing cognitive load in learning.

BACKGROUND LITERATURE

Ainsworth Shaaron, Loizou Th Andrea (2003) showed that students given diagrams performed significantly better on post-tests than students given text. Diagrams students also generated significantly more self-explanations that text students. Furthermore, the benefits of self-explaining were much greater in the diagrams condition. Kolloffel et al., (2008) found a format that combines text and arithmetic's was most beneficial for learning, in particular with regard to procedural knowledge, which is the ability to implement action sequences to solve problems. Diagrams were affecting negatively on learning and to increase cognitive load. Combining diagrams with arithmetical representations did not improve learning outcomes but reduced cognitive load. Leutner Detlev, Leopold Claudia and Sumfleth Elke (2009) found Constructing mental images reduced cognitive load and increased comprehension and learning outcome, when the mental visualization processes were not disturbed by externally drawing pictures on paper, whereas drawing pictures increased cognitive load resulting in reduced comprehension and learning outcome. Herrlinger Simone, Höffler Tim, Opfermann Maria and Leutner Detlev (2009) found significant effects between the type of learning material and text presentation mode. Performance was better in pictures added text condition, and when spoken instead of written text was used. Moreover, they also found the picture effect is chiefly strong in the spoken text condition. Gierus Jankowska Bogumila's (2011) study revealed that students' mental effort significantly increased in the self-constructing diagram condition, yet results on the posttest were mixed. Schwamborn Annett, Thillmann Hubertina, Opfermann Maria and Leutner Detlev's (2011) study result showed a major effect for self-construction with regard to mental effort. Means mental effort was significantly higher for those learners who were instructed to construct their own visualizations during learning. Kragten Marco, Admiraal Wilfried and Rijlaarsdam Gert (2013) found students have difficulties (1) in deeper understanding of the new content, (2) with diagrams that use unknown component conventions, and (3) with diagrams that have a small number of components and probably more abstract. Abdullah Nasarudin, Halim Lilia and Zakaria Effandi's (2014) study showed that the visual representation approaches had a positive collision on achievement, conceptual knowledge, meta cognitive awareness, awareness of problem-solving strategies, and student attitudes toward mathematical word problem solving.

Literature review about the effects of representational condition on cognitive load showed that students' mental effort significantly increased in drawing condition means the learners who were instructed to construct their own visualizations during learning indicated more mental effort. But another study result showed constructing mental images during learning a subject seems to reduce students' cognitive load. So what kind of visualization is effective for decreasing the cognitive load is a controversial topic for the researchers. However literature review proved that cognitive load is a central condition in the design of instruction. The present study fills the blank.

Previous researches on the effects of visualization on students' achievement exhibit visual representation approach had a positive impact on achievement. Especially when picture is added to the text students' performance was better. Another study also revealed that students' generated drawing helps them to understand a new topic. However using diagram without text for learning increases students cognitive load and negatively effects on learning outcome. So it is clear that using diagram to teach a topic is a controversial fact. The present study tries to solve this problem. It is also mentionable that new context creates some problem to the learners especially due to the lack of existing knowledge particularly on that context or topic.

Literature review on the topic revealed reading activity increases students' prior knowledge. It is also proved that efficacy of diagram depends on students prior knowledge. So selecting strategy to read a topic is a big problem for the students. Present study helps the students to choose right strategy for reading. Researches on the relation between mental efforts and achievement showed high context based learning environment contribute to extraneous cognitive load which is not beneficial for learning. It is also proved that cognitive style and motive has indirect effects on learning. So selecting right method for increasing motivation and germane cognitive load to enhance learning effectiveness is a big problem for the instructional designers. The current study helps to fill this gap.

METHODOLOGY

Purpose of the Study

The aim of the study is to know the best acceptable visual representational condition for learning. Here this perusal compares the two visual representation condition, one is self-constructed visual representation condition and the other is pre-constructed visual representation condition.

This study also investigates the most effective diagram condition in accordance with the levels of student's prior knowledge (low prior knowledge and high prior knowledge).

Hypothesis

H01: There is no significant difference between the students of self-constructed diagram condition and pre-constructed diagram condition on mental effort and performance of similar task.

H02: There is no significant difference on the performance between the lower prior knowledge students and high prior knowledge students according to the visual representation condition.

Population

The population of the study is class VIII grade students (Boys and Girls), under West Bengal Secondary Education having Bengali medium of instruction.

Samples

Data has been generated from 120 students of age 13 to 15 years from class VIII of four secondary schools of West Bengal.

Sampling Technique

For the students selection systematic random sampling technique has been used for the study.

Instrument Used in this Study

Prior Knowledge Test

To test the level of students existing knowledge on the topic solar system, researcher develops a questionnaire consisted of 10 close-ended multiple choice type questions.

Learning text

Researcher here uses the information about solar system as learning text material. This expository text about solar system is separated into ten pages. Each page has five or six sentences explaining some aspects of the phenomenon of solar system. There are two versions of this learning text. One, version, design for the first experimental group, do not include diagram, and instead has big blank boxes embedded bellow the text. These boxes are meant to serve as reminder for the students to draw diagrams within them.

The second version, instead for the second experimental group, has diagrams provided along with the text on each page in the same location as the box for the first group.

Mental Effort Test

To measure mental effort, a subjective rating scale is used similar to the Ayers (2006) and Bogumila Jankowska Gierus (2011). Specifically, at the bottom of each page of the learning text, participants are asked to rate their mental effort. That is they were asked, "How easy or difficult do you find the concepts on this page?" The rating consisted of a seven point scale rating from 1 (extremely easy) through 4 (moderate) to 7 (extremely difficult).

Achievement Test

To test (students) their understanding of solar system a post test is administered. This post test included twenty five closed-ended multiple choice type questions.

Design and data analysis

The study used a 2x2 pre-test and post-test experimental design. Data were analyzed using SPSS version 17.0. ANOVA, correlation, descriptive statistic were conducted to measure two type of treatment effect.

FINDINGS

This chapter summarizes the research questions set forth for the study, statistical procedures followed to analyze the data and descriptive statistical results of the data analysis. The data analysis was based on the data collected from 120 VIII grade students.

Preliminary Analyses

To make certain equality between the two types of visualization group on prior knowledge a t-test was performed. Result disclosed that two groups were same ($t(118)=.49$, $p=.62$). Mean prior knowledge score of self-constructed diagram condition is 7.03 (SD= 1.33) and pre-constructed diagram condition is 6.90 (SD= 1.60).

Main Analysis

Correlations

Correlation between the two dependent variables (mental effort and post test score) was in high range (See Table 1 for the correlation matrix).

	1	2
[1]Mental Effort		
[2]Post Test	-.22*	

Note. * Significant at 0.05 level.

Table 1: Correlation between the dependent variables

Mental Effort

To show a significant interaction between diagram condition and mental effort (F (1/119) = 30.50, P =.00) the analyses of variance (ANOVA) was performed. Table-2 summarizes the means and standard deviations of mental effort of two groups as a function of diagram condition.

Diagram Condition	Prior Knowledge	Mental Effort	Post Test
Self-Constructing	7.03(1.33)	34.90(2.21)	17.98(1.46)
Pre-Constructed	6.90(1.60)	32.98(1.53)	16.97(2.11)

Table 2: Means (and standard deviation) of mental effort as a function of diagram condition, post test score and prior knowledge.

The effect of diagram condition showed that the mental effort and achievement for the students in drawing condition was higher (M= 34.90 SD= 2.21), (M=17.98 SD=1.46) than the students of pre-constructed diagram condition (M= 32.99 SD= 1.05), (M=16.97 SD=2.11). This result rejects first hypothesis and answers that students in the self-constructing diagram condition will have a higher mental effort and achieved higher post test scores than the students in pre-constructed diagram condition.

Post Test Score

To prove a significant interaction between prior knowledge and post test scores (F (1/119) = 18.93, P =.00) the ANOVA was performed. Table-3 summarizes the means and standard deviations of the post scores as a function of independent variables.

Diagram Condition	Prior Knowledge	Mental Effort	Post Test
Self-Constructing	Low	36.68 (2.32)	18.09(0.81)
	High	33.87(1.32)	17.92(1.73)
Pre-Constructed	Low	33.08(1.18)	15.33(0.96)
	High	32.92(1.74)	18.06(1.96)

Table 3: Means (and standard deviations) of the post test scores as a function of diagram condition, Post test scores and prior knowledge.

The significant interaction between prior knowledge and post test scores demonstrates that low prior knowledge students achieved lower post test scores (M= 16.65, SD= 1.65) compared high prior knowledge students (M= 17.99, SD= 1.83). This result rejects the 2nd hypothesis and addressed that students with lower prior knowledge will have lower post test results and higher prior knowledge students will have higher post test results.

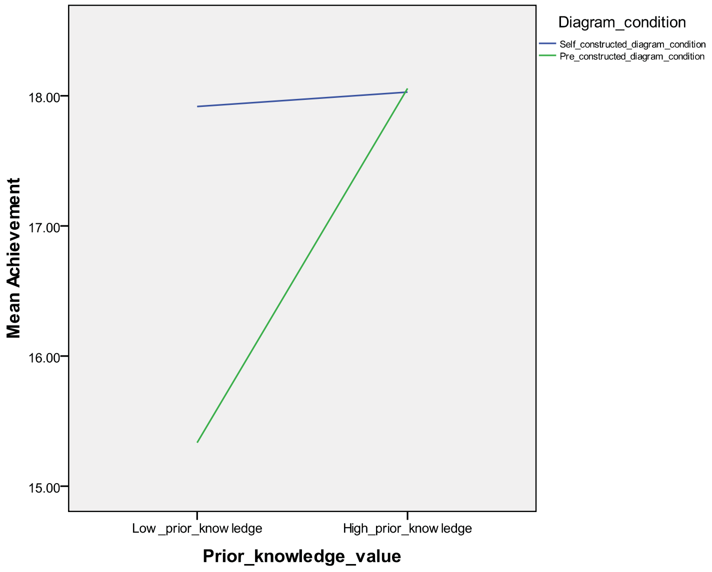

Figure 1: Post test score as a function of prior knowledge and diagram condition

To further explore the interaction between post test scores and prior knowledge according to the diagram condition (pre-constructed and self-constructing) see figure 1 and table 4.

Prior knowledge	Diagram Condition	Post Test scores
Low prior knowledge	Self-constructing	18.09 (0.81)
	Pre-constructed	15.33 (0.96)
High Prior knowledge	Self-constructing	17.92 (1.73)
	Pre-constructed	18.06 (1.96)

Table 4: Means (and standard deviations) of post test scores according to the diagram condition and prior knowledge

This result suggest that, in pre-constructed diagram condition higher prior knowledge students performed better than the lower prior knowledge students and self-constructing diagram condition was beneficial for low prior knowledge students for their better performance than high prior knowledge students. This result rejected the last hypothesis and addressed that the pre-constructed diagram condition is beneficial for high prior knowledge students but not for the low prior knowledge students, where the drawing condition is more effective for the low prior knowledge students but not for the high prior knowledge students.

DISCUSSION

The objective of the study was to determine the effects of two visual representation conditions (pre-constructed diagram condition and self-constructing diagram condition) and existing knowledge on achievement. This study is tried to give some contribution in advance visualization research by comparing these two visualization process. Moreover, students existing knowledge is marked out as an important factor in learning process.

Pre-constructed Diagram Condition Versus Self Constructing Diagram Condition

The result of this study demonstrated that students learned better in self-constructing diagram condition (when they actively drew diagrams) than the pre-constructed diagram condition (when they learned from provided diagrams). Moreover, mental effort of the students showed an interaction effect between the prior knowledge and diagram conditions. This means that students with lower prior knowledge achieved higher mental effort and students with higher prior knowledge achieved lower mental effort in both these two diagram conditions. However the results in the current study demonstrate that there needs to be a qualifier of this generalization: Low prior knowledge students benefit from actively drawing diagrams while learning, whereas higher prior knowledge students learn better with pre-constructed diagrams. Clearly, as Cook (2006) suggested, prior knowledge was an important individual difference variable that needed to be taken into consideration.

Higher Prior Knowledge Versus Lower Prior Knowledge

Result of this study demonstrated that self-constructing diagrams are more beneficial for the low prior knowledge students, because low prior knowledge students might confuse for understanding the pre-constructed diagrams. If they get the opportunity to draw their own diagrams related to context, they can use their own schemata to externalize their knowledge. However high prior knowledge students get more benefit from pre-constructed diagrams.

Significance of the Study

This study helped to rectify the most responsible diagram condition for student's mental effort which indicated the effective diagram condition (Pre-constructed diagram condition & self-constructed diagram condition) for student's achievement.

This study showed the effective diagram condition (Pre-constructed diagram condition & self-constructed diagram condition) for teaching of lower prior knowledge student's and high prior knowledge students.

This study explored which diagram condition is beneficial for the teachers to reduce students' mental effort and boost learning.

If students were in completely new topic then the teachers provided diagram or text book pictures might be confusing. This study tried to solve this problem. This introduction will be suggested what kind of diagram condition (the teacher provided or text book diagrams and self-constructing diagrams) are very useful in teaching and explaining scientific concepts in science education.

Delimitation of the Study

There was always the possibility that prior knowledge and post test learning was not accurately measured.

After the learning text, especially students in the drawing condition, seemed fatigue or anxious to finish the post test and may not have been careful and complete their responses.

The time spent by students in both conditions was inconsistent: students took much less time while learning from pre-constructed diagrams as opposed to self-constructing diagram condition. This speaks to cognitive load being higher for those students who had to construct their diagrams, and supports the theory that the drawing condition increased cognitive load.

CONCLUSION

This study supports the notion that prior knowledge has a significant impact on learning. Low prior knowledge students seem to learn better by self-constructing diagrams instead of learning from standard scientific diagrams. However higher prior knowledge students tend to learn better from pre-constructed diagrams.

To know students existing knowledge on a subject most researchers were used subjective questions. As a result researchers got various irrelevant data from the learners, even in several occasions they did not mention appropriate matter. Therefore, researcher faced the evaluation problem of learners' responses against the subjective questions. Present research encountered this problem using multiple choice type questions in both pretest and post test questionnaires.

References

Abdullah, N., Halim, L., & Zakaria, E. (2014). VStops: A thinking strategy and visual representation approach in mathematical word problem solving toward enhancing STEM literacy. *Eurasia Journal of Mathematics, Science & Technology Education, 10*(3), 165-174.

Ainsworth, S., & Loizou, A. Th. (2003). The effects of self-explaining when learning with text or diagrams. *Cognitive Science, 27,* 669-681.

Ayers, P. (2006). Using subjective measures to detect variations of intrinsic cognitive load within problems. *Learning and Instruction, 16,* 389-400.

Bogumila, G. J. (2011). Learning with visual representations through cognitive load theory. Masters of Arts dissertation thesis. Educational Psychology-Learning Sciences Stream, McGill University, Montreal.

Cook, M. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Wiley Periodicals, Inc. 90*(1), 1073–1091.

Herrlinger, S., Höffler, T., Opfermann, M., & Leutner, D. (2009). Cognitive load during learning from expository science texts: Multimedia and modality effects. Paper presented at the *Third International Cognitive Load Theory Conference,* March 2-4, 2009, Heerlen, The Netherlands.

Kolloffel, B., Eysink, H. S. T., de Ton, J., & Pascal, W. (2008). The effects of representational format on learning combinatorics from an interactive computer simulation. *Instructional Science, 37*, 503-517.

Kragten, M., Admiraal, W., & Rijlaarsdam, G. (2013). Diagrammatic literacy in secondary science education. *Research in Science Education, 43*, 1785–1800.

Leutner, D., Leopold, C., & Sumfleth, E. (2009). Cognitive load and science text comprehension: Effects of drawing and mentally imagining text content. *Computers in Human Behavior*, *25*, 284–289.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 43–52.

Paas, F. G. W. C., & Van Merrie¨nboer, J. J. G. (1994). Instructional control of cognitive load in the training of complex cognitive tasks. *Educational Psychology Review, 6,* 351–371.

Paas, F. G. W. C., & Van Merrie¨nboer, J. J. G. (1994). Variability of worked examples and transfer of geometrical problem-solving skills: a cognitive-load approach. *Journal of Educational Psychology, 86*, 122–133.

Schwamborn A., Thillmann, H., Opfermann M., & Leutner, D. (2011). Cognitive load and instructionally supported learning with provided and learner-generated visualization. *Computers in Human Behavior*, *27*(1), 89-93.

Schacter, D. L., Gilbert, D. T., & Wegner, D. M. (2011). *Psychology (2nd Edition)*. New York: Worth.

ANALYZING THE ROLE OF DIGITAL MEDIA IN SCIENCE EDUCATION: A DISTRIBUTED COGNITION APPROACH

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Science education is a difficult cognitive process because (1) the dynamic phenomena science studies are often not available to human perception and (2) students are required to imagine dynamic phenomena in detail using dense, opaque static representations developed over many iterations and revisions in science practice. In the traditional classroom, the teacher attempts to animate the static representations to aid students' imagination. The advent of digital media, with its potential for dynamic representations, provides new ways of solving this problem, heralding systemic changes in science education that are difficult to analyse and predict. We use a distributed cognition framework to analyse a case study of a private school in Mumbai, examining how cognition is distributed across teachers, learners and representations in a static media classroom, and how this distributed structure of cognition is changed by one form of digital media.

INTRODUCTION: THE PROBLEM OF SCIENCE EDUCATION

Learning science is a goal across educational systems around the world, with few exceptions. Yet science education is a difficult cognitive process for several reasons. To begin with, many of the phenomena that science studies are not directly available to human perception, such as the reactions between molecules or the movements of planets. The way these phenomena are captured is through mental models and external representations of those models, developed over several iterations and revisions within science practice. The final models and their representations are often dense and opaque products, containing no trace of the long process of their development.

In addition, because our primary media for storing and sharing knowledge in the past few centuries have been text-based, the external representations, at least till a few decades ago, have been constrained to static representations of dynamic phenomena. A significant, and difficult, problem in science education is thus to help students understand, and imagine, the relationship between these dense, opaque static representations and the dynamic phenomena they represent, and to help them develop detailed mental models of the unperceivable entities and systems that science often studies.

As an example of this, consider a chemical reaction. The reaction is a dynamic process occurring at a molecular level that is impossible to perceive. Instead, most students learn about chemical reactions by looking at chemical equations and graphs, both of which are static representations of the dynamic phenomena of the reaction. At best, learners may have the chance to enact the same reaction in a laboratory and observe changes in some macro level properties. Students are then expected to combine these multiple external representations in their minds to create a mental model that captures the dynamic reaction taking place. The ability to do so is termed representational competence and is a highly valued goal in science education (Pande & Chandrasekharan, 2014).

So far, the way to develop these mental models in learners has been through teachers in the classroom. The teacher would aid students' understanding and imagination by trying to animate the static representations through whatever means may be available, for example a classroom board or their own voice. However, the advent of digital media, with its potential for dynamic representations, is providing new ways of addressing this conversion problem. These dynamic representations can capture the dynamic phenomena of interest in a more accurate manner, reducing the burden of imagination on the learner.

Dynamic representations can expand the education system's scope radically, in ways comparable to the way the invention of written word and the printing press changed the oral learning traditions. Given the systemic nature of this ongoing shift, it is difficult to analyse the different roles digital media can/would play in the education system, and how to conceptualize, design and incorporate such media into this complex system, to bring about desired changes. In this paper, we seek to develop a theoretical framework that can enable such a system-level analysis.

THE DISTRIBUTED COGNITION FRAMEWORK

The distributed cognition framework was used by Hutchins (1995) to describe how an aeroplane cockpit with pilots and instruments that acted as cognitive artifacts was able to perform complex cognitive tasks, like landing, in a manner that was inexplicable by just talking about cognition at the individual level. Hutchins demonstrated this by detailing how the pilots used speed bugs to reduce their cognitive load while landing. Each aircraft model has a table of permissible speed ranges that the aircraft should stay within at different stages of descent and landing. These ranges vary by the actual load on the flight, and hence had to be looked up using a series of charts kept in the cockpit.

Hutchins describes how the co-pilot would perform this lookup and set the plastic bugs on the speed meter to indicate the relevant ranges for each stage. This allowed the pilot to simply perform a single lookup on the speedometer to ensure that the aircraft was flying within the permissible range. This in turn allowed the pilot to focus on the many other procedures that a complex task like landing requires. Hutchins' contention was that the cognition occurring during this process could only be described by considering a distributed cognition system between the pilots, the charts and the speed bugs that allowed for a rather different quality of cognition than would be achievable by individuals alone.

More recently, the distributed cognition model has been extended by Chandrasekharan and Nersessian (2014) to show how such a distributed system can tackle not just well-defined tasks like landing an aircraft, but even open-ended tasks such as scientific discovery. Through a case study of a bioengineering lab, they show how computer models can be used by scientists working in a lab to extend their cognitive powers. Specifically, by playing around with the model, the ability of the lab as a whole to imagine and simulate different scenarios increases in a manner that cannot be attributed any individual's cognition alone. Instead, the scientists and the model couple together to form a distributed cognition system that allows them to perform tasks of a complexity beyond what they could achieve on their own.

In this paper, we seek to extend this model to the process of education, particularly to science education. From a civilizational standpoint, scientific discovery is a collective, distributed process that can take place over distinct instances in time and space. One of the primary purposes of science education in this regard is to transmit the accumulated scientific knowledge of human civilization to learners so they can benefit from as well as contribute to that body of knowledge. The primary cognitive artifacts that enable this distribution are the media of transmission, and the question that arises is how the nature of the distributed cognitive task of scientific learning changes with the change in the potential of these media. Specifically, how can the potential of digital media to transmit dynamic representations of dynamic scientific phenomena enhance the distribution of scientific knowledge?

We begin by looking at a specific case of how digital media was used to flip the classroom in a private school in Mumbai. We examine how this pedagogical method of the flipped classroom changes the nature of distributed cognition in science education in the school, and then broader implications of these kinds of changes for the education system in general.

THE FLIPPED CLASSROOM AT R. N. PODAR SCHOOL

The flipped classroom is a method of instruction that aims to exploit the capabilities of digital media by allowing students to watch videos of lectures at home, while classroom time is used for problem-solving, project-based activities or other learning tasks that build on and reinforce the concepts introduced in the lecture. There is some debate as to the exact definition of a flipped classroom. In a survey of the literature Bishop and Verleger (2013) define it as a pedagogical method wherein technology is used to automate aspects of instruction that can be automated. This in turn should free up classroom time for collaborative and active learning, which cannot be automated. For our purposes, this definition should be quite suitable.

R. N. Podar School, a private school in Mumbai, has been using this flipped classroom methodology to teach science for the last two to three years. The school first started off using the flipped classroom method when some teachers were short on time available to finish the science curriculum for eighth grade students. With the final exams approaching, they turned to Khan Academy videos, which they sent to their students to watch before class so they could save time on lecturing. Because of the positive response to the measure from students as well as teachers, the school decided to implement this methodology across middle and high school, starting with the math and science disciplines. Eventually, to be better able to tailor the videos for their needs, the school decided to record its own video lectures. This brought the added advantage of having faces familiar to the students in the videos.

The implementation is still a work in progress, with videos for more topics being continually recorded so that the respective classroom sessions can be flipped. There also seems to be a learning curve associated with this new method. The role teachers play while recording or during class is not one they would be used to in a traditional lecture, and they have to plan and prepare afresh for these sessions. Students, too, have to undergo a paradigm shift and take more ownership of their learning by ensuring they watch the video before class. Some methods of enforcement, such as questions that have to be answered before class based on the videos, are being experimented with in this regard.

While the response to the initiative has been generally positive, there have been some drawbacks pointed out, especially by the students. These revolve around the recorded lectures not being engaging enough, or students not being able to clarify doubts arising from the videos. Video engagement should improve as teachers become more experienced at the recording process. The absence of a teacher during the recorded lectures, on the other hand, is an inevitable consequence of flipping the classroom, but can be partly mitigated by classroom groups on social media networks, where questions can be asked and answered. Currently these consist of WhatsApp groups and Facebook pages dedicated to each section, but other interfaces are also being explored.

The expectation from the flipped classroom is that the disadvantage of not having a teacher present during the recorded lecture should be more than offset by the benefits of the pedagogy. Part of the benefits accrue from having recorded lectures readily available for the students to re-watch and revise as necessary. However, the major positive feature of the flipped classroom is that it frees up classroom time for various learning activities and enhanced interaction. By shifting the basic exposition to the subject matter from the classroom to the home, it allows for other processes of learning, such as refutation of students' misconceptions, group projects, or exploration of higher-order questions, to take place in the class. Below are examples given by two teachers of the ways in which they use classroom time since their classrooms were flipped (summarized from interview notes):

Math Teacher: We generally make groups and conduct pair-and-share activities or games. The idea is to encourage collaboration within and competition among the groups. For rational numbers, we used a maze activity in which clues had to be solved to continue in the maze. For volumes, we divided various shapes among groups of 4 students and each group presented the volume of their shape using different methods such as models, questions, presentation, blog, etc.

Physics Teacher: We have both individual and group activities – sometimes we let the students choose whether they want to be in a group or not so they can learn in the way preferable to them. Generally these activities run over 3-7 days. In some group-wise activity, one group's task is to prove the other group wrong. Once, we asked the groups to find a seventh case for ray diagrams in lens – it can't be done, but in searching for that seventh case they learnt more than they had from the previous six cases.

DISTRIBUTED COGNITION IN THE FLIPPED CLASSROOMS

A Taxonomy of Relevant Classrooms

Before we begin analyzing the changes in distributed cognition that take place in a flipped classroom, it is important to reflect on what other kind of classroom(s) we will use as a basis for comparison. The obvious one that comes to mind is the traditional lecture-based classroom. However, the flipped classroom actually differs from such a classroom on two dimensions: (1) it focuses on the use of digital as opposed to textual media and (2) the basic exposition of knowledge takes place at home before the class rather than during class.

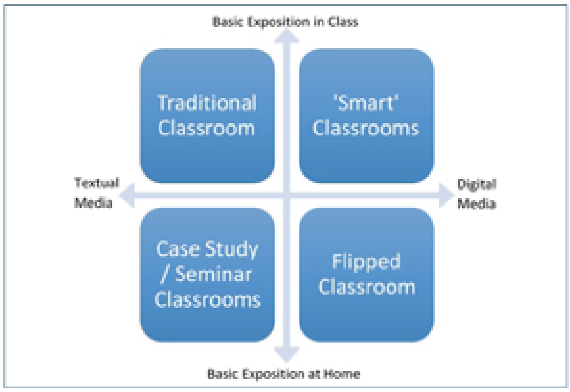

Figure 1: A two-dimensional taxonomy of classrooms

If we create a matrix based on these two dimensions, we actually get four broad categories of classrooms that are common in educational institutions (Figure 1). Of course, these are analytical categories, and empirical classrooms need not fall strictly into one of them. Nevertheless, they will provide a useful taxonomy from which to begin our analysis based on the distributed cognition framework. We briefly describe the four types of classrooms before proceeding:

1. *Lecture-based classrooms:* These, as mentioned, are the traditional classrooms wherein the teacher lectures, using little more than the textbook and a blackboard and perhaps some material paraphernalia, while the students mostly observe and take notes. The teacher is the sole knowledge-holder and the students are receivers.
2. *Case study / seminar based classrooms:* Students arrive to these classrooms having read (primarily) textual material in preparation for a class discussion and/or activity. Faculty act mostly as facilitators with some subject matter expertise, but are usually not sole knowledge-holders. This is common practice in certain higher education institutes, case studies for example in law and business schools, and seminar formats for example in certain post-graduate courses.
3. *'Smart'-classes:* A fashionable trend in the education industry, these are classrooms equipped with digital equipment so that teachers can use digital media in the classroom. Apart from the media, other facets remain similar to the lecture-based classroom. Also, the classroom media is not readily available outside the classroom.
4. *Flipped classroom:* As mentioned, here the students are exposed to the material through digital media at home, and build on that knowledge in class through discussions and/or activities. Faculty may occasionally choose to present fresh, more advanced content but primarily the focus is on student involvement in the classroom.

A Distributed Cognition Analysis

To explore the key changes in distributed cognition brought about by the flipped classroom, we need to first identify the components of distributed cognition. Hutchins (2000) identifies three key components:

> "…at least three interesting kinds of distribution of cognitive process become apparent: cognitive processes may be distributed across the members of a social group, cognitive processes may be distributed in the sense that the operation of the cognitive system involves coordination between internal and external (material or environmental) structure, and processes may be distributed through time in such a way that the products of earlier events can transform the nature of later events" (pp. 1-2).

Within a high school science classroom, since we are primarily interested in how the quality of distributed cognition leads to better learning by individual students. The components of distributed cognition of primary interest can hence be identified as follows:

I. The interaction between learners and the knowledge media

II. The interaction between teacher and learners, as well as among learners

Each of these interactions can be affected by earlier events, and indeed the order of events is one characteristic that distinguishes the flipped and lecture-based classrooms. Also, each of these can take place inside or outside the classroom, but for purposes of simplicity we will ignore interactions made possible by social media for now (the use of social media will impact all classroom types, though in dissimilar ways – but we will not get into that here). We now are ready to examine how each of the above components is affected by the flipped classroom.

Interaction between learners and knowledge media

This component is primarily affected by the axis representing the type of media being used. We have already discussed how digital media allows for the use of dynamic representations of the dynamic scientific phenomena being studied. These dynamic representations reduce the burden of translation and imagination on the learner, and potentially reduce the amount of scaffolding required by the instructor during the initial exposition of content, as compared to the traditional classroom restricted to textual media. However, there is an important difference between the way digital media is used in 'smart' classes and the flipped classroom: in the former it is mostly used by the teacher, and with students having little or no control, while in the latter, because it is used mostly at home, students can both pace its use according to their needs as well as use more interactive forms of digital media.

Another advantage of the flipped classroom is that the recorded lectures are readily available for review at any time to the learners. Thus these videos act as an aid to the learner's memory. In the other types of classroom, the learner would have to rely on textbooks and notes to review what had been taught in class, but these are again static representations of a dynamic lecture. In addition, if the working memory or attention of a student was stretched at any particular point in the classroom lecture, they risked losing out on important basic content that may or may not be dynamically reproducible. With the recorded lectures, however, learners can rewind and re-watch a video as many times as needed, thus allowing them to choose the load on their working memory.

Interaction between teacher and learner, and among learners

The distributed cognition in the flipped classroom can be seen to be enhanced simply because of the interaction between teacher and learner that is made possible both inside and outside the classroom. In the other types of classroom, such interactions were mostly limited to particular stretches of time and space. With the flipped classroom, these constraints are lifted as through videos, such interactions are now possible outside the classroom as well. The quality of interactions is necessarily one-way, since ignoring social media connections, only the teacher can communicate with the students, but even in lecture-based and 'smart' classes, students possess little subject knowledge and hence can contribute only to a limited extent in classroom discussions.

On the other hand, the one-way communication outside the classroom when flipped allows for a much more robust two-way interaction between teachers and students during actual class time. As one teacher put it, "We get more time for interaction. Earlier we were pushed to finish the syllabus, but now we can provide individual attention as needed." Teachers also report more and better questions being asked in class, with one commenting on how "as part of this process, we learnt more and taught less: for some questions, we had to get back to the students."

The greater interaction and participation by students also helps informal assessments, as per teachers. In fact, one of the stages in the four-stage flipped classroom model that R.N. Podar School tries to follow is refutation, where student misconceptions are drawn out in class and addressed. While not impossible in traditional classrooms, the quality of this activity is reported to be richer in the new method.

The quality of collaboration between learners can also be seen to improve. Because students now come to class with some sense of what the new topic is about, a greater range of activities and interactions are enabled, as should be evident from the examples of activities cited in the previous section. Also, more time is reportedly available for collaborative activities among students. All of these allow for enhancements in the potential for distributed cognition within the classroom.

IMPLICATIONS FOR SCIENCE EDUCATION

The printing press revolutionized education by extending human civilization's ability to distribute ideas and discoveries to the masses at a pace impossible with the earlier oral learning traditions and the few hand-made copies of written texts. All that one need acquire was the ability to read, and a whole world of knowledge would open up. Of course, the training to read still needed to be attained, and illiteracy in many countries still isolates portions of the population from this knowledge. Written texts also constrains the media for sharing and storing information to static representations, and hence constrains the quality of distributed cognition.

Digital media holds the potential to change education systems at a scale comparable to the printing press, by lifting both the above constraints. The flipped classroom is one example of how this potential can be exploited to extend the scope of distributed cognition within the scope of a traditional schooling structure. Other initiatives, such as MOOCs, have tried to free education from institutional bindings altogether (although the success and scope of MOOCs remains debatable). Other dynamic media to change the education system are being developed at a fast pace, including video games, simulations based on body-based controllers, laboratory work coupled to simulations, graspable mathematical notations etc. The effect of these dynamic representations in the classroom, and how these would change the education system, is currently very difficult to analyse and predict. The distributed cognition framework which we have sketched provides a starting point to develop this analysis.

One potential is for a greater distribution of learning outside institutions, and according to Bishop and Verleger (2013), this possibility has raised questions about traditional college education and the value the education provides, given the high cost of tuition and attendance. Their contention is that traditional institutions should respond to this threat by increasing the value of the classroom experience beyond what a lecture can deliver, by using in-class time for collaborative and activity-based learning that cannot be automated. The flipped classroom provides one way to do this. Similar changes in practice may follow with other dynamic representations as well.

Acknowledgements

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References

Bishop, J. L., & Verleger, M. A. (2013). The flipped classroom: A survey of the research. *Proceedings of the 120th ASEE Annual Conference and Exposition.* Atlanta, GA.

Chandrasekharan, S., & Nersessian, N. J. (2014). Building cognition: the construction of computational representations for scientific discovery. *Cognitive Science*, 1-37.

Hutchins, E. (1995). How a cockpit remembers its speeds. *Cognitive Science, 19*, 265–288.

Hutchins, E. (2000). Distributed cognition. In W. Kintsch (Ed.), *International encyclopedia of the social and behavioural sciences* (pp. 2068- 2072). Oxford: Elsevier Sciences Ltd.

Pande, P., & Chandrasekaran, S. (2014). A general account of representational competence. [Under Review]

EMERGING IDEAS OF GENERALIZATION, PROOF AND PROVING AMONG GRADE 6 STUDENTS

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This paper reports a small part of a design experiment which aimed at enabling Grade 6 students to make the transition from arithmetic to algebra. The focus on the intervention was to develop students' understanding of symbols and rules of operating on the symbols in the context of algebra by building a deep understanding of arithmetic. Further, it aimed at developing an appreciation of the use of algebra in rich contexts. In this paper, we discuss two of these contexts which are useful for developing two important ideas of mathematics, that of generalization and proof. We discuss Grade 6 students' first attempts to work on these tasks and grapple with these key ideas of mathematics. Though we feel that these students had sufficiently robust understanding of symbols and syntactic aspects of algebra, it was not sufficient to fully understand the demands of the two contexts.

INTRODUCTION

The recent years have witnessed a significant rise in interest in students'capacities to generalize, reason and argue mathematically, in other words to think mathematically. This has led to exploratory studies about students' abilities to generalise, reason, argue and prove as well as develop such capacities among students through teaching interventions. The emphasis on generalization and reasoning, recognized as among the most important processes in learning mathematics, also distinguishes the recent surge in process-oriented classrooms from the traditional product-oriented classrooms. Though both generalization and reasoning have assumed an important role in reform-oriented classrooms across the world, and when given appropriate opportunities students across elementary and secondary grades also are capable of engaging in these processes, the transition to formal proof and proving – the hallmark of mathematical knowledge, largely expected in the secondary school, is still to be understood. Moreover, the addition of these dimensions in the classroom has changed the nature and culture of classrooms, focusing on student participation and production and validation/ justification of mathematical ideas in interactions between participants of the classroom.

Algebra is a domain where both generalization and justifying/ proving play an important role. These provide the contexts which lend meaning to the symbols that get introduced in algebra and also have been found useful for promoting algebraic thinking. Algebra provides the language to succinctly describe the generalization in a pattern and also to justify specific number patterns (for e.g. among three consecutive numbers). Given the vast number of studies which document students' inability to understand symbols in algebra and to meaningfully use and manipulate them (see Banerjee, 2011 for a review), developing an understanding of algebra in rich contexts (like the ones mentioned above) seems to be a reasonable option (e.g. Rojano & Sutherland, 1991; van Reeuwijk & Wijers, 1997). Research in the past shows that these situations could be challenging (e.g. Stacey, 1989; Reid & Knipping, 2010) but creating appropriate classroom cultures which engage children in communication using natural language, signs, gestures, symbols could help them generalize and reason with algebraic symbols (e.g. Radford, 2003; Warren & Cooper, 2008; Rivera, 2010). In this paper, our attempt would be to illustrate Grade 6 students' emerging understanding of generalization and proof/ proving that arose in some particular contexts as they participated in a year-long intervention on beginning algebra. We would demonstrate how Grade 6 students tried to arrive at generalized rules for a pattern and highlight the contributions of various students towards the outcome together with the skills and knowledge that they brought to the situation. We would also highlight the difficulties which students face as they tried to make a transition from reasoning to proving with algebra.

METHODOLOGY AND FRAMEWORK OF THE STUDY

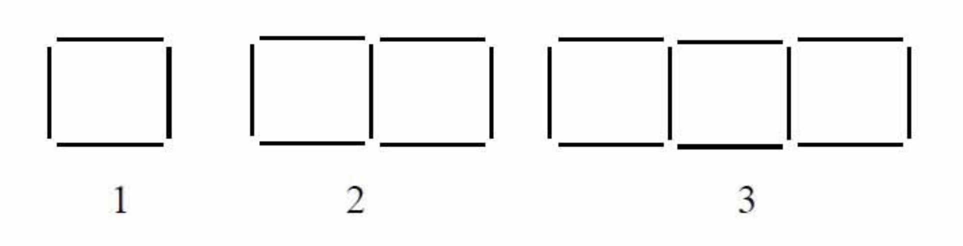
The aspect of the study that is being presented in this paper is part of a larger design experiment which consisted of five trials with Grade 6 students over two years, the first two being pilot trials. The later three trials formed the main study. The students came from two schools (one English medium and one vernacular medium), belonging to low and medium socio-economic backgrounds. Students were randomly selected from a list of volunteers after their Grade 5 final examination for the first trial in summer but they were subsequently invited to attend the latter two trials. The trials were held during the vacation periods of the school, during summer and Diwali. They were taught in the same medium of instruction as of the school by the research team members. None of the activities/ tasks that would be discussed in this paper were familiar to them.

The teaching intervention in all the trials included two kinds of activities - '*reasoning about expressions*' (which included discussions on possibilities and constraints on operations in the contexts of evaluating/ simplifying expressions, the meaning of symbols and comparing and judging equality/ equivalence of expressions) and '*reasoning with expressions*' (dealing with activities like representing relationships, pattern generalization, justification and proof). It aimed to bridge the gap between arithmetic and algebra by exploiting the structure of arithmetic and give meaning to beginning symbolic algebra. It was ensured that reasoning formed the core of the classroom culture, whether the tasks were computational tasks or non-computational. It was also hoped that once students understood algebraic symbols and transformations to signify some meaning and having some purpose, students would be able to use them in contexts and display meaningful actions on the symbolic representations they would create for the situations. Such situations were created in all the trials of the main study.

In this paper, we would focus on two tasks which were used in the third and final trial. We introduced the pattern generalization task (growing patterns of lines or dots or squares) and a game called the 'think-of-a-number' game (e.g. Think of a number. Multiply it by 2. Add 4. Subtract the original number. Subtract 2. Subtract the original number. What is the number you get? Do all of you get the same answer? Can you explain why this is happening?). These required students to represent the situation, generalize it and also provide some justification or proof. Even though these tasks were situated in the numerical world, they are characterized by the scope of generalization to a range of similar situations. We would try to understand the emergence of the crucial ideas of generalization and proof as they worked on these problems. We would also attempt to explore what advantages these students had while working on these tasks given their understanding of expressions revealed in the context of '*reasoning about expressions*' (Banerjee & Subramaniam, 2012) and what more is required in order to gain sufficient understanding of these situations.

Such problems/ tasks were introduced by the teacher as a whole group discussion/ activity followed by further working on the same or other similar tasks in pairs or individually. The pattern generalization task involved creating a generalized rule for continuing the pattern and identifying the equivalence of various rules proposed in the class. The 'think-of-a-number' game began as a puzzle proposed by the teacher inviting students to solve the mystery but subsequently required the students to create their own such puzzles. The purpose of getting students to work in pairs was not so much to analyse the usefulness of collaborative learning but to create a space where they could share their initial thoughts with their neighbours, given the complexity of the tasks. We spent a total of six 45 minute sessions on these two tasks. Data was collected for the trials by video-recording the classes, detailed teaching notes and reflections or each day, record of every day's work done by children, pre and post-tests and interviews after some duration of the second and the third trial. In this paper, we would use parts of this data to show their facility and difficulties with the processes of generalization and proving, revealed through the two tasks.

IDEAS ABOUT GENERALIZATION



How many matchsticks will be required to make the 4th figure?

How many matchsticks will be required to make the 34th figure?

How many matchsticks will be required to make the nth figure?

Figure 1: Matchstick pattern of growing squares

After a short warm-up pattern generalization task involving polygons and the number of diagonals from one point, the first task in the classroom was to generalize a matchstick pattern of growing number of squares (Figure 1).

Due to their extensive exposure to arithmetic expressions, the first attempt was to write arithmetic expressions depicting recursive relations between consecutive figures in order to predict the number of matchsticks required to make some number of squares. There was no apparent difficulty in generating functional relationships which could help make the predictions. The following is a transcript from the first episode of this task from one of the classrooms (a similar discussion happened in the other one too).

Teacher: Think of an effective way of counting the matchsticks.

Joel: In first one it is 4, in second 3 is more

Teacher: 3 is more, what should I write?

Students: +3

Teacher: 4+3. So how are you saying that? What you said is there is 4 and then 3 has been added. Therefore. What about the next one?

Students: 4+3+3, 4+6

Teacher: you can also directly write 4+6. Next?

Students: 4+3+3+3

Teacher: What will be the 5th?

Students: 4+3+3+3+3, 5 times 3

Teacher: What about the next?

Students: 4+3+3+3+3+3 or 4+6+9

Teacher: Can you tell me something easier to write?

Students: 4+6+9, 4+5×3

Teacher: Okay. Now if I ask you about 12th figure?

Students: 4+3+3+

Some others: 4+11×3.

Teacher: Why did you choose this 11? Yes Mahesh.

Student: Teacher because we are increasing 6.

Teacher: We are increasing 6. I have not followed. Please explain.

Mahesh: 5+6=11

Teacher: 5+6, where did the 6 come from?

Aashish: If any number is there, we have to minus 1 and multiply by 3.

Teacher: Okay. This is a reasonably good explanation. If there is any number, you reduce it by 1 and multiply by 3. Here you decrease 12 by 1 to get 11 and multiply by 3.

Saurabh: 6 is 6 more than 12. That is why you add 6 to 5.

The first verbal expression of '…in second 3 is more' was an important articulation which was converted by the group as '+3', a symbol which they were quite familiar by now for representing change or relationship. The group preferred the expression with recursive addition of 3 rather than expressions of the kind '4+6+9', appreciating the possibility of generalization of the former. The recursive addition of 3 was converted quickly to a functional relationship connecting the number of squares and number of 3's in an expression. The last two interventions by Ashish and Saurabh were the first attempts to verbalize the pattern that they were seeing. Saurabh's rule of 'adding 6 to 5' (that is, add 6 more 3's to the existing 5 3's) was a more local rule, being generated on the basis of another expression they had written for making six squares: 4+5×3. This helped avoid the 'linearity error' many students make, which lead them to write the expression 4+10×3 (2 times 5 =10) for 12 squares. Ashish's intervention was more general, he was in fact stating the general rule of finding the number of matchsticks for any number of squares. This is the one the class used to find the number of matchsticks for 62 squares. In some time, to describe the rule for the n^{th} position or n squares in this pattern, a student gave the rule $4+n-1\times3$. The explanation given was 'n-1 is 61 [pointing to the 62^{nd} position] and like that n-1'. Another said 'whichever number minus 1 and in n it is minus 1'. However, this verbalization, although clear in their minds with regard to the sequence of operations, is ambiguously presented in the written expression, which they did not realize.

Subsequently, students across the two classrooms (English and the vernacular medium) generated a variety of expressions as rules for the same pattern. We could see two kinds of attempts with respect to the creation of the rule: expressions representing counting mechanism highlighting the structure of the pattern (e.g. $4+(m-1)\times 3$, $3\times m+1$, $2\times m+(m+1)$) and complex expressions exemplifying pattern in the numbers (e.g. $4\times(m+1)-(m+3)$, $5\times m-(m\times 2-1)$ and $3\times(m+1)-2$). They faced no difficulty with the process of generalization, the verbalization of a rule and converting it into an algebraic expression. They seemed to have grasped some important ideas of generalization. They did not approve of expressions which could not display the pattern suitably for all situations. They carefully identified the constancies in the expressions and pattern in the changes across the expressions leading to the rule. It can be argued that the expression is meaningful only when it bears a close resemblance to the structure of the pattern and is connected to the process of counting. However, we feel that both kinds of generalizations are important and valuable. In this case, students made sense of these expressions as representations for the process of counting or as exhibiting relationship between the numbers. This kind of 'playfulness and inventiveness' with expressions was possible due to the nature of understanding of expressions they had developed in the earlier part of the intervention. This process was particularly helped by allowing students to verbally state the general pattern that they saw in the series of arithmetic expressions. The students attempted to understand the symbols and identify appropriate syntax for the algebraic expressions which matched the verbal rule they stated. This cannot be considered meaningless simply because the resulting expression does not match the visual pattern. This process of verbalizing and generalizing in ways so that it has predictive value are generally found difficult in the various exploratory studies.

The think-of-a-number game provided another opportunity for us to evidence students' ability to generalize. When the instruction used in the task was simple like 'Think of a number. Add 6. Subtract 2. Subtract the original number. Subtract 3', students reasoned: '*50-50=0, 6-5=1*'. Though the student used a particular number to communicate her thinking, it displayed the structure of the argument clearly. This paved the way for using the letter to denote the starting number. The representation of the arithmetic or algebraic expression in this context closely matched the sequence of instructions thereby making it possible for students to start symbolizing the puzzle. A very simple situation created by one student in the class and its subsequent solution by another student illustrates the way they were trying to make sense of this task and their ability to relate the arithmetic and the algebraic solutions. In response to the question '*Think of a number. Add 2. Subtract 2. Add original number. Subtract original number*', a student remarked '*She told to add 2, then subtract 2. So we will get 0. And again add original number and subtract original number, so it becomes 0. x+2-2+x-x = x (+2-2=0, +x-x=0)*'. The translation of the verbal explanation to the symbolized form is another aspect of generalization. Students had developed a strong structure sense for both arithmetic and algebraic expressions and used consistent rules for transforming arithmetic or algebraic expressions (see Banerjee & Subramanium, 2012 for detailed discussion on this issue). This is likely to have helped them in this task as well, where they skillfully analyzed the operations and transformations on the initial number, often treating this number differently from the other numbers used in the context.

IDEAS ABOUT PROOF AND PROVING

Though students displayed some genuine understanding of generalization, they did not show much appreciation of the ideas of proof or proving that naturally arose in these two contexts. When asked whether all the rules generated for the square matchstick pattern were equivalent, some were not sure as they compared the expressions by focusing on the surface features, like comparing $3n+1$ with $n+n+n+1$ and arguing that in the first expression we have $3n$ whereas in the second we have n and +1 is same in both (derived from a strategy of comparing terms that was used quite successfully while comparing arithmetic and algebraic expressions without computation). Others argued that they must be the same as they are generated from the same pattern. A few students thought of substituting numbers in the expressions and check if all the expressions led to a common value during the classroom discussion. A large majority of them resorted to simplifying the expressions to the simplest form. Even after simplifying all the algebraic expressions and arriving at the same result for all, there was at least one student who expressed that '*unless the value of the letter is known, it would not be possible to judge the equivalence of the expressions*'. This leads to a doubt whether all students were able to see the purpose of using the letter or the idea of 'proof', a fairly well documented phenomena in the studies on proof and proving. In the earlier sessions of the trial, they had demonstrated sufficient understanding of equality and equivalence of expressions, which could be arrived at by carrying out various kinds of valid transformations on them. However, in this context, they did not see that expressions once shown to be equivalent do not need further corroboration with numbers and it is general enough to hold for all values of the letter. They also made syntactic errors while transforming them.

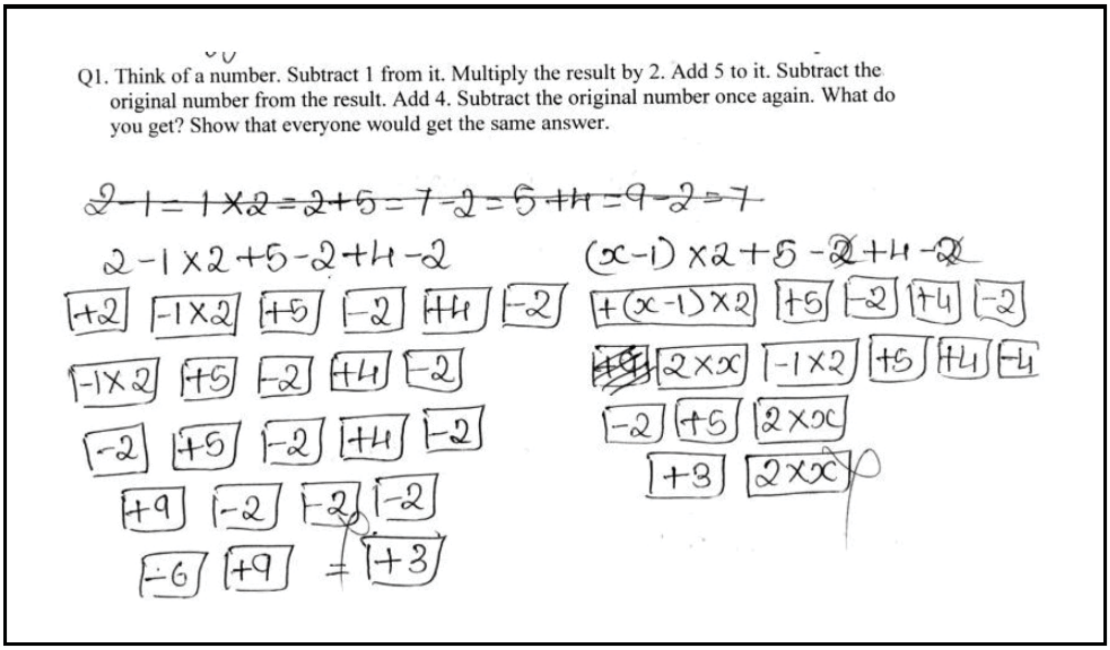


Figure 2: A student's attempt to prove using numbers and letter

In the 'think-of-a-number' game, some students often decided to try various numbers as the starting point and arrived at a result and then induced the pattern of relationship between the two. This process though useful in figuring out how the two (starting and the ending number) were related, did not throw much light on why this was the case. On various occasions of individual solving of such tasks given by the teacher or generating such problems on their own in the class, we came across ideas on proof and proving. Some believed that since the result holds well for multiple instances, it was sufficient to 'prove' the correctness of their conclusion (like, the sequence of instruction would lead to the number they started with or a constant). Some others, as in the verbal explanation stated above, treated numbers as 'quasi-variables' and manipulated expressions in particular ways to show the generality of the conclusion. See Figure 2 for such an attempt, which is incorrect but gives a glimpse of how students tried to use arithmetic expressions and algebraic ones to prove the result. The error is precisely because of the interference of the 'starting number' (2 in this case) with the use of letter. There were a few who could systematically symbolize the instruction algebraically and through manipulation explain why the conclusion holds true for all numbers. As the problems became more complex (posed by the teacher or generated by students), the mental tracking of transformations on the original number was harder and errors in representing and manipulating were observed.

Again, like in the case of showing equivalence of algebraic expressions in the pattern generalization task, they were not sure if the symbolic expression added any insight into the situation. This was further revealed as many of the typical errors students make while manipulating symbolic expressions re-emerged, sometimes even leading to meaningless manipulation. For instance, when they found that a particular set of instructions on the starting number led them back to the starting number and manipulation on a wrong representation led them to the value 0, they immediately concluded that x must be 0 as they did not know the value of x. They were of course not appreciating the goal or the purpose of the whole task. It was very hard for them to resolve the conflict as they did not anticipate what the manipulation should lead them to, thereby indicating a lack of its purpose.

The interviews conducted with seventeen students few months after the end of this trial further substantiated these ideas on proof and proving. The interviews explored students' solution to a pattern-generalization task and 'think-of-a-number' game, similar to the one used in the post-test of this trial. The richness of the classroom discussions were not reflected in the individual performance in the post-test or the interviews, with few students being able to complete the tasks successfully. The pattern-generalization task required students to generalize a pattern and show two rules to be equivalent. Students had variable ability to arrive at the generalized rule and only a few could show the equivalence of the different algebraic rules through simplification without any support. Besides asking for the utility of algebra in the 'think-of-a-number' game, the students were asked to represent a set of instructions, identify the correctness of an expression, judge equivalence of expressions and make a problem for an expression. Even though quite a few students correctly identified a valid representation, could make a question for an algebraic expression, could anticipate the result of simplification of the expression, they were unsure of the use of algebra for the situation. A typical response articulated by one of the students was '*a number represents a general number and if the same operations are carried out on the number, it can be shown that everyone would get the same answer*'.

DISCUSSION AND CONCLUSION

Students displayed sufficient capacity for generalizing in these contexts. This generalization was facilitated by their ability to articulate their reasoning in natural language and their prior experience of reasoning with such symbols. They had sufficient exposure to the arithmetic and algebraic symbols and had been reasoning about validity of syntactic transformations and equality and equivalence of expressions. This of course influenced the ways they saw the use of expressions in the contexts we discussed in this paper. They were readily seen to use expressions (arithmetic or algebraic) to represent the situations meaningfully. However, there were often syntactic errors in the representation which were hard to resolve. Similarly, though they were quite comfortable generating a representation in both the contexts, it was not obvious to them the purpose of using the letter. In the context of pattern generalization, the letter was surely a number and therefore it was more acceptable. However, when the discussion moved to showing the equivalence of two or more rules generated for the same pattern, it was not clear whether they all appreciated that the expressions must necessarily be equivalent or that simplification of expressions is general enough and does not need to be followed by substitution of a number. The 'think-of-a-number' game provided opportunities to the students to engage in representing a numerical situation algebraically. They could make sense of the expression but since they could explain the situation using narratives or using arithmetic expressions by treating numbers in a 'quasi-variable' way, they did not see algebra as adding much value.

Their earlier experience created a predisposition for symbolic representations and thinking and reasoning with an expression. However, fewer students could convert this understanding to one which could enable them to successfully complete the tasks of reasoning *with* expressions or appreciate the 'purpose of algebra'. The issue is not simply one of transferring the abilities from the syntactic world to the contexts where algebra is to be used as a tool or of creating a situation so that the letter gets embedded in the context and thus creating meaning for the letter or algebra. Two elements that play an important role in these tasks are (i) the culture of generalizing, proving and verifying, with which the students in traditional curricula have very little experience and which needs to be developed and (ii) students' belief about the effectiveness of using algebra in these tasks. One can probably explain the re-emergence of many syntactic errors and meaningless manipulation on the letter and the expressions as they failed to appreciate the purpose of algebra and the goal that they were trying to achieve.

References

Banerjee, R. (2011). Is arithmetic useful for the teaching and learning of algebra? *Contemporary Education Dialogue, 8*(2), 137–159.

Banerjee, R., & Subramaniam, K. (2012). Evolution of a teaching approach for beginning algebra. *Educational Studies in Mathematics*, *81*(2), 351-367.

Radford, L. (2003). Gestures, speech and the sprouting of signs: a semiotic-cultural approach to students' types of generalization. *Mathematical Thinking and Learning, 5*(1), 37-70.

Reid, D. A., & Knipping, C. (2010). *Proof in mathematics education: Research, learning and teaching*. The Netherlands: Sense publishers.

Rivera, F. D. (2010). Visual templates in pattern generalizing activity. *Educational Studies in Mathematics*, *73*, 297-328.

Rojano, T., & Sutherland, R. (1991). Symbolizing and solving algebra word problems: the potential of a spreadsheet environment. In F. Furinghetti (Ed.), *Proceedings of the Fifteenth Conference of the International Group of the Psychology of Mathematics Education* (Vol. 3, pp. 207-213). Assisi, Italy: PME.

Stacey, K. (1989). Finding and using patterns in linear generalizing problems. *Educational Studies in Mathematics*, *20*(2), 147-164.

van Reeuwijk, M., & Wijers, M. (1997). Students' construction of formulas in context. *Mathematics Teaching in the Middle School*, *2*(4), 273-287.

Warren, E., & Cooper, T. (2008). Generalizing the pattern rule for visual growth patterns: Actions that support 8 year olds' thinking. *Educational Studies in Mathematics, 67*, 171-185.

A MIDDLE SCHOOL SCIENCE TEACHER'S CLASSROOM TALK: DISCOURSE CHARACTERISTICS AND QUESTION TYPES IN A UNIT ON ENERGY

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The purpose of this research study is to explore the discourse characteristics and question types as a middle school science teacher develops common knowledge on the concepts of energy in her classroom. The teacher uses a standards-based curriculum and accompanying student workbook that promotes mediation of oral knowledge referred to as "dialogic discourse." The whole-class discussions between the teacher and her students are audio-recorded and transcribed verbatim. Analysis of one representative discourse excerpt, that is, "understanding kinetic energy" reveals the teacher constantly asking questions in order to develop common knowledge. The sample excerpt also reveals four types of questions: fill-in-the-blank, second-order, descriptive, and explanatory. Although the teacher in this study had professional development to implement science lessons from a sociocultural perspective, the excerpt shows that the teacher struggles to engage students in productive talk. Thus, the study implies the need for professional development that promotes a give-and-take exchange of ideas that centers on student engagement and thoughtfulness as the standards-based curriculum intends. As the study suggests teachers who are willing and trying to adopt dialogic discourse need to be supported, monitored over time and not left to their own discretion during implementation.

Keywords: dialogic discourse, sociocultural perspective, common knowledge

INTRODUCTION

Most science educators and current curriculum documents endorse "give and take" discussion methods as a preferred form of classroom discourse (e.g., Shwartz, Weizman, Fortus, Krajcik & Reiser, 2008). The reality, however, is that teachers typically resort to a question-and-answer discussion format that puts teachers at the center of the classroom experience while relegating students' questions (and consequently their learning) to the background of the classroom experience (Krajcik, Reiser, Fortus & Sutherland, 2008). Barnes (1976) has cautioned that teachers do not provide students with opportunities "to ask their own questions, to formulate hypotheses, or to make intelligent responses other than those predetermined by the teacher's own implicit associations of thought and frames of reference" (p. 30). Even in contemporary times, Mercer and Howe (2012) have noted that in whole-class settings, teacher-student interaction is dominated by "teacher talk"—a type of interaction in which teachers use closed questions simply to seek brief responses in order to ensure that at least some students repeat the right answers. However, teacher questions: How did you know that? Why? Enable students to use language as a tool for reasoning and to express key ideas in their own words (Wolf, Crosson & Resnick, 2006). In order to check students' understanding, provide them with accurate information, or correct their misunderstandings, teachers should strategically balance authoritative talk with dialogue (Mortimer & Scott, 2003). Eshach (2010) has noted that whole-class teaching is the most common instructional approach and it has been insufficiently studied. Lehesvuori et al. (2013) have recommended that in order to capture the essence of classroom communications between teachers and students, more micro-scale exploration is needed of classrooms. Thus it is important to understand through a fine-grained analysis of transcripts, how a middle school science teacher, who has received professional development in a standards-based science curriculum, developed and established common knowledge about energy across time.

THEORETICAL FRAMEWORKS

Science curricula and pedagogical practices are being shaped by national policies (NRC, 2012) that have been informed by a sociocultural perspective; language is at its core for individual and collective thinking and learning (Vygotsky, 1978). According to Vygotsky, language is both a cultural tool and a psychological tool that transforms thinking. It is a cultural tool because it is used to develop and share knowledge among members within a community, and it is a psychological tool because it provides structure and content to the process of producing individual thoughts. The mediation of oral language is referred to as "dialogic discourse," and it is consistent with teaching models that have adopted the notion that knowledge is co-constructed within a sociocultural context (Driver, Asoko, Leach, Scott & Mortimer, 1994). In this process of knowledge construction, students are encouraged to question, evaluate, and challenge the ideas of others (Berland & McNeil, 2010). The statements of others are not simply accepted but undergo scrutiny through critical analysis, and in this process, students justify their own views as well as support or refute the ideas of their peers (Mercer, 2009). Teachers use language to provide a cumulative, continuing, contextual frame that enables students to engage with new information they encounter (Alexander, 2004).

A critical analysis of the few existing studies on science classroom discourse from a sociocultural perspective of learning revealed the character of dialogue between teachers and students in four interrelated ways: (a) "productive disciplinary engagement" (Eshach, 2010; Scott & Ametller, 2007; Scott, Mortimer & Aguiar, 2006, p. 607), (b) solving open-ended problems (McNeill & Pimentel, 2010), (c) wonderment questions (Aguiar, Mortimer & Scott, 2010), and (d) dialogue that connects past and present learning experiences (Mercer, Dawes & Staarman, 2009). In line with discourse studies, the following research questions guided this study: What discourse characteristics and question forms are evident as a middle school science teacher attempts to develop common knowledge related to the concept of energy?

SIGNIFICANCE OF THE STUDY

This study is significant for three primary reasons. First, understanding how this teacher conducted whole-class discussions and how she developed students' conceptual understanding on the topic of energy in order to establish common knowledge over time will provide insights into the nature of classroom discourse at a time when standards-based curriculum are promoted. Secondly, because the teacher implemented a standards-based science curriculum from a sociocultural perspective of learning, it is important to know whether classroom discourse parallels the curriculum's intentions. Finally, this study also provides a platform for future research that probes into ways of developing common knowledge through classroom discourse. This research will allow teachers and administrators to become aware of why and how such discourse plays out in the reality of an urban classroom in ways that can transform teaching and learning in more meaningful ways.

METHODOLOGY

Research Design

This was an interpretive discourse study that adopted notions advocated by Mortimer and Scott (2003) that explain how teachers use discourse to mediate students' conceptual understanding of science concepts from a macro perspective as well as Hoon and Hart (2006) that emphasize situating classroom discourse within a sociocultural perspective of learning to develop scientific knowledge, support student meaning making, and maintain a narrative.

Study Context

The Science and Mathematics Academy (SMA) is situated in the heart of a large urban city in a mid-western state. SMA is a Public School Academy secondary school that focuses on science and math with students in grades seven and eight. The total school population is 387, with 331 students living in an urban city and 56 students living in the surrounding areas. Of the 387 students, 227 students are on free or reduced lunch. At the time the study was conducted, 161 students were in the seventh grade, which is the focus grade of this study; of these, 155 were African-American, three were Caucasian, two were Hispanic, and one was Arab-American. There were 94 boys and 67 girls in seventh grade.

The teacher who participated in this study implemented the Investigating and Questioning Our World Through Science and Technology (IQWST) curriculum and the associated project-based learning approach (Kracjik, Czerniak & Berger, 2002; Schneider, Krajcik & Blumenfeld, 2005) that promotes inquiry and reflection as well as student engagement in student-directed scientific practices supported by technology and collaboration. The major learning goals in the seventh-grade physics unit are to understand that (a) there are different types of energy, and that (b) energy can be transformed from one type to another.

Participants

The participants, referred to by pseudonyms, in this study consisted of a seventh-grade science teacher and her students. In all, the teacher taught 68 students, ages 13-14, in four sections of seventh-grade science class. For the purpose of this study, one section consisting of 18 students was used of which ninety six percent of the students were African-American.

At the time of the study, the teacher had approximately three years of teaching experience. The teacher holds a Bachelor of Science in Elementary Education and an Associate of Arts in Liberal Arts. Along with her colleagues, the teacher participated in a five-day summer institute conducted by University of Michigan professors and graduate students as well as a lead teacher. The professional development program included support strategies for teachers in the areas of science content, inquiry pedagogy, and contextualized learning focusing on Big Ideas using the IQWST curriculum. The institute emphasized coherence (development of science ideas), deep and meaningful student understanding, concepts and explanations, and assessment of students. A major goal for teachers in the summer institute was to understand how to use IQWST pedagogies within the framework of an educative curriculum. The session also focused on how to implement the IQWST seventh-grade physics unit curriculum.

Data Collection

The classroom and science center visit portion of a two-year study took place from January 2010 to May 2010 during 30 periods consisting of 55 minutes each. The researcher personally observed all of the classroom sessions and related events and recorded field notes. At the same time, the researcher used integrated circuit (IC) system and videotapes to record the large-group classroom discussion during which the teacher developed the concepts of energy with students using the IQWST workbook activities that focused on the concepts underpinning the science center energy exhibits. These IC recordings of discourse were transcribed verbatim. A sampling of student IQWST workbooks that contained activities were collected as evidence of the work completed in the classroom. The IQWST workbooks provided evidence of student work correlated to the forms and transformation of energy lessons taught by the teacher.

DATA ANALYSIS

An interpretive discourse analysis following the notions of Hoon and Hart (2006) as well as Mortimer and Scott (2003) was used to analyze teacher-student classroom discourse transcripts. Four representative instructional events were selected from the large corpus of data. The rationale underpinning this sampling is based on consistency of students' completion of workbook lessons and references made by the teacher to these lessons as she developed common knowledge on the forms and transformation of energy. The dialogue in these transcripts portrayed consistent use of question forms used by the teacher. No a priori codes from the discourse analysis literature were imposed on the data.

Inter-Rater Reliability

An external audit consisting of two US-based researchers with Ph.Ds. (one in science education, one in English literature, and both with experience in discourse analysis) was conducted to evaluate the accuracy of the coding and to determine whether the findings, interpretations, and conclusions reflected the data. Both external researchers agreed that the research was dependable. Establishing the inter-rater reliability is one important way to validate a qualitative study because Lincoln and Guba (1985) have stated that reliability and validity in qualitative research are congruent.

RESULTS AND DISCUSSION

Based on the four instructional events cited in Table 1, four discourse characteristics were identified: (a) teacher-posed questions, (b) teacher-explanations, (c) teacher responses, and (d) teacher references to past learning. The overall data revealed five types of teacher-posed questions: (a) fill-in-the-blank questions to prompt students to provide her with correct responses, (b) affirmation questions to ensure that there is no doubt in their minds, (c) second-order questions that reinforce ownership of student understanding, (d) descriptive questions to elicit information, and (e) explanatory questions to probe students' scientific explanations. For the purpose of this submission, we focus on the analysis of second instructional event, understanding kinetic energy, to provide our results and discussion.

Understanding Kinetic Energy

Cathy guides students through an investigative activity designed to identify the factors that influence kinetic energy. The purpose of the entire investigation lesson was for students to learn that objects in motion have kinetic energy and that the amount of kinetic energy an object has is dependent on the object's mass and speed. Another purpose that directly connects to the goal of "questioning and designing investigation," which is a critical attribute of the IQWST curriculum, is to develop students' ability to recognize variables and design a fair test to isolate the effect of a single variable. Excerpt 2 reveals how Cathy develops students' understanding of kinetic energy.

Excerpt 2:

2.1 Cathy: Please read the purpose for this activity…

2.2 Bridget: The purpose of this activity is to determine which factors affect the amount of kinetic energy a falling object has. You will design a scientific experiment by changing one variable at a time.

2.3 Cathy: We have two findings, the independent and dependent. You are going to use Play-Doh to measure how much energy something has. How can you use Play-Doh to measure how much energy something has? I have a little, tiny piece of Play-Doh. And I have a medium-sized piece of Play-Doh. I have two pieces. If I put them in my fingertips and press—which one is going to squish first?

2.4 Tasha: The smaller one…

2.5 Cathy: Why?

2.6 Tasha: It has less mass.

2.7 Cathy: If I take two cans, and this is what you're going to do… Corey, please read the instructions.

2.8 Corey: Use the table to record your data when investigating how the speed of the falling object can affect the change in thickness of the modeling clay.

2.9 Cathy: How does speed affect what somebody is doing? If I'm testing speed… and I'm going to use these two cans… To make it a fair test… this is the question… if I'm changing the speed, how many things should you change in the experiment? Listen to the question… how many things should you change in the experiment?

2.10 Avery: One

2.11 Cathy: Avery said it. If I'm changing the speed, should I change anything else in the experiment?

2.12 Corey: No

2.13 Cathy: You're going to take a ball of Play-Doh. You're going to measure it to about two centimeters. You're going to take one can. You're going to put a piece of newspaper on the floor, and you're going to take your Play-Doh. You're going to take your ball of Play-Doh and put it on here. You're going to take one can and you're going to drop it onto that Play-Doh. First off, you're going to measure that Play-Doh. You're going to take a ruler and tell me how high is this Play-Doh? Right now, it's about two centimeters. You're going to take the can and drop it. You're going to measure the Play-Doh again. What do you think is going to happen when I drop it?

2.14 Michael: It's going to get smashed.

2.15 Cathy: It's going to get squished. I dropped it. It squished. You're going to measure it again. You're going to take it and take it back to the same size. It was two centimeters before. If it was two centimeters before, how big are you going to make it again?

2.16 Michael: Two centimeters…

2.17 Cathy: Thank you! It's two centimeters again, and you're going to take the same can… instead, this time, you're going to not throw it hard enough so I have open cans of food in my room. You're going to throw it down at the Play-Doh. After you throw it, what do you think you're going to do? You're going to measure it again. From now until 10:30, you should be independently writing your predictions. You can actually write in your books your predictions. What do you think is going to happen with that Play-Doh when you drop it versus throwing it? What's going to happen and why? When you are finished with the predictions, go ahead and use the equipment. The great things about predictions are that you don't have to be right (Classroom Video, 1-8-10)

Excerpt 2 reveals that Cathy is following the IRE pattern of interaction (Mehan, 1979), or triadic dialogue (Lemke, 1990), by constantly asking questions to guide her instruction on scientific investigation. Excerpt 2 also reveals 11 teacher-posed questions and no student questions. Cathy asks four types of questions (frequency included): There are three fill-in-the-blank questions, requiring brief oral responses from students (2.5, 2.9, 2.11, 2.13, 2.15); four second-order questions (2.9, 2.13, 2.17); four descriptive questions (2.3, 2.13, 2.17); and two explanatory questions (2.5, 2.17).

While attempting to adopt a new way of teaching, Cathy falls into the trap of repetitive talk as a method of ensuring that students clearly understand what she is trying to teach them. Rather than probing for students' deeper understanding, Cathy continues to give long-winded instructions about what her students need to complete (2.13, 2.17). After asking a question, Cathy immediately gives specific instructions about how to answer that question (see 2.3). Cathy demonstrates the procedure before allowing students to conduct the investigation (2.13, 2.15). Cathy explains how to design and conduct a fair scientific test that enables students to assess the influence of one variable on another variable while all other variables are held constant (2.9). As well, Cathy wants students to understand the importance of multiple trials to establish the validity of a constant answer (2.15).

Cathy uses explanatory questioning to guide students to respond in writing (2.17). Besides questions that elicit obvious answers (2.4, 2.5, 2.10, 2.12, 2.14, 2.16), she asks "Why?" questions (2.5, 2.17) to elicit explanations and "What do you think?" (2.17), a second-order question (Ebenezer et al., 2010), to probe their predictions. A mixture of questioning types constitutes "authoritative" teaching that may be identified as teacher modeling, and then Cathy allows her students to conduct the investigation as they construct meanings for themselves. This type of teaching simulates what Scott et al. (2006) have described as "productive disciplinary engagement" (p. 607) although there is much show and tell on Cathy's part. Although Cathy uses the IQWST workbook lessons that foster classroom discourse as an essential component of inquiry through experimentation and argumentation (Krajcik & Sutherland, 2010), only a few questions are explanatory.

The instructional events reveal that Cathy's classroom discourse is akin to Mercer and Howe's (2012) observation of whole-class settings in which teacher-student interactions are dominated by teacher talk and in which teachers use closed questions simply to seek brief responses in order to ensure that at least some students repeat the right answers. A way of improving the teacher's interaction model is to apply less authoritative and more dialogic dialogue to help students construct their own knowledge about the concept of energy. The predominant fill-in-the-blank-type questions should be sparse and be replaced with questions that encourage students to put main ideas into their own words and press students to elaborate on these ideas. For example, asking, “How did you know that?” or “Why do you think that?” develops students’ understanding (Wolf, Crosson & Resnick, 2006). The art of questioning is important in developing students’ knowledge and understanding of scientific concepts.

IMPLICATION

The preferred form of classroom discourse in the IQWST curriculum is a give-and-take exchange of ideas that centers on student engagement and thoughtfulness (Krajcik et al., 2008). Cathy attempted to parallel classroom discourse to the curriculum’s intentions by probing her students to discuss their reasoning. However, the questioning did not extend beyond students providing one or few word statements and Cathy giving detailed instruction at every instance. Even though Cathy participated in professional development specific to the implementation of the unit on energy, she falls back on teacher-dominated talk. Thus, the results of this discourse study reflect only a fraction of a sociocultural perspective of learning advocated by discourse researchers mentioned above. The reasons might be because the professional development is only one week-long and it may not have included the art of dialogic communication. As well, it is Cathy’s first attempt at implementing the IQWST curriculum with its discourse practice. One way of improving the IQWST professional development program is to develop teacher training videos that embed different possible branch points in a classroom discourse that might be very useful in the type of communication it aspires in its teachers. This video approach might provide more insights into the classroom communication that is needed for implementing standards-based curriculum such as the IQWST.

It is important to understand that learning mediated through dialogue happens over time and should be studied over time (Mercer, 2008) with the goal of conceptualizing the interactive cognitive development and learning of the teacher. Administrators and researchers who are observing the implementation of science lessons from a sociocultural perspective should be intellectually empathetic as teachers struggle to move towards dialogic discourse because it takes time to develop proper language use. As well as being empathetic with the time needed to develop dialogic discourse, teachers who are willing and truly trying to implement dialogic discourse need to be supported, monitored in their use of this type of communicative approach, and not left to their own discretion during implementation. Follow up from colleagues, administrators, and researchers regarding how teachers are progressing over a specific time period should be consistent and a part of job-embedded professional development in order to ensure that teachers are implementing dialogic discourse where appropriate.

References

Aguiar, O. G., Mortimer, E. F., & Scott, P. (2010). Learning from and responding to students' questions: The authoritative and dialogic tension. *Journal of Research in Science Teaching, 47*(2), 174-193.

Alexander, R.J. (2004). *Towards dialogic teaching. Rethinking classroom talk (First edition).* York: Dialogos.

Barnes, D. (1976). *From communication to curriculum*. Harmondsworth: Penguin Educational.

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education, 94*(5), 765-793.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Ebenezer, J., Chacko, S., Kaya, O. N., Koya, S. K., & Ebenezer, D. L. (2010). The effects of common knowledge construction model sequence of lessons on science achievement and relational conceptual change. *Journal of Research in Science Teaching, 47*(1), 25-46.

Eshach, H. (2010). An analysis of conceptual flow patterns and structures in the physics classroom. *International Journal of Science Education, 32*(4), 451-477.

Hoon, S. L., & Hart, C. (2006). A cross-disciplinary analysis of science classroom discourse. In W. Bokhorst-Heng,M. Osborne and K. Lee (Eds.), *Redesigning pedagogies: Reflections on theory and praxis* (pp. 191-202). Netherlands: Sense Publishers.

Krajcik, J., Czerniak, C., & Berger, C. (2002). *Teaching science in elementary and middle school classrooms: A project based approach* (2nd edition). Boston, MA: McGraw-Hill.

Krajcik, J., Reiser, B. J., Fortus, D., & Sutherland, L. (2008). *Investigating and questioning our world through science and technology.* Ann Arbor, MI: Regents of the University of Michigan.

Krajcik, J. S., & Sutherland, L. M. (2010). Supporting students in developing literacy in science. *Science, 328*(5977), 456-459.

Lehesvuori, S., Viiri, J., Rasku-Puttonen, H., Moate, J., & Helaakoski, J. (2013). Visualizing communication structures in science classrooms: Tracing cumulatively in teacher-led whole class discussions. *Journal of Research in Science Teaching, 50*(8), 912-939.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. NJ: Ablex Publishing Corporation.

Lincoln, Y., & Guba, G. (1985). *Naturalistic inquiry (Vol. 75).* Beverly Hills: Sage.

McNeill, K. L., & Pimentel, D. S. (2010). Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation. *Science Education, 94*(2), 203-229.

Mehan, H. (1979). *Learning lessons: Social organization in the classroom.* Cambridge, MA: Harvard University Press.

Mercer, N. (2008). Talk and the development of reasoning and understanding. *Human development, 51*(1), 90-100.

Mercer, N. (2009). Developing argumentation: Lessons learned in the primary school. In *Argumentation and education* (pp. 177-194). US: Springer.

Mercer, N., Dawes, L., & Staarman, J. K. (2009). Dialogic teaching in the primary science classroom. *Language and Education, 23*(4), 353-369.

Mercer, N., & Howe, C. (2012). Explaining the dialogic processes of teaching and learning: The value and potential of sociocultural theory. *Learning, Culture and Social Interaction, 1*(1), 12-21.

Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms*. London: McGraw-Hill International.

National Research Council. (2012). *A framework for K-12 science education. Board on science education, division of behavioral and social sciences and education*. Washington, DC: National Academies Press.

Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching, 42*(3), 283-312.

Scott, P., & Ametller, J. (2007). Teaching science in a meaningful way: Striking a balance between ‘opening up' and ‘closing down' classroom talk. *School Science Review, 88*(324), 77.

Scott, P. H., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*(4), 605-631.

Shwartz, Y., Weizman, A., Fortus, D., Krajcik, J., & Reiser, B. (2008). The IQWST experience: Using coherence as a design principle for a middle school science curriculum. *The Elementary School Journal, 109*(2), 199-219.

Vygotsky, L. S. (1978). *Mind and society: The development of higher mental processes.* Cambridge, MA: Harvard University Press.

Wolf, M. K., Crosson, A. C., & Resnick, L. B. (2006). *Accountable talk in reading comprehension instruction*. CSE Technical Report 670. National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

TRAVERSING THE EPISTEMOLOGY OF PROBABILITY IN INDIAN MATHEMATICS TEXTBOOKS

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The purpose of this paper was to study the views adopted by Indian curriculum makers, regarding the nature of probability, as reflected through textbooks, and to reflect on the possibilities and challenges of including the epistemologies of probabilities in the school curriculum. To understand the notions and practices that have been associated with the epistemology of probability, NCERT Mathematics textbooks (written after The Kothari Commission, 1966) were examined, reviewed and analyzed in a historically-chronological manner. As predicted, the classical and the experimental interpretations of probability dominants the school mathematics curriculum and the subjective approach remains uncovered in school textbooks, even today.

INTRODUCTION

Every subject domain espouses several knowledges, but to understand the kind(s) of knowledge children gather, tacitly, a prima facie instrument to study is the textbooks. The decision of content selection, in-turn of knowledge, lies with curriculum makers and on the choice of textbook writers. Textbooks, thus, become agencies through which knowledge is transformed and constructed (Chevallard, 1988; Kang & Kilpatrick 1992, call this didactic transposition), and through which the envisioned goals and objectives of a curriculum are concretised (Ball & Cohen, 1996). Textbooks, particularly in mathematics, act as mediators through which the dispositions and intentions of curriculum framers, textbook writers and mathematicians are dispensed to the students.

Thus, if one needs to know how and what kind of understanding students form about the nature of a domain, Mesa (2004) emphasises on analyzing textbooks, stating that textbook-analysis could help in answering several questions (though hypothetical) related to the linkages between the intended curriculum envisaged by curriculum or policy makers and the attained curriculum that is actually learned by the students. Analyzing content helps one discover the authors' epistemological decisions while selecting a specific content -what has led to the legitimization of a preferred piece of knowledge (Apple, 1986); what would students learn, if they followed the text entirely (Mesa, 2004); how would students construct meaning from the text (Weinberg & Wiesner, 2011); and what notions would the students develop by reading the text alone (Kang & Kilpatrick, 1992).

This paper has been conceptualized to study the epistemologies adopted in Indian mathematics textbooks specific to the domain of probability.

The nature of defining and interpreting probability, as a mathematical construct, has undergone significant epistemological shifts. Since textbooks are the first, and sometimes, the only source of knowledge transmission, I was keen to study if our textbooks have kept pace with this evolving nature of probability. An attempt has been made to study which approaches of interpreting probability have found a place in the mathematics curriculum, and, further, to discuss their implications in promoting probabilistic thinking.

UNDERSTANDING PROBABLITY

As a broader framework, the two main approaches to define and understand probability include the Objective Approach and the Subjective Approach. The Objective Approach can be, further, subdivided into the Classical and Frequentists approach (Batanero, Henry & Parzysz, 2010; Konold, 1989; Prodromou, 2012).

Classical Approach of Defining Probability

For classicists (also referred to as theorists), probability emerged from the idea of proportionality and they state that the probability of happening or not happening of a 'favourable' event is dependent on a combination of all the outcomes that should be equi-probable. This notion is quite analogous to the part-whole relationship of a fraction. Consequently, to find the probability of an event, one needs to enumerate all the possible combinations and, then, consider the proportion between the desired event and all the enumerated possibilities. An inherent assumption of the classical approach is on equal likeliness of the events. Thus, in the classical approach, probability of an event is considered a priori.

Frequentists' View to Quantify Probability

The proponents of the frequentist (empiricist or experimental) probability regard the probability of a simple event through observations of the trend of relative frequencies, obtained from repeated trials. Based on Bernoulli's principle of the law of large numbers, the probability of an event is empirically (rather hypothetically) based on the principle of stabilization of frequencies, after a repetition of similar trials. Thus, for the frequentists, quantification of probability is embedded in the physical properties of the object or the randomiser. Therefore, since this observable randomness can be produced or stimulated, assigning frequentist probability to a single case event is, often, not easy.

From a pedagogical viewpoint, Fischbein (1975) elaborates experimental probability learning as being associated with: a) a specific experimental paradigm and b) a probability matching paradigm. Within the specific experimental paradigm, a person is presented with a succession of trials and, on each trial; one is required to predict the outcome before it occurs. For example, predict the chances of getting a black or a white ball before the draw is made. In the probability matching paradigm, a sequence (unknown to the participant), randomly determined by some process, with the probability of each outcome being fixed, is presented and the person is expected to approximate the probabilities of the respective outcome based on its relative frequencies. The core idea is to maximise the probability of success on every trial, hence, it is also termed as expected probability.

Subjectivists' Interpretation of Probability

The conception of probability being subjective emerged from Bayes' assumptions that considered probability of an event being based on observable consequences. According to the subjectivists, probability is an expression of personal beliefs or of perceptions related to an event. Since probability is an estimated value of a future event, its value will depend upon numerous factors, such as the observer's knowledge, conditions under which the observations were made and the models that were used to represent the situation (Batanero, Henry &

Parzysz, 2010). Probability, according to the subjectivists, cannot be deterministic. Rather, it would be subject to revisions, based on the availability and re-availability of information. Subjective probability opens opportunities to different descriptions of the same event and, thus, to different judgments. As Kyburg, 1974 (cited in Batanero et al, 2010, p. 24) explains, "randomness [for subjectivists], is no longer a physical objective property, but has a subjective character and probability does not measure a magnitude, such as length or weight, but only a degree of uncertainty, specific to each person".

A Comparison of the Three Interpretations

The main controversy between the subjectivists' viewpoint and that of the others, is in the embeddedness of the idea. According to the objectivists, probability can be assigned to an event that can be repeated, while for the subjectivists, probability is interpreted in the degree of belief, meaning, thereby, that the probability of an event is entrenched in the mind, rather than in the object that created randomness. For the subjectivists, probabilistic judgments are manifestations of personal judgments (Hawkins & Kapadia, 1984). For the frequentists, however, probability is embedded in the objects of randomness. There is, thus, an inherent reliance on the physical, mainly on symmetrical properties of the randomisers. Subjectivists can assign probability to a single, individual event, but, since frequentists calculate probability, as a limit towards which relative frequencies of an infinite class of similar events tend, their presumption rests on equal-likeliness of a class of events.

METHOD

This work has been organised by a series of broad questions: Which approaches of understanding probability have been espoused in the textbooks?, How have the NCERT textbooks presented the content of probability?, Have the textbooks done justice in representing the three views of probability?, Which approach(es) has(ve) been most dominant with curriculum makers?.

Taking off from where the textbooks emerged as a teaching resource in India, i.e. NCERT textbooks written after the first policy on school education of independent India, (The Kothari Commission, 1966), school mathematics textbooks published by NCERT were studied for content on probability. In order to know how, if at all, the notions of understanding probability have changed in these 50 years, the books were traversed in a historically-chronological way. Thus, I started to review the mathematics textbooks written after 1966 to the most recent ones.

In these, almost 50 years, there have been five phases of development and revision of textbooks: 1966-1975, 1975-1986, 1987-2000, 2000-2005 and 2005-current year. From each phase, one textbook, from each grade, was selected as a representative sample.

To understand the perspectives of probability, textbooks from all the five phases were studied on any chapter/section that was titled 'Probability', 'Chance' or 'Data'. In all such selected chapters/sections, all tasks (problems, exercises, text that preceded the exercises, including examples) were considered. For each task, the following four questions were answered: What is the main idea of the task? In order to attempt the task, what does the author expect the reader to do? Does the task reflect any particular approach? In solving the task, which approach is the most dominant? The responses to these questions helped in the conclusion of the larger question: Which notions of probability are most preferred by the curriculum framers or textbook writers.

During the analysis, it was found that the responses on a task, obtained from any of the four questions given above, overlapped with each other. Thus, the questions complemented each other in intent.

ANALYSIS

The first, so-called, textbooks in mathematics for the school level in India were produced under a detailed programme undertaken by the Central Committee on Education, set up by The National Council, in 1961. Subsequently, the textbooks were released in 1969. In this first phase (1969-75) of textbook development, the objective of teaching mathematics at the senior secondary classes (considered, then as Class X and Class XI) was to help students to acquire an understanding of the nature of mathematical definitions and of principles of mathematical proofs (foreword NCERT, 1969). In these textbooks, I was unable to find any chapter on either statistics or probability. Thus, one can conclude that in those years (1969-75), probability and statistics were not taught to school students.

Probability emerged in the senior secondary textbooks only in 1975. From 1975-86, NCERT had launched a combined series of five books for Classes XI and XII. Topics related to calculus, coordinate geometry, complex numbers and higher algebra were introduced as part of high school mathematics curriculum. In Part IV of this series, entitled 'Higher Algebra', there were two chapters on probability: ‘Chapter XXVII: Chance in Mathematics: An Introduction to Probability’ and ‘Chapter XXVIII: Random Variable and Probability distribution’. As is evident from their titles, the former chapter treated probability in an axiomatic way and the latter chapter provided an experimental approach of calculating probabilities. In the first chapter (Chapter XXVII, NCERT 1978), probability had been considered as a measure of chance, but the chapter did not provide any context or explanation of what chance and unpredictability are. The reader does not get to know the real meaning of fortuitousness. Big ideas, such as of mutually exclusive events, independent events and addition rules, were mentioned, but treated as priori constructs. The content was dominated by Kolmogorov’s axioms of probability. In the second chapter, (Chapter XXVIII, NCERT 1978) objects that can be used to generate randomness, such as coins, dies, playing cards and so on, have been extensively referred to. Ideas of discrete random variables and probability distributions were given in this chapter. Most of the tasks were based on the idea of pay offs or of winning that get established via experiments with games of chance. The concept of probability distribution, as patterns emerging from repeated experiments with devices of randomness (dice, cards, coins), find a mention. This chapter, though projected in the frequentists’ paradigm, fails to meet to its true nature. Examples and exercises reflect a static, dull vision, devoid of any actual stimulation or experimentation. By dividing the content in two separate chapters, it was evident that the text book writers had perceived the axiomatic nature and the experimental nature as being distinct and no cord could be established between the two approaches.

In the textbooks written in 1986-2000, the content of probability was squeezed in a single chapter of Class XII textbook. In its 15 sub-sections, the chapter covers all the major ideas, such as of random events, sample space, theorems of probability, conditional probability, random variables, probability distributions and binomial distribution. On analyzing the text, it was found that this chapter, too, professed a very theoretical, definitive and an algebraic way of dealing with probability.

Following the recommendations of the National Curriculum Framework for School Education-2000, the mathematics textbooks were revised again and adopted from 2000-2004. In this temporal phase, the curriculum makers felt that since, at the higher secondary stages (Classes XI and XII) mathematics is pursued as a subject of choice, and since the expectations from mathematics for science students would be different from those who take commerce, the mathematics course at higher secondary classes must be divided into compulsory and elective components. Thus, the textbooks for these grades were divided into three parts, A, B and C. The 'A+B' combination was offered to science students and the 'A+C' combination was offered to the commerce stream students. A chapter on Probability was included in the compulsory component i.e. Part-A of the Class XII (NCERT, 2003) textbook. In this 45 page chapter, topics related to random experiments and sample space, probability of an event, theorems of probability, random distributions and applications were mentioned. Akin to its predecessors, here, again, most of the content followed an axiomatic approach, with sporadic instances of use of experimentation and randomisers. In addition, many examples, problems and exercises were similar to those of yesteryears. The content of this phase was rather dull, disappointing and mostly repetitive.

In the mathematics textbooks, written after the National Curriculum Framework, 2005, probability, for the first time, finds a place in the middle school curriculum (Class VII, onwards). In the Class VII mathematics textbooks, a section titled ‘Chance and Probability’, in the chapter, ‘Data Handling’, hints of a dynamic outlook towards doing probability. Readers are expected to first make predictions, then conduct experiments with random generators and, finally, match the closeness of their prediction to their observations. The idea of quantifying prediction, as a pre-construct of an experiment, is established, thus introducing the learners to the idea of quantifying fortuitousness. “If you toss a coin, can you always correctly predict what you will get? Try tossing a coin and predicting the outcome each time…You will find that the observations show no clear pattern...it is a matter of chance that in a particular throw you get either of these [Head or Tail]”, (NCERT 2006a pg. 74). The chapter does not establish any a priori approach to probabilistic experiments and brings out the essence of doing probability, as based on unpredicted patterns. In Class VIII textbooks, the section on probability begins with a subjective approach, but soon turns to the old school of objectivism. Some of the examples have gone too far in assuming equal-likeliness of events. In one such task, weather predictions are being made based on the trend of yesteryears. Equal-likeliness has, thus, been assumed even on weather: “What could you say about the chance in terms of probability? Could it be one in 10 days during a rainy season? The probability that it rains is then 1/10. The probability that it does not rain = 9/10 … The use of probability is made in various cases in real life... Metrological department predicts the weather by observing trends from the data over the past many years”, (NCERT 2006b, pgs. 86-87). From Class IX onwards, probability enjoys the status of a separate, independent chapter. In the Class IX textbook, probability has been expressed as a measure, a ratio of frequencies (the authors call it a “statistical approach of probability”). In Class X, the theoretical approach emerges as a dominating feature and this continues to the higher classes. In Class XII, the idea of conditional probability, based on calculating the probability of occurrence of an event, followed by the occurrence of an already occurred event, has been presented, but the examples draw over non-real, artificial contexts. Here’s an example: “A doctor is to visit a patient. From the past experience, it is known that the probabilities that he will come by train, bus, scooter or by other means of transport are respectively 3/10, 1/5, 1/10 and 2/5. The probabilities that he will be late are 1/4, 1/3 and 1/12, if he comes by train, bus and scoter respectively, but if he comes by other means of transport, then he will not be late. When he arrives, he is late. What is the probability that he comes by train?" (NCERT 2006f, p. 554).

RESULTS

While analyzing the textbooks, it was evident that probability has been a neglected area in school mathematics for long. Such a conjecture can be made over two observations: first, a quick glance on the Tables of Content reveals that, in all these years, except after 2005, probability was mostly presented as the last chapter of the book. If sequencing of chapters has any significance, even subtly, in establishing the worthiness of a domain, then this feature is worth noting; second, till 2005, probability was taught only in the higher grades of schooling. One of the possible reasons for neglecting probability in junior classes can be attributed to the Piagetian influence on deciding the maturity level of children to acquire a particular concept. For long, developmental theories have restricted several mathematical concepts to be taught below a certain maturity level. It was felt that younger children have no notion of chance and, thus, probability should be introduced only after the onset of the formal operational stage, that is, in higher grades (Piaget & Inhelder, 1975). Though one is not sure if the Indian mathematics curriculum framers were also influenced by these theories, the absence of even the simplistic notions related to chance in the junior level textbooks, written before 2005, lead to such an inference. It is only after 2005, with the new vision of a school mathematics curriculum, that concepts related to probability are now being introduced in the middle school.

It has been noted, across textbooks, that the content of probability has remained dominated by classical interpretations, and only in very few instances has the experimental notion been introduced. Most of the concepts were stated in terms of a definitive relation between the total events and the ones to occur: "the number of desired outcomes divided by the number of possible outcomes." Only about 10% of the problems were stated in the experimental (frequency) approach.

Further, till 2005, there existed a stark divide between classical and experimental approaches. So much so, that in the textbooks of 1975-2000 these approaches have been treated in separate, independent sub-sections, if not as separate chapters. No linkages could be traced between the two aspects. It is only after 2005 that an attempt has been made, at least in the middle grade level, only at introductory stages, to link classicists and experimentalists.

REFLECTIONS AND SUGGESTIONS

Across the years, it has been found that the content of probability has been dominated by the axiomatic (theoretical) approach, as espoused by Kolmogorov, in the 20th century. The Axiomatic approach, though convenient for determining probability, is fraught with some limitations. To begin with, Kolmogorov's work, as one would expect, is very formal, precise and relatively complicated and hard to understand by non-mathematicians. The Axiomatic approach gives no clue to the real meaning of probability. Since, at the school level, students ought to be exposed to the fundamental meanings, being confined to only the theoretical aspects will present a rather narrow, insufficient way of looking at probability.

Simultaneously, it is imperative to comment on the fact that only talking about the experimental approach will also delimit the essence of probability. Probability is a study of fortuitousness of an event wherein we quantifying the chances of an event yet to happen. Contrary to this basic idea, empiricists, rather calculate probability on the premise of replicating events, on the assumption of an already existing pattern and then determine its uncertainty. In order to imbibe the experimental approach in textbooks, appropriate pedagogy has to be followed, such as making predictions, conducting experiments and, finally, matching the closeness of prediction to the outcomes.

Often, probability is neither objective nor open to a frequency interpretation. The third approach, i.e. the subjective approach, which counts on intuitive conceptions has not found its due place in the textbooks. It must be acknowledged that the first conception that many children form of any uncertain situation, comes from their informal subjective experiences. When teaching probability, some account should be made of informal, nascent perceptions that children hold regarding chance and uncertainty. Since subjective probability relies on a comparison of perceived likelihood, it can be used to induct not -so -mathematically-sophisticated children or primary children to the idea of guessing fortuitousness. Moreover, to teach objective probability, some acquaintance with fractions is required, but children who are not-so-good with fractions or those at the earlier stages of schooling can be helped by encouraging them to present their intuitive or subjective views about chance and probability. The subjective ideas can, thus, be encouraged at the primary level. They can even be taken as precursors, before quantifying, to help initiate meaningful communication in an otherwise dull, calculation dominated probability class (Hawkins & Kapadia, 1984; Borovcnik & Kapadia, 2009).

Thus, to encourage probabilistic thinking, the content should be presented in a blended mode, deriving from the strengths of each interpretation of probability. Teaching probability at the school level should present enough intellectual excitement and scope for students to express their intuitions (subjectivity), weigh evidences (empirically), make meaningful quantifications based on strong arguments and, finally, establish a relationship between their judgments and computation.

References

Apple, M. (1986). The politics of official knowledge: Does a national curriculum make sense? *Teachers College Record, 95*(2), 222- 241.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is-or might be-the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, *25*(9), 6-8, 14.

Batanero, C., Henry, M., & Parzysz, B. (2010). The nature of chance and probability. In Graham, A. Jones (Eds.), *Exploring probability in school. Challenges for teaching and learning* (pp. 15-37). NY: Springer.

Borovcnik, M., & Kapadia, R. (2009). Research and developments in probability education. Special issue on Research and Developments in Probability Education. *International Electronic Journal of Mathematics Education*, *4*(3). Retrieved from http://wwwg.uni-klu.ac.at/stochastik.schule/IEJMEFINALIEJMEFINAL/IEJMEp00introdE.pdf.

Chevallard, Y. (1988). On didactic transposition theory: Some introductory notes. Paper presented at the *International Symposium on Research and Development in Mathematics Education*, Bratislava, Czechoslavakia.

Fischbein, E. (1975). *The intuitive sources of probabilistic thinking in children*. Dordrecht, The Nehtherland: Reidel.

Hawkins, A., & Kapadia, R. (1984). Children's conceptions of probability: A psychological and pedagogical review. *Educational Studies in Mathematics*, *15*(4), 349-377.

Kang, W., & Kilpatrick, J. (1992). Didactic transposition in mathematics textbooks. *For the Learning of Mathematics*, *12*(1), 2-7.

Konold, C. (1989). Informal conceptions of probability. *Cognition and Instruction, 6,* 59-98.

Kyburg, H. E. (1974). *The logical foundations of statistical inference*. Boston: Reidel.

Mesa, V. (2004). Characterizing practices associated with functions in middle school textbooks: an empirical approach. *Educational Studies in Mathematics, 56*, 255-286.

National Council of Educational Research and Training (1969). *A textbook of Mathematics. Class XI*. New Delhi: NCERT.

National Council of Educational Research and Training (1978). *A textbook of Mathematics for Classes XI-XII. Book IV*. New Delhi: NCERT.

National Council of Educational Research and Training (1988). *Mathematics. A textbook for Class XII. Part II.* New Delhi: NCERT.

National Council of Educational Research and Training (2003). *Mathematics. A textbook for Class XII.* New Delhi: NCERT.

National Council of Educational Research and Training (2006a). *Mathematics. A textbook for Class VII*. New Delhi: NCERT.

National Council of Educational Research and Training (2006b). *Mathematics. A textbook for Class VIII*. New Delhi: NCERT.

National Council of Educational Research and Training (2006c). *Mathematics. A textbook for Class IX*. New Delhi: NCERT.

National Council of Educational Research and Training (2006d). *Mathematics. A textbook for Class X*. New Delhi: NCERT

National Council of Educational Research and Training (2006e). *Mathematics. A textbook for Class XI*. New Delhi: NCERT

National Council of Educational Research and Training (2006f). *Mathematics. A textbook for Class XII.* New Delhi: NCERT.

Piaget, J., & Inhelder, B. (1975). *The origin of chance in children*. (L. Leake. P.; Burrell and H. D. Fischbein, Trans., Original work published in 1951). New York: Norton.

Prodromou, T. (2012). Connecting experimental probability and theoretical probability. *ZDM Mathematics Education*, *44,* 855-868.

Weinberg, A., & Wiesner, E. (2011). Understanding mathematics textbooks through reader-oriented theory. *Educational Studies in Mathematics. 76,* 49-63.

IMPROVING THE PERFORMANCE OF PHYSICAL SCIENCE LEARNERS: A CASE STUDY AT MANDLETHU SCHOOL, MPUMALANGA PROVINCE, SOUTH AFRICA

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Learner performance in science subjects, especially Physical Science, is cause for concern in South Africa, since learners perform poorly in both internal and external examinations and assessment tests. Various research projects have identified the reasons for poor performance. This paper, which is based on quantitative data collected from Physical Science learners and a Physical Science, reports on ways to improve the performance of learners in Physical Science at secondary schools in the Mpumalanga Province of South Africa. Grades ten, eleven and twelve learners, as well as the Physical Science teacher, were interviewed to ascertain the causes of poor performance. The main reasons cited by learners for poor performance was that they experienced difficulty in grasping basic science concepts that were taught in primary school and answering questions in the examination. Learners also experience difficulty in expressing themselves in English. Recommendations are made that will assist both teachers and learners to overcome these issues, in order to improve performance of learners in Physical Science.

Keywords: learner performance, basic concepts, language.

INTRODUCTION

Since the end of apartheid, South Africa has been working to improve the quality of its mathematics and science education. However, international comparisons show that South African students rank at the bottom of the countries included in the Trends in International Mathematics and Science Study (TIMSS). There is evidence of very low-performing ninth grade students in South Africa in Natural Sciences, with the percentage of students with achievement too low for estimation between 15 percent and 25 percent (TIMSS 2011 International Science Results). This is cause for concern; hence this study examines the causes of poor performance in Physical Science, in order to device ways of improving performance.

LITERATURE REVIEW

According to National Senior Certificate examination technical report (2012, 45-61), 511152 candidates wrote the National Senior Certificate examination in 2012, 377829 passed the examination with a National percentage of 73.9 %. The percentage of Grade 12 learners who qualified for Bachelor's studies nationally is 26.6% in 2012. The number of learners who wrote Physical Science in 2012 is 179194. 109918 passed with a National percentage of 61.3%. Despite a recent increase, there are schools that do not produce quality and high numbers of learners who pass Physical Science.

In South African schools the subject Physical Science at grades 10, 11 and 12 covers both Physics and Chemistry topics. Six study units or knowledge areas are covered by the curriculum. These study units/knowledge areas are: Matter and Materials, Chemical

Systems, Chemical Change, Mechanics, Waves, Sound and Light and Electricity and Magnetism.

Research indicates that there are factors that cause poor performance of learners at high school across all subjects (Lemmer, 2000, p. 81). The key causes of poor performance in any subject are: lack of facilities and material resources, high educator and administrator turnover, teacher's workload, shortage of qualified educators, poor teaching methods, inadequate communication ability of learners and educators in the language of instruction, unmotivated educators and a tendency to place the greatest demand on educator's time and energies in terms of discipline, lesson planning, unproductive paper work and time management. Researchers agree that the factors associated with poor performance of learners in science in South Africa are the following: inadequate communication ability of learners and educators in language of instruction, large classes, lack of qualified science educators, poor teaching methods, inadequate educator knowledge, poor time management, lack of material resources (e.g. textbooks, scientific calculators and laboratory equipment), disruption in class, content coverage and lack of professional leadership. Mji and Makgato (2006, pp. 253-264) and Howe (2003, pp. 1-13) discuss the issue of knowledge and skills particularly in science and emphasizes the fact that many South African science educators have little content knowledge of how to teach science. In many schools worldwide science education is practiced in a traditional age-old manner, that is, dictative, and authoritarian which has eliminated all forms of imagination. According to Christensen et al., (1995), when this form of teaching approach was used in American schools, critical analysis of the results of learners indicated clearly that this system had failed. Thus, for the transformation of science learning, Christensen et al., (1995) points out there must be change in the strategies and methods used in the classroom.

In their criticism on how science is taught in the classroom, Driel, Beijaard and Verloop (2000) argue that teachers usually present science as a rigid body of facts, rules to be memorized and practiced by students and theories which they regard as absolute. Constructivists believe that emphasis should be on designing activities which provide active knowledge, instead of traditional knowledge transmission. Teachers are encouraged to investigate students' knowledge. In order to assign appropriate methods for teaching science, learners' misconceptions need to be identified (Kennedy, 1998). Constructivist theorists hold the view that teachers should deal not only with learners having high abilities or high motivation for science, but they should also look at the learners' cognitive and affective dimensions. By giving attention also to these dimensions, teachers will be shifting towards inquiry skills (Driel, Beijaard & Verloop, 2001).

In general, constructivism puts emphasis on the ways that people create meaning of the world through a series of individual constructs (de Jong, 2005). The constructivist teaching and learning models require learning that is hands-on, whereby students are actively involved in the learning process allowing them to build a better understanding; minds-on, allowing for learners to develop their cognitive processes, and encourage them to question validity of the situation; and authentic, presenting learners with real-life problems that they may be faced with, in order to develop them to take a critical look in order to obtain the best possible solution (Christensen et al., 1995).

Concerning the language of science, South Africa is a multilingual country with 11 official languages. In her study to determine the factors that influence poor performance in mathematics and science, Howe (2003, p. 8) discovered that native English speakers performed best in mathematics and science of all language groups while the Afrikaans speaking attained the next highest score. Science educators must consider number of issues including their teaching approaches, and techniques, interpersonal interactions to ensure the effectiveness of science teaching, so that they motivate their learners towards acquiring necessary scientific skills, scientific knowledge, values and attitudes and provide high quality of science education for all learners (Lemmer et al., 2006, p. 11).

Problem Statement

The overall performance of the Mandlethu FET School has been poor for a long time, and the performance of science subjects is below expectations. The average pass rate for science subjects has been below 35% for the past three years. Lack of adequate resources for teaching and learning of science subjects has been reported to contribute to low pass rate in rural schools of South Africa by other scholars. However, the ability of SGB and school management has an impact on the school performance as well. It is unknown whether the SGB and school management at Mandlethu FET School are capable of supporting the teaching and learning of science subjects at the school.

The Aim of the Study

The aim of the study was to build the capacity of science teaching and learning at the Mandlethu FET School in order to improve pass rates of science subjects, so that learners ca n qualify for admission to tertiary institutions which may address science skills shortage in South Africa.

The Objective of the Study

The objective of the study was to ascertain what the causes of poor performance in Physical Science are, in order to design an intervention programme so that performance of learners can be improved.

RESEARCH METHODOLOGY

Research Design

The study was conducted in the form of a case study at Mandlethu FET School. A mixed method research design was employed whereby, qualitative and quantitative data wa s collected. The case study was selected in order to create a baseline for schools in Nkangala District Municipality of Mpumalanga Province.

The Study Area

The study was conducted at Mandlethu FET School in Vlaglaagte Location 1 in Empumalanga, Mpumalanga province in South Africa. The school has about 253 learners; 9 educators; 1 admin clerk, 2 general assistants and 2 kitchen helpers as of 2012. It is located in a township about ± 76 km northeast of Pretoria. The township has about 300 000 inhabitants, the majority of whom are the Ndebele people.

Sampling

A survey was conducted at Mandlethu FET School, in Mpulanga Province in South Africa Nine (out of 48) Physical Science learners (3 from each of grades 10, 11 and 12) were purposive sampled and face-to-face interviews were conducted using a structured questionnaire. From each grade a poor performing student, an average performing student and a student who performed well were chosen to be interviewed. Appointments were made with the participants prior to the interviews. The interviews were conducted at the school boardroom. Two people were involved in interviewing each respondent where, one person was the interviewer and the other person was the scribe. In order to gain further insight into poor learner performance in Physical Science at the school, the teacher was also interviewed. (there is only 1 Physical Science teacher at the school)

DATA ANALYSIS

Audio recorders were also used to assist scribes to capture the proceedings. The recordings were transcribed and analyzed by coding and memoing (Babbie, 2010). The analytical procedures for qualitative data included seven (7) phases: (a) data organization; (b) data immersion; (c) generating categories and themes; (d) data coding; (e) offering interpretations through analytic memos; (f) searching for alternative understanding; and (g) writing of the report (Marshall & Rossman, 2011).

FINDINGS AND DISCUSSION

Learner Perspectives

Data indicated that the learners in the sample had chosen Physical Science as a subject because it is a requirement for the choice of career that they want to pursue. They experience difficulty in the following areas of the chemistry curriculum:

1. Defining terms
2. Chemical reactions
3. Electron configuration
4. Organic chemistry
5. Writing formulae
6. Experiments in Physical Science

Most of the areas of difficulty relate to the chemistry topics of the curriculum. With the exception of organic chemistry the areas of difficulty are elementary chemical concepts which form part of the Intermediate and Senior phase Natural Science Curriculum. Learner s need to have a clear grasp of these basic concepts before they can learn and understand the more complicated aspects of the secondary school Physical Science curriculum. Since learners have difficulty in grasping elementary concepts, it seems that the problem emanates from inadequate teaching and learning of Natural Science in the above mentioned phases. In order to overcome these difficulties the teaching and learning of science in the primary school needs to be investigated and researched, however, in order to assist learners in the present focus group, the above mentioned topics need to be reviewed and revised. The areas of the physics curriculum that they experience difficulty are:

1. Difficult terminologies
2. Mechanics
3. Momentum
4. Electricity
5. Force
6. Calculations

In most of the above areas the basics are covered in the Natural Science curriculum in the primary school and the comments made for how to address the problem for the chemistry aspects of the curriculum apply. An in-depth review of basic concepts in science needs to be undertaken in order to assist the learners come to grips with secondary school science curriculum.

The type of questions that pose problems for learners are explaining terms, one word answers, multiple choice questions, matching and calculations. A possible way of overcoming these issues would be for the teacher to use previous exam questions as guided class-work exercises. Learners need ample exposure to answering these types of questions in order to master the technique of answering them. Students need to be exposed to and guided in answering multiple choice questions, in particular, as early and as frequently as possible as the grade 12 examination in Physical Science always has multiple choice questions.

Since most of these learners are Ndebele speaking, language issues are also cited as a problem that they experience in their learning and understanding of Physical Science. In order to address the language issue in science the teacher should use the following strategies:

1. Develop a science terminology dictionary
2. Write all new terms encountered in a lesson together with their meanings on the board and ask learners to copy them into the terminology dictionary. Students must learn these terms and their meanings. Set aside time to test them orally or in writing as often as necessary.
3. Start the dictionary in grade 10 and continue with the same dictionary until grade 12.
4. Code switching should be avoided so that learners become familiar with the use of English as the medium of instruction in the physical science class.

This will develop not only their science language ability but also their conceptual understanding of science.

In order to improve their performance in physical science learners engage in self/ individual study, summarizing the text book on their own, practicing calculations and trying to answer previous examination question papers. There is a suggestion that group studies should be introduced with mentors to assist in their studies. This avenue should be explored by the researchers in conjunction with the subject teacher and school management.

Much can be achieved in improving performance if this suggestion is put into practice. Mentors need to be identified and trained. Group study activities can be extended to include other schools in the area.

Although learners should be encouraged to read and summarized their textbooks, this can often be time consuming and exhausting for grade 12 students. Summaries of lessons taught should ideally be provided by the teacher so that learners can spend time on more meaningful study activities such as answering application exercises and previous examination papers. External examinations (conducted in grade 12) and internal assessment tasks (for all grades) include questions on different ability levels according to the requirements of the South African curriculum for Physical Science. Learners make no mention of the use of a personal home study time table or roster to study. The school needs to encourage learners to develop a study time table and use it to guide them in their studies at home, over the weekends and during the school holidays. This will help learners in becoming organized regarding their studies and will teach them time management skills. Time management skills are not only need for study purposes but will also assist learners in the examinations as well as in their personal lives.

Educator Perspectives

Educator's perspectives of issues needing attention in the teaching and learning of Physical Science

1. Challenges in teaching of Physical Science
    - Lack of methodology of teaching Physical Science subject.
    - Scientific language barrier: Physical Science language cannot be translated into IsiNdebele for learners.
    - Lack of assessment tools (there is no bank of questions).
2. Support required improving teaching
    - Help with teaching of learners
    - Assistance with practical investigations.
    - Interpretation of practical concepts. d. Motivation of learners
3. General comments by the teachers that need to be attended to
    - Learners cannot cope with English language.
    - Learners cannot define fractions, electricity etc.
    - Majority of learners come from very poor family background. They are not exposed to so many things such as new technology.
    - Majority of learners did not have proper career guidance to choose the right subjects.

RECOMMENDATIONS

Students and the teacher need to be provided with assistance on the topics that are mentioned in this article. The teacher needs guidance and support in improving his pedagogic content knowledge. Guidance needs to be provided to both teacher and learners in the area of assessment. For the learners, they need to be exposed to a variety of types of questions and how to answer them. The teacher needs guidance on setting of balanced assessment tasks. Basic science concepts and terminology needs to be reviewed.

CONCLUSION

Improving learner performance in Physical Science requires that attention be given to basic science concepts that are taught in the primary school and that learners are exposed to being taught Science in the medium of English.

References

Babbie, E. R. (2010). *Introduction to social research.* Belmont, CA : Wadsworth Cengage learning.

Christensen, C. A., Massey, D. R., Isaacs, P. J., & Synott, J. (1995). Beginning teacher education: Students' conceptions of teaching and approaches to learning. *Australian Journal of Teacher Education, 20*(1), 19-29.

de Jong, T. (2005). The guided discovery principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 215–229). Cambridge, UK: Cambridge University Press.

Department of Basic Education. (2012*). National senior certificate examination technical report*. Pretoria: Government Printer.

Department of Basic Education. (2001). *National strategy for mathematics, science and technology education in general and further education and training.* Pretoria: Government Printer.

Driel, J. H., Beijard, D., & Verloop. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38*(2), 137-158.

Howe, S. J. (2003). Language and other background factors affecting secondary pupils' performance in Mathematics in South Africa. *African Journal of Research in SMT Education, 7,* 1-20

International Association for the Evaluation of Educational Achievement. (2011). TIMSS International results in science. TIMSS and PIRLS International study center. Retrieved from http://timssandpirls.bc.edu

Kennedy, M. M. (1998). Education reform and subject matter knowledge*. Journal of Research in Science Teaching, 35*, 249-263.

Lemmer, E. (Ed.). (2000). *Contemporary education: Global issues and trends.* Sandton: Heinemann Higher and Further Education (Pty) Ltd.

Lemmer, E. M., Meier, C., & Van Wyk, N. (2006). *Multicultural education: An educator's manual*. Pretoria: Van Schaik Publishers.

Marshall, C., & Rossman, G. B. (2011). *Designing qualitative research (Fifth Edition).* Thousand Oaks, CA: Sage Publications.

Mji, A., & Makgato, M. (2006). Factors associated with high school learner's poor performance: A spotlight on mathematics and physical science. *South African Journal of Education, 26*(2), 253 – 266.

South Africa, Department of Education. (2002). *Revised national curriculum statement grades10 - 12 (Schools) policy: Physical science.* Pretoria: Department of Education.

EFFECT OF BLENDED LEARNING STRATEGY ON LEARNING SCIENCE AMONG SECONDARY SCHOOL STUDENTS

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The shift in emphasis from science as a body of knowledge to science as a process of inquiry revolutionized the idea of how students learn science. It is quite accepted that there is a need for tapping the wide applicability of online learning combined with Face-to-Face instruction for enhancing science learning. Blended learning is a pedagogical strategy which skilfully integrates online learning techniques such as online delivery of materials through web pages, discussion boards and email and Face-to-Face instruction. The present research is an attempt to study the effect of blended learning strategy on science process skills and science achievement a4t secondary level. The study was of quasi-experimental in nature and pre-test – post-test non-randomized control group design was employed. The experimental group of ninth standard students was taught six chapters of science using the blended learning strategy whereas the control group was taught the science chapters by the regular teacher using the conventional teaching method. The study revealed that blended learning is more effective than conventional method in enhancing science process skills and science achievement among secondary school students. It implies a greater scope for adopting blended learning strategy to optimise science learning at secondary level.

INTRODUCTION

The construction of deep scientific knowledge results from actively practicing science in a structured learning environment. The shift in emphasis from science as body of knowledge to science as a process revolutionized the idea of how students learn science. The claim that science is a uniquely objective area of human intellectual endeavour is being critiqued and the proposition of learning science within social and personal context started gaining momentum in the academic world. As a result, science teachers are pressurized to provide variety of experiences to learners, which are consistent with nature of science. As well as becoming scientifically literate, today's students must be equipped with process skills that will enable them to observe keenly, successfully communicate, reflect objectively and analyse logically However, many of the teachers find it difficult to perceive science as a process of exploring and in effect, too often, science learning is narrowed down into usual routinized mastery of conventional explanations and techniques of established science. The old pedagogy was criticized for presenting content in lecture format to be memorized. Our school pedagogic practices, learning tasks and the texts we create for learners tend to focus on receptive feature of children (NCERT, 2005). Science teaching becomes all the more challenging in the case of integrating technological tools and techniques into process of learning. In this context, blended learning has its relevance in enriching the quality of learning science by tapping the wide potentialities of providing more flexible ways of learning through online mode and the richness of the 'social presence' in the classroom. Along these lines, Dziuban, Hartman and Moskal (2004) in a research brief noted that blended learning should be viewed as a pedagogical approach that combines the effectiveness and socialization opportunities of the classroom with the technologically enhanced active learning possibilities of the online environment. This view is supported by iNACOL, the International Association for K-12 Online learning which defines blended learning as combining online delivery of educational content with the best features of classroom interaction and live instruction to personalize learning, allow thoughtful reflection, and differentiated instruction from student-to-student across a diverse group of learners. We can consider blended learning as an educational formation that integrates online learning techniques including online delivery of materials through web pages, discussion boards and/or email with traditional teaching method. It has also wide scope for extending immense opportunity for children to ask questions, describe objects and events, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others and all of these are critical elements of learning science. Providing several online options in addition to traditional classroom training actually increased what students learned (Graham & Allen, 2005). One of the most specific advantages is the opportunity to quickly establish a sense of community amongst student learners (Garrison & Kanuka, 2004). Within the blended learning classroom, students meet in face-to- face instruction, and then have opportunities to collaborate, communicate with the open dialogue, to experience critical debate through a world-wide open platform which in turn facilitates greater reflection on the part of learners. Therefore, it has wide scope for development of autonomy, self-efficacy and individual organizational skills. While there is substantial blended learning literature on the student experience, course design, and even the professional development of teachers, the most neglected research area is teaching practice: how and why teachers balance the blend of online and classroom components (Torrisi-Steel & Drew, 2013). The researches available were mainly focused at higher education settings and very few researches available on design of blended learning strategy in improving science learning at secondary level. Review reveals that many times, the term 'blended learning' term was loosely used and is a contested concept without having unanimous understanding about various components of it. Considering the criticality of designing blended learning strategy and finding its effect on enhancing learning science including science process skills and science achievement at secondary school level, the present study was planned.

OBJECTIVES

To find the effect of blended learning strategy on secondary school students'

1. Science Process Skills
2. Science Achievement

RESEARCH HYPOTHESES

1. Blended learning Strategy is effective in enhancing Science process skills among secondary school students
2. Blended learning Strategy is effective in enhancing Science achievement among secondary school students

SAMPLING

Purposive Sampling technique was employed in selecting the schools. Two CBSE schools were selected from Bangalore city for the study, one of them having the provision of online learning platform 'thinkquest.org' by Oracle Education Initiatives. BGS National Public School was selected for the Experimental Intervention. The intact group of 38 Ninth standard students of the school was regarded as the experimental group. The intact group of 36 Ninth standard students of Jyoti Kendriya Vidyalaya, Bangalore was selected as the control group since it is not enrolled in www.thinkquest.org. This ensured that the control group students' access to learning materials through the online platform was completely controlled since the control group students do not have access to that website either in the school or outside the school.

RESEARCH DESIGN

The study is of **quasi-experimental** in nature wherein a pretest-posttest non-equivalent groups design was employed. Pre tests were conducted to both the experimental and control groups to assess Science Process Skill and Science Achievement. The experimental group was taught six chapters of Science using the Blended Learning Strategy whereas the control group was taught the Science chapters by the regular teacher using the conventional teaching method. Then post tests were conducted to both the groups.

TOOLS

A Science Process Skill test and Science Achievement test were developed and validated by the investigator and the reliability coefficient (Cronbach's alpha) for the tests were found to be 0.86 and 0.87 respectively. An interview schedule was prepared to understand the difficulties face by students while learning through blended learning strategy.

BLENDED LEARNING AS A PEDAGOGICAL STRATEGY

The current research adopted blended learning continuum proposed by Eduviews (2009) which ranges from 'classroom instruction which includes online resources with limited or no requirements to be online' to 'fully online curriculum with options for Face-to-Face instruction'. The present piece of research adopted Model 4 wherein the Science classroom instruction is blended with substantial required online elements extending beyond the school day. With the growth of blended learning, pedagogy of blended learning also is evolving. The blended learning models are so flexible and adaptive so teachers can create instructional activities that give students the opportunities to work collaboratively, tapping their interests and abilities in social learning (Eduviews, 2009). A blended learning design suggested by Huang and Zhou (2005) was adapted for the present study. The procedure of designing blended learning strategy consists mainly of three stages:

1. Pre-Analysis
2. Activity and Resource Design
3. Instructional assessment

1. Pre-Analysis: Several observations and analyses were conducted in order to ascertain whether blended learning strategy could be used, and if so, to what extent online learning could be blended with face-to-face instruction. It includes analysis of the science curriculum, environmental features of the school and students' characteristics. The purpose of this task was to lay a sound foundation for organization of learning activities. Based on these analyses, an analysis report was prepared.

2. Activity and Resource Design Stage: The unique feature of blended learning design is that it focuses on which activities and resources are appropriate for the online learning contexts and which activities are appropriate for the classroom contexts. The content analysis of 6 units of 9th standard Science was carried out by specifying various concepts, meaning of those concepts, explanation with examples, and law/theorem. After analyzing the content, different resources and tools for transacting those concepts were identified and selected and a comprehensive picture of the strategy was worked out. The teaching-learning materials like write-ups and videos to be uploaded on the www.thinkquest.org web site, thought provoking questions to be asked to the students through message board and the demonstration/experiments to be carried out during the face-to-face instruction were designed. In addition to this, project descriptions to be uploaded on the online project page and the criteria for the evaluation of the project were also prepared.

Instructional Assessment Stage: The final step in the design of blended learning strategy is the instructional assessment. Instructional assessment is based on the instructional objectives and the activities carried out. It is mainly the assessment of students' worksheet, work done online by analyzing the articles published in students' web page, their online interaction with others, examination of content knowledge through tests, participation and interaction during face-to-face sessions etc.

EXPERIMENTAL INTERVENTION

The intervention was carried out for 69 Periods of 45 minutes each extending about 20 weeks. The experimental group was taught the six units of Science (Matter in Our Surroundings, Is Matter Around Us Pure, Force and Laws of Motion, Gravitation, Why Do We Fall Ill?, Natural Resources) using blended learning strategy. F2F instruction included lecturing, discussion, demonstration and experiment and Power point presentation. Out of the 69 periods of transaction, 20 periods were allotted for online learning.

Online learning was facilitated using a web based learning platform such as'thinkquest.org. A web page was created by the researcher in 'www.thinkquest.org', through which online activities were undertaken. Various write ups on topics like gravitation, natural resources, matter etc were uploaded as the content progressed in the Face-to-face instruction. The PowerPoint presentations used in the classroom and other relevant video clips were also uploaded using the provision 'upload'. Meanwhile, lecturing, demonstrations and experiments were undertaken in the classroom as the content demanded. The discussion in the classroom was continued in the discussion forum using message board and visa-versa. Online threaded discussions on various curricular issues were conducted. Students were asked to publish various write-ups on their own web page by referring the various websites prescribed by the researcher and referring online library materials available in the website. Students were also instructed to watch the video uploaded in researcher's web page and critical review of the video was posted by students. Further discussion on the topics was continued during the face-to-face instruction. Students interacted with other members of the online platform, which included both teachers from their own school as well as students and teachers of different schools and countries by using the facilities such as message, ask me, list, vote etc. The feedbacks and varied perspectives students gained online were further expanded upon by the researcher during face-to-face sessions.

For an example, students were asked to go through the web links provided on the researcher's web page on Buoyancy and Archimedes Principle and further discussion was carried out in the classroom by elaborating students' ideas. Students performed experiments in groups to get hands on experience on Archimedes' Principle. The applications of Archimedes' Principle were again discussed in the classroom and video of experiment on Archimedes' Principle was uploaded on the web page of the researcher. The video provided through the online learning platform helped the students to revise the procedure of the experiment and thus helped in reinforcing the learning. In addition, students interacted with the researcher on various issues in buoyancy online to get more clarity. Based on the guidelines provided by the researcher, students created their own web pages and published write ups on various topics. For example, after being given explanation on 'gravitation' during face-to-face instruction, students were asked to go through the web page created by the researcher and were asked to prepare their own write ups on gravitation. Necessary feedback was provided to the students by the researcher and the discussion on the topics continued during the face-to-face instruction.

The researcher interacted with the students by making use of the provision 'message board' by asking some questions to answer or encouraging students to comment on various issues put forwarded through the web page. An online project also was conducted by students on 'Pollution' and criticality of the project was in data collection by interacting people from the locality to identify the immediate concern and through online interaction with students and teachers of other countries to understand the global significance of 'pollution'. A skit was followed and the video of it was uploaded for a larger reach. As exemplars, a few snapshots are presented below.

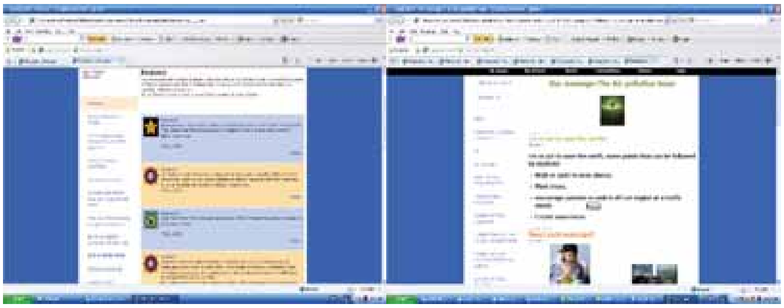

Figure 1: Snapshots of the online project

Conventional Method of Teaching in Control Group

In the control group, any kind of online learning was absent. The topics were being taught through demonstration and lecturing, followed by responses from students. The interaction with the teacher and among students was limited. A few experiments were conducted in an isolated manner in the lab and they were not a continuation of the lectures/discussions held in the class.

After the intervention, post- tests were conducted to both the experimental and control groups. The obtained data was analyzed using ANCOVA and the details are given below.

ANALYSIS AND FINDINGS OF THE STUDY

I. Effect of Blended learning Strategy on Science Process Skills

The following null hypothesis was formulated to find the effect of blended learning strategy on science process skills among secondary school students.

H_{01}: There is no significant difference between experimental group and control group in adjusted mean science process skill scores when their *pre-science process skill* is taken as a covariate.

The adjusted mean post test scores of science process skills of the experimental and control group when the mean pre-test scores of science process skill is adjusted to 17.27 are tabulated as below.

Group	N*	Adjusted Mean Scores of Science Process Skills	
		Pretest	Posttest
Experimental Group	38	17.27	23.32
Control Group	36		20.50

* 'N' denotes the number of students who appeared for both pre-test and post-test on science process skills.

Table 1: Comparison of adjusted mean scores of science process skills between experimental group and control group

To test the statistical significance of the mean scores, 2X2 ANCOVA was administered on the post test scores, taking pre-science process skills as covariate. The result is presented in the following table.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Groups	236.949	1	236.949	17.213	.000
Error	977.373	71	13.766		
Total	37110.000	74			

Table 2: ANCOVA result of science process skills of experimental group and control group with pre-science process skills as covariate

The above table reveals that the difference in the adjusted mean post test scores in science process skills of the experimental group and the control group is significant as $F=17.213$ and $p<0.01$. This indicates that blended learning strategy is more effective compared to the conventional method of teaching in developing science process skills. The result is in agreement with that of Bayrak and Bayram (2009) that web based instruction which considers student centred collaborative learning environment enhances science process skills better, compared to traditional teaching. The result of the study is also in tune with the result obtained by Tan, Yeo and Lim (2005) that computer supported collaborative learning enhances science process skills of secondary school students. In addition, the finding is in congruence with that of Saat (2004) that web based learning environment helps students to acquire science process skills. This result is in agreement with that of the finding of Ferreira (2004) that multi sensorial activities and dialogue help children to develop science process skills. Hence one possible reason for the positive effect of blended learning might be the flexible classroom dynamics and learner centeredness with greater engagement by students. Students were provided with such learning experiences that actually triggered students to 'do science'. In addition to this, various multisensory activities such as demonstration, computer assisted instruction, experimentation, videos and simulations uploaded online and the online projects gave students opportunities to observe, classify, compare and infer. The different modes of activities which were sequenced appropriate to the content gave students opportunities to explore more about nature and resulted in the development of science process skills.

II. Effect of Blended Learning Strategy on Science Achievement

The following null hypothesis was formulated to find the effect of blended learning strategy on science achievement among secondary school students.

H_{02}: There is no significant difference between experimental group and control group in adjusted mean science achievement scores when their *pre-science achievement* is taken as a covariate

The adjusted mean post test scores of science achievement of the experimental group and control group when the mean pre - test scores of science achievement is adjusted to 27.55 are tabulated as below.

Group	N*	Adjusted Mean Scores of Science Achievement	
		Pre test	Post test
Experimental Group	35	27.55	38.12
Control Group	36		33.80

* 'N' denotes the number of students who appeared for both pre-test and post-test of science achievement.

Table 2: Comparison of adjusted mean scores of science achievement between experimental group and control group

To test the statistical significance of the mean scores, 2X2 ANCOVA was performed on the post test scores, taking pre-science achievement as covariate. The result is presented in the following table.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Groups	328.296	1	328.296	16.632	.000
Error	1342.225	68	19.739		
Total	95081.000	71			

Table 3: ANCOVA result of science achievement of experimental group and control group with pre-science process skills as covariate

Analysis of the data showed that the experimental group which was exposed to blended learning strategy showed significant improvement in achievement in science compared to the control group which was taught through the conventional method. The result is indicated by the F value ($F=16.632$ and $p<0.01$). The result of the study is in tune with the result obtained by Moodley (2004) who studied the effects of computer-based dynamic visualization simulations on student learning in high school science and found that students' understanding and performance were better in classes where teachers used the computer-based dynamic visualizations to complement their traditional teaching. Since there are research findings (Sridevi, 2008) which indicate that the science process skills were significantly associated with the achievement levels of students, it can be inferred that the reasons for the improvement in science process skills can be implied to the similar results in science achievement. The most plausible reason might be the reinforcing effect of multiple modes of transaction catering to the individual learning style. It might have helped the students to understand the concepts clearly and the reflection of participants in online forums might have helped them to analyse the concepts in different contexts. Since both online and face to face classroom activities were carefully organized with large student participation, possibility of transforming the content and absorb, assimilate or accommodate into their existing cognitive structure 'schema' was intense and therefore they could understand and apply his/her own learning in other contexts as well. Those activities were complementary to each other and might have reinforced to result in better Science achievement.

IMPLICATIONS

The present study was taken up in the context of blending online learning with face-to-face instruction in science learning. The study highlights positive effects of blended learning strategy over the conventional approach in fostering learning science among secondary school students. The findings of the research have several implications in the present educational system. The study presents a model of integrating online learning with face-to-face instruction in secondary schools. Thus, the present research has implications on framing Government policies to improve quality of Science learning. The study may initiate discussions in education sector for evolving new initiatives in pedagogical approach to enhance meta-cognition among learners and to empower students to become 'Global Learners'.

CONCLUSION

The study was an attempt to study the effect of blended learning strategy on Science leaning among secondary school students. The study found that by effectively blending online learning to the Face to Face instruction, science process skill and science achievement could be improved and the learners can be transformed into global learners. Blended learning strategy can be considered as one of the new initiatives in pedagogical approaches by integrating ICT in science education.

References

Bayrak, K. B., & Bayram, H. (2009). The effect of web based learning method in science education on improving the students' scientific process skills. Paper presented at the *International Conference: The Future of Education.* Retrieved from http://www.pixelonline.net/edu_future/common/download/Paper_pdf/ENT31-Bayrak.pdf

Dziuban, C., Hartman, J., & Moskal, P. (2004). Blended learning. *Educause Centre for Applied Research Bulletin*, *Issue 7.* Retrieved from http://net.educause.edu/ir/ library/pdf/ERB0407.pdf

Eduviews. (2009). *Blended Learning: Where online and face-to-face instruction intersects for 21st century teaching and learning.* Retrieved from http://www.blackboard.com/resources/k12/Bb_K12_WP_BlendedLearning.pdf

Ferreira, L. B. M. (2004). Role of a science story, activities and dialogue modelled philosophy for children in teaching basic science process skills of fifth graders. *Dissertation Abstracts International, 65*(6), 2069.

Garrison, R., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *Internet and Higher Education, 7*, 95-105.

Graham, C.R., & Allen, S. (2005). Blended learning environments. In C. Howard & J. V. Boettecher & L. Justice et al (Eds.) *Encyclopedia of distance learning* (pp. 172-179). Hershey, PA: Idea Group Inc.

Huang, R., & Zhou, Y. (2005). Designing blended learning focused on knowledge category and learning activities – Case studies from Beijing Normal University. In C. Bonk & C. Grahams (Eds.), *Handbook of blended learning: Global perspectives, local design*. San Francisco, CA: Pfeiffer Publishing.

Moodley, S. (2004). The effects of computer based dynamic visualization simulations on student learning in high school science. *Dissertation Abstracts International, 65*(8), p. 2941.

National Council of Educational Research and Training. (2005). *National Curriculum Framework*. New Delhi: NCERT.

Saat, R. M. (2004). The acquisition of integrated science process skills in a web-based learning environment. *Research in Science & Technological Education, 22*(1), 23-40.

Sridevi, K. V. (2008). *Constructivism in science education.* New Delhi: Discovery Publishing House Pvt. Ltd.

Tan, S. C., Yeo, J., & Lim, W.Y. (2005). Changing epistemology of science learning through inquiry with computer-supported collaborative learning. *Journal of Computers in Mathematics and Science Teaching*, 24(4), 367-386.

Torrisi-Steele, G., & Drew, S. (2013). The literature landscape of blended learning in higher education: The need for better understanding of academic blended practice. *International Journal for Academic Development 18*(4), 371-383.

I CARE ABOUT THE BEAUTY IN SCIENCE: AESTHETICS IN SCIENTIFIC PRACTICE AND PEDAGOGY

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In this article, we argue that an aesthetic appreciation and motivation for understanding science is missing in the majority of discussions about learning today, which are instead focused on more instrumental perspectives. We introduce a four-pronged formative framework to aid our understanding of the value of aesthetic experiences in science, and develop this framework through an examination of three different kinds of participants in science, technology, engineering, and mathematics (STEM) fields. Looking at the experience of professionals in the field, a popular television series, and practices of teachers, we develop a more finely tuned understanding of how an aesthetic perspective is both more authentic to the field and holds great potential for understanding STEM in a way that supports transformative experiences.

STEM TRENDS

Why should we study the disciplines of science, technology, mathematics, and engineering (STEM)? The typical answers given to this question are instrumental in nature. The core of an instrumental focus suggests that STEM disciplines are essential for jobs in the future, for the growth of national economies, world progress, and so on. A recent federally funded five-year Strategic Plan for STEM Education was developed in partnership with U.S. Department of Education. This report listed the main reasons for investing in STEM education as: *"The jobs of the future are STEM jobs… Our K-12 system is 'middle of the pack' in international comparisons… Progress in STEM is critical to building a just and inclusive society"* (National Science and Technology Council, 2013, p. vi). While we do not deny the importance of these goals, we believe that these instrumental reasons do not connect with the deeper motivations and passions that sustain learners in educational contexts. We suggest that this push toward the instrumental may be partly why many people feel disconnected from science as a subject from schooling onward (Firestein, 2012), and why students often find science content to be dry or dull (Millar, 1991).

We argue that STEM teaching is missing a key element – that of an affective, aesthetic understanding of content. There can be a feeling of delight and personal pleasure that comes from participating in sciences – a perspective reiterated by mathematicians and scientists across contexts and throughout history (Root-Bernstein, 1996). Rather than taking an analytic, objective step back, practicing scientists encourage an involved and subjective step into the material. The creative success of many scientists comes from their ability to appreciate the beauty in the work they do, the world around them and the ways in which science can provide insight into that world. As one scientist explained in Root-Bernstein, Bernstein and Garnier (1995):

> The scientific world is extremely beautiful. I'm much more interested – I mean, if you ask me what I really care about – I care about the beauty in science; and this novelty of discovery is a really aesthetic pleasure. It's just comparable, I think, to

any other of the great artistic emotions. It isn't rational. It's beyond reason. (p. 126).

However, the inherent beauty of science is often lost in schools' rigid treatment of STEM disciplines; and its fact driven, instrumental ways (Henriksen, 2014; Root-Bernstein, 1996; Root-Bernstein & Root-Bernstein, 1999). In addition, standardized, high-stakes testing has further emphasized factual, decontextualized science knowledge (Giroux & Schmidt, 2004), and steered away from a focus on the inherent beauty in scientific ideas (Firestein, 2012; Schwab, 1982). This has increased the gap between scientific practice and instruction, and removed what learners find exciting and compelling – ultimately leading to weaker scientific literacy among adults (Miller, 2014). There is also an inherent mismatch between the representation of scientific knowledge in schools and scientists and experts' impression of it (Firestein, 2012).

In this paper, we provide an argument for appreciating and including aesthetics in STEM education, contrast it with instrumental reasons, and situate our work within three research studies. In the first study, we focused on an analysis of interviews with some of the leading cosmologists in the world to identify their instrumental and aesthetic motivations in how they approach their work. In the second study, we conducted a qualitative analysis of instrumental and aesthetic approaches as exhibited in a popular science television series. Finally, we conducted an analysis of interviews with award-winning, creative STEM teachers to understand better the role that aesthetic plays in their practice. In essence, this paper presents a program of research around aesthetics, and teaching and learning in the STEM fields. Although these three studies can stand alone in design and findings, they connect within an overarching area of research, which helps us develop some important themes on the intersection of aesthetics, science, and education.

We divide the following sections are in three key parts, describing: (a) the instrumental arguments typically made for learning in the STEM disciplines; (b) a framework for investigating aesthetic aspects of learning; and (c) outlines of our three on-going research studies on the intersection of science and aesthetics.

Framing the Instrumental

In recent years, a focus on maintaining competitive economic advantage has been fueling instrumental approaches to science education. STEM education has been associated with such competitive concerns – exacerbated by a range of forces such as the advent of international tests (e.g., TIMMS and PISA) and globalization, making standardized comparisons across nations easier to accomplish. For instance, in the United States, President Obama tied together STEM achievement with this historical sense of slipping supremacy by comparing America's industrial and technological progress with Asian countries, suggesting a new generation's "Sputnik moment" had arrived (White House Press Office, 2010).

Such concerns have manifested themselves in a number of different ways, resulting in a similarly diverse spectrum of solutions and perspectives on how and what to focus on in STEM education. Pedagogically, this has manifested itself in a variety of teaching styles that have achieved differing levels of success. From drill and memorization to more constructivist inquiry-based science teaching, the vast majority of science teaching focuses on the functional goals of learning science. Typically, these instrumental concerns surface in reference to economics, social justice (like gender and race inequalities in STEM areas), or developing scientific literacy.

In addition, nations often use science as a gauge of their ability to maintain economic and innovative supremacy. This instrumental focus thrives by honing in on the ability and number of STEM degree-holding graduates, and international rankings of standardized scores for K-12 students. Arguments for promoting an interest and real-world application of science for future workforce success fall into this category.

Finally, competency in STEM fields is increasingly seen as a necessary requirement to be an informed citizen; this kind of scientific literacy has been another area of concern for many political and economic leaders. Awareness of major scientific events such as climate change, exponential population growth, technological shifts, and food supply or health issues, like obesity, require such scientific awareness and literacy, as do everyday decisions such as vaccinations.

Framing the Aesthetic

Clearly, instrumental reasons are important for educators to consider, and we do not dispute their role in teaching and learning science. Every profession has its practical goals; and for teachers, the future success of their students is clearly important. That said, another goal of education is to advance curiosity, promote new questions, and improve literacy and the life of the mind across subjects. Therefore, we argue that giving short shrift or ignoring the aesthetic aspects of learning can be deeply detrimental to the very nature of STEM work and learning. Part of the challenge of course is how we define what we mean by the aesthetic.

Our understanding emerges from Girod's (2007) exploration of the role of aesthetics in science and the four dimensions of the aesthetic experience that he laid out. The first of the themes identified by Girod is beauty in the representation of scientific ideas. This intellectual beauty can be appreciated with varying degrees of content knowledge — it does not take a fully trained scientist to appreciate the ripples made by dropping a stone into a pond. This affective appreciation of scientific beauty can be inspired from increasingly abstract instances of science — formulas and theories — when scientists have the knowledge necessary to perceive and appreciate their explanations.

The visceral reactions of scientists in their interactions with their work are the focus of this second theme: the awe, wonder, and fright that can arise from witnessing beauty in the sublime. This feeling arises as an appreciation for the sheer scale of a subject or of the extraordinary comprehension necessary to have developed something that explains it.

The third element of this framework encompasses the beauty many scientists write about when they understand their work to have revealed a sort of divine structure in the universe; beauty as truth. This is frequently the kind of language used by cosmologists and astrophysicists, the feeling of enlightenment that comes from discovering something that seems perfectly and purposefully arranged.

The final theme in this framework *is beauty in the experience* of research itself. This Deweyan perspective speaks to the pleasure or excitement of "inquiry," and unites the subject of science back to its experience with participants. This aesthetic experience is a dynamic one, in which an understanding and interaction with the subject changes both the participant's perception of the world and the subject itself.

While Girod (2001) worked to examine the use of this framework in practice, a great number of other science education studies examined the role of aesthetics in other, more nuanced forms (for example, Jakobson & Wickman, 2008). Our aim here is to extend the discussion aesthetic plays in motivation and sustained engagement in STEM fields, and to support efforts that focus on participation in this way.

In the next part of the paper, we focus on three research studies that seek to apply Girod's four-fold framework. The first research study consists of qualitative analysis of 27 in-depth interviews with top ranked cosmologists to understand better the role of instrumental vs. aesthetic motivations in their own work. The second study does a similar analysis but this time of popular representation of science and scientists on TV. Finally, we look at how award-winning teachers in the STEM disciplines describe their own work in instrumental and aesthetic terms. These three studies connect in a program of research that seeks to understand the role of aesthetics in the teaching of STEM disciplines.

THREE STUDIES: WHERE AESTHETIC MEETS SCIENCE

Aesthetics and Cosmologists

The complete interview transcripts from the twenty-seven cosmologists whose content provides the bulk of Origins: The Lives and Worlds of Modern Cosmologists by Alan Lightman and Roberta Brawer (1990) also provide the data for our first exploration of instrumental and aesthetic values held by practitioners in the field. Using the four-dimensional framework for aesthetic understanding developed from Girod's work and our categories for understanding instrumental motivations, we completed a preliminary coding of these transcripts in the qualitative software, NVivo. We developed codes to reflect intellectual beauty, beauty in the sublime, beauty as truth and as experience. Within each of these, subcategories have emerged that we are analyzing to incorporate into the framework.

The interviews cover a range of technical and personal detail, offering insight into the motivations these scientists held as they entered the field, and the affective nature of their continued participation. Books that piqued interest and inspired further investigation offer one common thread amongst the interviews. The interviewees discussed these books in aesthetic terms (e.g., being "turned on" to science, developing "serious interest"), which is a theme that developed throughout the interview, even if initially accompanied by an instrumental or practical reason for pursuing science or math. Such sustained aesthetic references speak to the compelling nature of aesthetic appreciation that Girod and Wong (2002) identify as being a key characteristic differentiating aesthetic understanding from conceptual understanding.

One of codes that appears most frequently is that of beauty as experience. The scientists often discuss their research experience in affective terms, talking about their work and their reactions to others' in terms of being "worried," finding things "fun" and "exciting" or being "bothered" by certain ideas. This is one kind of aesthetic connection to the material, which drives continued engagement with problems and a passion extending that engagement. When discussing the message, Robert Wagoner, astrophysicist at Stanford, tried to communicate to the public about the importance of his work and explained, "I really got worried about people being too concerned with their everyday life and not looking out to be aware of their cosmic environment, to put things in perspective."

This attempt to evoke emotional reactions to the vastness of the cosmos is an almost exact definition of our third category: sublime beauty – beauty in awe and wonder. This reiterates the importance that an aesthetic understanding of science can hold a means of communicating value and providing accessible points of contact with the public.

Overall, what we see when we look at this is that successful STEM practitioners do not focus on the instrumental aspects of their field when speaking about what is exciting or motivating or what drives curiosity in science. This resonates with messages of interest and sustained motivation, and is a recurring theme throughout our other studies.

The Aesthetics of *Cosmos*

In a qualitative study on aesthetic representation of science in popular culture, we analyzed the transcripts of an immensely popular and critically acclaimed television documentary series, *Cosmos: A Spacetime Odyssey*. This is an updated version, or sequel, of the original series, *Cosmos: A Personal Voyage*, hosted, written and co-created by renowned astrobiologist, Carl Sagan. Such popularity comes seldom to science documentary shows, which became our rationale to analyzing the elements in the show that could have helped gain this popularity among public at large.

Although the beauty of science is often lost in its presentation as a school subject matter, programs like *Cosmo*s manifest a different pedagogical approach, in which the public at large finds science both compelling and exciting. When presented as such, it serves to strengthen a better interest and understanding of science. Therefore, our particular interest in this study was to examine how this aesthetic framing could have affected public engagement with science, and whether it shows promise as an approach to foster scientific literacy.

This study, specifically, involved a qualitative textual analysis of the transcripts of all 13 episodes of the documentary series. We obtained the transcripts from an online TV and movie transcript database, *Springfield! Springfield!* First, we examined the videos to verify the accuracy of the transcripts and identify the overall structural and multimodal elements in the series. We also used this viewing to highlight appropriate positions for further detailed analysis in the transcripts. Second, we coded the transcripts using a qualitative coding software HyperResearch, noting every instance of a theme.

When coding, we started with a top-to-bottom approach, using Girod's (2007) framework of aesthetic in science. While we used these four themes as the starting point for our coding scheme, we were open to other examples and themes that speak to the aesthetic framing and present an appealing pedagogical approach to science. We repeated this process for all the episodes. Multiple iterations of coding helped ensure that all the instances and examples of themes/codes in the text were thoroughly identified (Anfara, Brown & Mangione, 2002).

Our analysis of the transcripts identified five emergent themes, which included versions of Girod's four themes. Out of Girod's four, we found the concept of beauty in sublime to be a prominent theme. Here is an example where Cosmos portrayed science as sublime, capable of inspiring awe and wonder, and even fear:

> In order to imagine all of cosmic time, let's compress it into a single calendar year…On this scale…we humans only evolved within the last hour of the last day of the cosmic year. (Episode 1).

The fifth new theme that we found – which was consistent throughout the show – highlighted the representation of scientists as adventurers, detectives, and explorers. For example, "Halley set out to solve this mystery as a detective would, by gathering all credible eyewitness testimony" (Episode 3).

The emphasis of the show on beauty and aesthetics in science, and the excitement that the profession beholds, at one level, captures the essence of Carl Sagan's "*Cosmos* perspective," but also aligns well with the aesthetic framework described in this paper.

We believe that this line of work has the possibility of informing current discourse on scientific literacy and STEM learning — by shifting the focus from instrumental reasons for learning science to ones that connect with deeper themes of aesthetic experience that can make science a more compelling and engaging experience.

The Instrumental and the Aesthetic in Teaching Science

Henriksen (2011) interviewed eight teachers who won (or were finalists for) the national "Teacher of the Year" award in the United States. As teachers who have been noted as "exemplary" through this award, she analyzed their understanding of creativity, the ways in which they demonstrate this in their classrooms, and the ways in which their outside activities and personal creativity influences their teaching practice. The presence of both aesthetic and instrumental references in these interviews provides an interesting insight into the many factors that contribute to teaching, learning and classroom practices in the STEM disciplines.

Of the original eight interviews, we selected three for preliminary analysis for aesthetics and instrumental themes, based on their teaching of STEM subjects. Mr. K is a middle school math teacher, while Mrs. T and Mr. G teach science at the middle school level. One of the authors conducted the preliminary coding in NVivo using the same basic framework for identifying references of aesthetic understanding that fall along Girod's four dimensions, and our previously referenced three-category instrumental framework.

These award-winning teachers put much emphasis on creative teaching and used compelling examples of teaching/learning in the classroom. Given this, it was not surprising that many of the lessons they described as "creative" also had strong characteristics of aesthetic learning. For example, Mr. K had his students participate in a "number line dance" where students make positive and negative signs with their arms in front of their bodies and then point to the left or the right to indicate going "up" and "down" the number line. Mr. K, on the other hand, writes, sings and creates rap music videos related to mathematics. Mr. G had his students learn science concepts using theatre, such as playing different organisms in an ecosystem or particles in an atom, in order to understand concepts being covered. This sense of being in and part of an abstract concept, and deep and experiential learning of a concept, is part of the engaged and transformative experience of aesthetic learning.

However, we also noted that these teachers also included an instrumental focus at times, particularly in sharing the rationale, goals, and rewards of the profession. Several of these teachers practice in schools with students coming from low-socioeconomic backgrounds and limited resources, intensifying their desire to present subjects as practically useful and relatable to students' everyday lives. When asked about the rewarding aspect of teaching, Mr. K considers the student beyond the subject, saying, "[W]hen a former student comes back years later and is all grown up and being a productive member of society I really think of myself, 'Yeah, yeah, I think I helped play a part in that.'" Mrs. T's explanation revolved around seeing "a future that might be brighter than what [the students] originally anticipated." Although, again, this instrumental articulation of pride is couched in her larger narrative of constant experience and "science being everywhere."

What we see among some of the best teachers in the field is that instrumental reasons do naturally pop up (all professions have their practical goals, and teaching is no exception), in that they consider their students' job security and academic accomplishment. However, these award-winning teachers manage to connect with and navigate these instrumental aspects, while also going beyond them, to speak about their personal interest in the subject and pursuits outside of teaching more aesthetically. Instrumental aspects of teaching and learning will always be present in the profession – and we do not quibble with the importance of teachers working toward instrumental goals to help their students relate to the content in practical ways, and find success and security in their fields. However, we do emphasize that among highly effective teachers, the story does not end there – they also place a strong focus on aesthetic interests in terms of curiosity, and unique and engaging approaches to content. They focus on ways to highlight both curiosity and excitement for ideas, along with relevant and practical demands of the profession. This requires navigating a tension between the aesthetic and the instrumental, as clearly both are valuable in the effective and impactful teaching of STEM content.

CONCLUSIONS AND CONTINUATIONS

This paper describes a preliminary framework for thinking about aesthetics in STEM education, through the discussion of three different research studies that deal with aspects and approaches to this. These three studies are part of a program of research on aesthetics and STEM teaching, and provide us with a look at aesthetic vs. instrumental reasons for learning STEM content, compared from different perspectives. We assert that aesthetic reasons for learning in STEM subjects – and thus aesthetic or creative approaches to teaching them – are often overlooked and de-emphasized in most education policy and curriculum (though to be fair our work is situated within the context of education in the USA). Much of the high-stakes and standards-based approach to learning that has characterized recent educational policy eschews aesthetic reasoning, curiosity, and wonder, in favor of more straightforward, decontextualized and facts-only based learning. Much of this is driven by instrumental reasons such as job growth in these fields, global economics, and the need for countries to be more competitive in tested STEM competencies.

While we do not deny that instrumental reasons are important, we assert that they have received disproportionate attention in the teaching of school STEM curriculum, which may adversely affect interest, motivation, curiosity, and thus competency in these fields. This also does not align with the reasons that inspire people who pursue these fields professionally. We therefore suggest that an aesthetic perspective is valuable in its own right and as a means by which these instrumental motivations can be strengthened.

While instrumental reasons must naturally show up in the teaching of STEM content – for the most successful of classroom teachers, the aesthetic reasoning or connection to content also is important. At least within the context of the USA, educational policy has de-emphasized the aesthetic in the standardized teaching of science – the most exceptional, award-winning teachers still find ways to bring it in. In this paper, we have suggested, and shown through several pieces of research, the way that aesthetic approaches and reasons in STEM teaching and learning are important. In addition, we have tested the framework proposed by Girod. While the instrumental will still necessarily play a role in classroom teaching, the story does not end there, and we must find a way to incorporate the aesthetic – giving service to both. This work suggests that there is promise and need for additional research in this area.

References

Anfara, V. A., Brown, K. M., & Mangione, T. L. (2002). Qualitative analysis on stage: Making the research process more public. *Educational Researcher, 31*(7), 28–38.

Firestein, S. (2012*). Ignorance: How it drives science*. US: Oxford University Press.

Girod, M. (2001) Teaching fifth grade science for aesthetic understanding. Unpublished doctoral dissertation, Michigan State University, East Lansing. Retrieved from ProQuest. (UMI Number: 3009113).

Girod, M. (2007). A conceptual overview of the role of beauty and aesthetics in science and science education. *Studies in Science Education, 43*, 38 – 61.

Girod, M., & Wong, D. (2002). An aesthetic (Deweyan) perspective on science learning: Case studies of three fourth graders. *The Elementary School Journal, 102*(3), 199 – 224.

Giroux, H. A., & Schmidt, M. (2004). Closing the achievement gap: A metaphor for children left behind. *Journal of Educational Change, 5*, 213-228.

Henriksen, D. (2011). We teach who we are: Creativity and trans-disciplinary thinking in the practices of accomplished teachers (Doctoral dissertation). Retrieved from ProQuest. (UMI Number: 3489807)

Henriksen, D. (2014). Full STEAM Ahead: Creativity in excellent STEM teaching practices. *The STEAM Journal, (1)*2, Article 15.

Jakobson, B., & Wickman, P. O. (2008). The roles of aesthetic experience in elementary school science. *Research in Science Education, 38,* 45 – 65.

Lightman, A., & Brawer, R. (1990) *Origins: The lives and worlds of modern cosmologists*. New York: Harvard University Press.

Millar, R. (1991). Why is science hard to learn*? Journal of Computer Assisted Learning, 7*(2), 66–74.

Miller, J. (2014). *Public understanding of science, assessment of encyclopedia of science education.* Netherlands: Springer.

National Science and Technology Council. (2013). *Federal Science, Technology, Engineering and Mathematics (STEM) Education 5-Year Strategic Plan.* Washington DC: NSTC.

Root-Bernstein, R. S. (1996). The sciences and arts share a common creative aesthetic. In A. Tauber (Ed.), *The elusive synthesis: Aesthetics and science.* Dordrecht, The Netherlands; London: Springer.

Root-Bernstein, R. S., & Root-Bernstein, M. (1999). *Sparks of genius: The thirteen thinking tools of the world's most creative people.* New York: Houghton Mifflin.

Root-Bernstein, R., Bernstein, M., & Garnier, H. (1995). Correlations between avocations, scientific style, work habits, and professional impact of scientists. *Creativity Research Journal, 8*(2), 115-137.

Schwab, J. J. (1982). *Science, curriculum, and liberal education: Selected essays*. Chicago: University of Chicago Press.

The White House, Office of the Press Secretary. (2010). Remarks by the President on the economy in Winston-Salem, North Carolina [For immediate release].

ENHANCING URBAN TEACHERS STEM AND LEADERSHIP CAPACITIES: A PRELIMINARY REPORT ON A UNIQUE PRIVATE-PUBLIC-PUBLIC PARTNERSHIP

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This paper discusses an example of a partnership to enhance the STEM (Science, Technology, Engineering & Mathematics) teaching and leadership capacities of teachers in a large urban school district in the United States. Incorporating educational innovation and instituting systemic change in public school systems is a complex endeavor (Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000). We describe our instructional approach, using the power of experience (Dewey, 1938) involving real world, hands-on engagement with tools and pedagogies. Our fellowship program is driven by our research on the Technology Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006), which guides us in discussion of our instructional practices, and our findings on teacher efficacy and leadership of our fellows.

INTRODUCTION

Incorporating educational innovation and instituting systemic change in public school systems is a complex endeavor (Blumenfeld et al. 2000; Guskey, 1990), requiring not just instructional change and teacher professional development but rather a systematic involvement of a range of stakeholders so that the innovation can be sustained over a period of time. In this paper we describe an example of a teacher education program that was formed through a unique private-public-public partnership that seeks to develop the STEM and leadership skills of 125 teachers in the Chicago Public Schools over three years. Especially of interest is the manner use of blended and hybrid technologies and approaches to engage teachers in the project on a year-around basis.

This paper serves as a first report on a work in progress, focusing on the first year of a three-year project. Within the broader context of the project, we will focus on the instructional strategies used to develop teachers' capacity in STEM education and leadership. Integrating technology into the academic environment requires skills and creativity from the teachers' technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006). However, building a teachers' TPACK requires specific training since most technologies are not designed for classroom and academic settings (Koehler & Mishra, 2008). The MSU UrbanSTEM & Leadership program uses the power of experience (Dewey, 1938) to develop the capacity of classroom teachers in STEM disciplines to design transformative and innovative, multimodal instructional experiences and active learning communities of practice – all as means of enhancing the quality of instruction in their own classrooms. The MSU UrbanSTEM and leadership program launched with an intensive face-to-face, two week, summer cohort session in 2014. Twenty-five STEM teachers in Chicago applied what they learned from the summer session to their classroom teaching experiences and to their interactions with other teachers in their schools.

This paper addresses the overall design of the program, and is divided into the following overarching sections: (a) view of project from stakeholder perspectives, (b) curriculum and practices, and (c) program evaluation including changes in teacher competence, teacher leadership, and teacher ability to integrate technology into their pedagogy.

PROJECT FROM VARIOUS PERSPECTIVES

Overall Partnership & Project

This program was the result of ongoing discussion and relationship building between a global IT company and Michigan State University. The IT Company has a strong history of commitment to education (primarily in India) and was seeking to expand its work into the US (since it now has a large presence in the country). Michigan State with its land-grant tradition and commitment to both public schools and urban education was a good fit for this partnership. Chicago Public Schools, the third-leg of this partnership (the third largest urban school district in the nation) emerged as a key partner in this process—given MSU's ongoing relationship with them. Microsoft emerged towards the end as an important partner as well. Through a series of interactions we saw that our interests and values were aligned, while we each brought separate strengths to the table.

Chicago Public School Partnership and Perspective

Chicago Public Schools (CPS) is the third largest school district in the nation with 664 schools serving 394,000 students. To support the district's 22,500 teachers, Chicago Public Schools engages partners with proven success records to provide professional development aimed at increasing the student achievement for all learners. An exemplary model of such collaboration is the Michigan State University (MSU) Urban STEM program in which CPS and MSU work together to identify, recruit, and support STEM teachers in this one-year graduate certificate program grounded in the context of a large urban district.

Similar to many large urban districts, Chicago Public Schools is presented with numerous challenges in the pursuit to offer all students with high-quality opportunities to engage in learning. The lowest performing schools in the U.S. are often in Urban metropolitan areas (Tajalli & Ophiem, 2004). This disparity exists because of external challenges such as poverty, transience, and socio-political forces. Other challenges exist within the four walls of a school including punitive behavior management, poor teacher preparation, and underfunded teacher training and induction. Ultimately, these factors combine into a heavy weight bearing down on our most under-represented student's shoulders, preventing them from learning, opportunity, and success beyond K-12 education. This is especially true when engaging students in STEM related instruction where cultural, racial, economic, and gender divides are ever present.

Goldhaber (2002) concluded that what teachers learn in their education and course work adds to their teaching and classroom capabilities. The MSU Urban STEM Fellowship takes Goldhaber's perspective and responds to these challenges by working with CPS to identify successful teachers working in under-served schools to improve their instruction thus breaking down barriers, especially with minority girls, and allowing students equal opportunity to explore STEM content in a safe, hands on, learning environment. There are unique challenges and strategies required to meet these challenges for the development of a genuine program.

Instructional Framework

For the past 15 years, the Michigan State University Master of Arts in Educational Technology (MAET) program has been offering a hybrid summer graduate school experience specifically targeted towards K-12 practitioners. This structure for the 9-credit summer program consists of two weeks of intense face-to-face instruction followed by 3 weeks of online instruction. This innovative (Terry et al., 2013) and award winning (Mishra et al., 2012) model gave us the basis for creating a structure for the MSU UrbanSTEM fellowship program. We had the unique opportunity with the MSU UrbanSTEM fellows to iterate on this idea and stretch a 9 credit graduate certificate into a year-long hybrid experience. Face-to-face time is crucial for developing a sense of community and camaraderie (Wolf, 2011). We continued with the 2-week face-to-face summer model and embedded 4 face-to-face meetings and online meetings throughout the following school year.

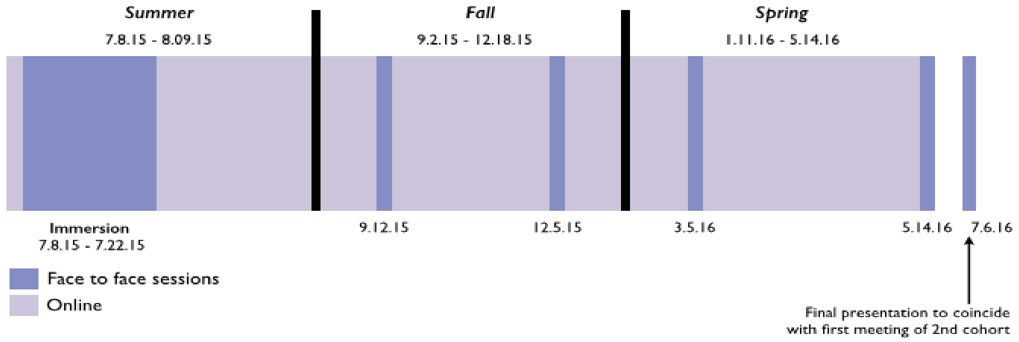

Figure 1: A typical calendar year of the MSUrbanSTEM project

CURRICULUM & PRACTICES

Face-to-Face Summer Session: Wisdom Begins in Wonder

During the eleven-day face-to-face summer session, the teaching team laid the crucial foundation for building a sustainable learning community. Our key goals were to provide a transformative shift in the fellows by providing new ways to interpret ideas, technology, pedagogy, and new ways of thinking. The basic structure of each day was formulated to disrupt what the fellows had come to know as *adult learning or teacher professional development.* Assignments such as the iImage, Explain it to Me video, teaching demonstrations and others were intertwined with Quickfire Challenges (Wolf, 2009), discussions, and hands-on activities. This face-to-face time allowed us to build a strong foundation for future learning. The assignments included: presentations by the fellows of their best lesson plans, creation of short problem-based learning videos, engaging in workshops on the role of improvisation in teaching, visits to science museums, development of a project to be implemented through the fall and spring semesters, and a range of other micro, and macro design activities. Additionally, the fellows (25 teachers) participated in the fellowship by engaging with the projects they have completed, including the book that they published entitled, *The Roots of STEM: A collection of lesson plans for teachers by teachers,* Michigan State University, 2014.

Fall semester: Designing (& re-designing) Practice

Throughout the fall semester, the fellows continued to explore the key program themes, but also began to focus on application-oriented activities. There were various assignments, activities, and instructional support that facilitated the fellows' initial implementation of the program themes. The major project assignment that the fellows work on throughout the year is their DreamIT project, which also commenced in fall. Fellows shared their projects with various stakeholders in the form of teaching demonstrations (Swenson & Mitchell, 2006), where they collected, reflected, and acted on feedback related to their projects. Fellows were also asked to identify a STEM related book that addressed their content from a unique perspective. Through a deep reading, review, and author interview, the fellows continued their exploration of STEM topics, while expanding their professional learning network. Authors interviewed by the fellows included the science popularizers such as Karl Zimmer, Larry Gonick, authors of mathematical fiction such as Gaurav Suri and many others. Instructional support was provided to the fellows both remotely and face-to-face throughout the fall. Finally, instructor and peer feedback mechanisms were used by instructors to support and document fellows' growth and success.

Spring semester: Rocking the Leadership Boat

During the spring Semester, fellows focused on leadership in their academic context as well as what it means to be a leader in STEM education. The discussions in the spring semester were guided by the book *Rocking the Boat: How to effect change without making trouble* by Debra Meyerson. This book explores the idea of "tempered radicals" — i.e individuals who work towards transformational ends through a thoughtful incremental process. In order to explore topics in STEM Leadership, each fellow created a Personal STEM Leadership Manifesto. Based on the spirit of The Personal MBA designed by Kauffman (2010), the Personal Manifesto allowed students to create an annotated bibliography of books, websites, and other resources to use as a foundation for addressing a problem or exploring a question in STEM academic leadership in their personal context. The manifesto was used to help fellows identify instrumental and missional thinking in the school setting, and it also produced memos and blog post designs that encouraged change in some aspect of their academic space. Fellows also presented their work at a special session at the Annual Conference of the American Educational Research Association in Chicago. Additionally, fellows continued to refine their professional web presence and build on their DreamIT projects from the previous semester. These assignments allowed fellows to creatively immerse themselves in various aspects of STEM and leadership as it pertained to their real world experiences as well as directly connecting with leaders in the field.

PROGRAM EVALUATION

There is preliminary data on the impact of the MSU UrbanSTEM & Leadership program on the 25 teachers' ability to develop a classroom experience that enhances the quality of learning. We used four separate instruments to measure this impact: (a) we measured student ability to lead and collaborate among their colleagues with the Educational Leadership Self Inventory (ELSI); (b) we used the Teacher Efficacy Scale (TES) to measure teachers sense of competence in educating their students; (c) we created a technology survey that allowed us to get a better understanding of how proficient the fellows were with using various programs and technology; and finally (d) we used the Technological Pedagogical Content Knowledge (TPACK) scale to assess how effectively the teachers use technology in the classroom and teaching practices.

Teachers' understanding of TPACK allows them to rethink their academic environment and more effectively use technological resources to their advantage (Koehler et al., 2011). Built from the idea of designing and educative experience (Dewey, 1938), first, the fellows were asked to take all four assessments prior to the summer face-to-face educative experience as a pre-assessment. Then, they were asked to retake each assessment in the beginning of the fall semester as a post assessment. The fellows then retook these four assessments at the end of the fall semester, and finally at the end of the spring semester, creating a total of four waves of instrument data. The assessments were used to examine if teachers' leadership qualities, teaching efficacy, knowledge and use of TPACK, and use of technology may have changed as a result of being participants (fellows) in this program.

The preliminary results indicate that participants gained a deeper understanding of TPACK and they developed as overall educators. After completing a one way repeated measures analysis of variance on the first three waves of the TPACK data, we found that there was a significant increase in the overall TPACK of the fellows (see figure 2). Additionally, there was a significant increase in technological content knowledge (TCK) and technological pedagogical knowledge (TPK), which means that our fellows are becoming more effective in implementing technology into their classroom and teaching practices.

A one-way repeated measures ANOVA was conducted to evaluate the null hypothesis that there was no change in scores on the ELSI survey when measured before, after, and further after participation in the program (N=22). We found significant changes in the learning process subscale, as well as the school culture sub scale, but most importantly the overall instrument show statistically significant growth (see figure 3).

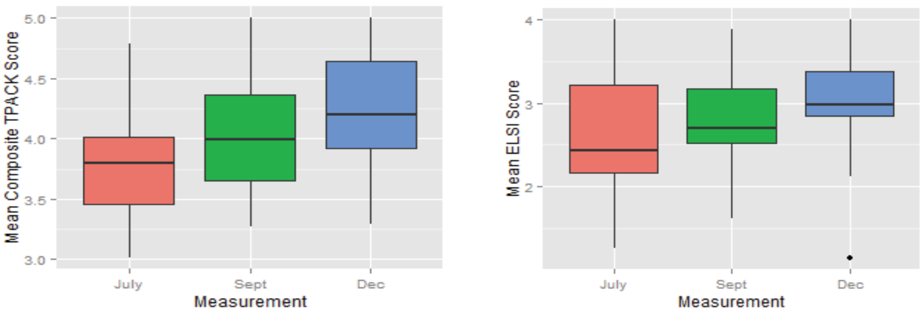

Figure 2: (TPACK) & Figure 3: (ELSI) showing means and standard variations

We ran a one-way repeated measure ANOVA for the Teacher Efficacy Scale (TES) as well. The effects of the TES were greater than that of the ELSI and the TPACK, which could be because of the participants' exposure to new knowledge in general. Finally, we found that there were significant group differences when we completed an ANOVA for the Technology survey.

In addition to the four instruments used in this study, we are completing a qualitative analysis of the Fellow's Dream IT project assignments and from the summer reflections. We have found common themes emerging from our analysis. A few key themes are:

- An emphasis on the role of Aesthetics in STEM teaching and learning
- Focusing on Creativity, both in their practice and thinking of curriculum implementation

- Growth and development in the kinds of Disciplinary Connections being made
- Growth in identity, passion, and philosophy of teaching or learning
- Development of personal Leadership styles and collaboration

Many of these themes were created from the mission of the UrbanSTEM program because we specifically were hoping to find these themes in the Fellows' writing. However, several themes emerged while coding the various documents. Finally, when the Fellows were asked how likely it is that they would recommend the UrbanSTEM program to a friend or colleague (what is known as the Net Promoter Score), the average answer was a 9.6 on a Likert-type scale between 0 (not at all likely) and 10 (extremely likely).

CONCLUSION

All of the different components come together to tell an on-going story about how the participants have not just enjoyed and appreciated the experience but also grown from it. Ongoing analysis and data collection will seek to expand on the data already collected with an eye on better understanding the impact of this fellowship on classroom pedagogy. The research evolving from this program specifically supports its influence on teacher professional development and leadership in STEM. Furthering teacher's capacity to integrate technology into their pedagogy and increasing teacher competence can have a great impact on student learning and engagement (Harris & Sass, 2011), especially for students of color in STEM topics (Museus, Palmer, Davis & Maramba, 2011). A more competent and diverse teacher can also influence other dynamics that play a crucial role in urban school settings, such as the racial achievement gap or the SES achievement gap. Additionally the focus on leadership encourages the fellows to share their knowledge and ideas thus creating a community that practices the creative integration of technology in the classroom.

References

Blumenfeld, P., Fishman, B. J., Krajcik, J., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist, 35*(3), 149-164

Dewey, J. (1938). *Education and experience.* New York: Kappa Delta Pi.

Guskey, T. R. (1990). Integrating innovations. *Educational Leadership, 47*(5), 11-15.

Goldhaber, D. (2002). The mystery of good teaching: Surveying the evidence on student achievement and teachers'characteristics. *Education Next, 2*(1), 50-55.

Harris, D. N., & Sass, T. R. (2011). Teacher training, teacher quality and student achievement. *Journal of Public Economics, 95*(7), 798-812.

Kaufman, J. (2010). *The personal MBA: A world-class business education in a single volume*. Verlag: Portfolio Penguin.

Koehler, M. J., & Mishra, P. (2008). Introducing TPACK. In AACTE Committee on Innovation & Technology (Eds.), *Handbook of technological pedagogical content knowledge for educators* (pp. 3-29). New York: Routledge.

Koehler, M. J., Mishra, P., Bouck, E., DeSchryver, M., Kereluik, K., Shin, T. S., & Wolf, L. G. (2011). Deep-play: Developing TPACK for 21st century teachers. *International Journal of Learning Technology, 6*(2), 146–163.

Michigan State University MSU-Wipro STEM Fellows. (2014) Roots of STEM: A collection of lesson plans, for teachers, by teachers. Retrieved from http://www.msuurbanstem.org/teamone/wp-content/uploads/2014/09/Roots-of-STEM-book.pdf

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A new framework for teacher knowledge. *Teachers College Record 108*(6), 1017-1054.

Mishra, P., Koehler, M., & Wolf, L. G. (2012). The educational psychology and educational technology program. Retrieved from http://punya.educ.msu.edu/wp-content/uploads/2013/02/AACTE-TechnologyAward-MichiganState.pdf

Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C., (2011). Special Issue: Racial and ethnic minority students' success in STEM education. *Association for the Study of Higher Education, 36*, 1-140.

Swenson, J., & Mitchell, D. (2006). *Enabling communities and collaborative responses to teaching demonstrations.* Red Cedar Writing Project, Michigan State University.

Tajalli, H., & Ophiem, C. (2004). Strategies for closing the gap: Predicting student performance in economically disadvantaged schools. *Educational Research Quarterly, 28*(4), 44-54.

Terry, L., Mishra, P., Henriksen, D., Wolf, L. G., & Kereluik, K. (2013). Making it meaningful: The reciprocal relationship between technology and psychology. *TechTrends, 57*(3), 34-39.

Wolf, L. G. (2009, Aug. 19). Quickfires explained. Retrieved from http://www.leighgraveswolf.com/2009/08/19/quickfires-explained/

Wolf, L. G. (2011). Faculty versus student perceptions of the quality and relevance of a master's degree in educational technology (Order No. 3489755). Available From Dissertations & Theses @ CIC Institutions. (915788795).

USING EXPLICIT ARGUMENTATIVE INSTRUCTION TO FACILITATE CONCEPTUAL UNDERSTANDING AND ARGUMENTATION SKILLS IN SECONDARY SCHOOL CHEMISTRY STUDENTS

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The study investigated effects of Argumentative instructional strategy on Chemistry students' conceptual understanding of chemistry concepts in Senior Secondary Schools in Lagos state, Nigeria. 120 SS2 chemistry students from two randomly selected senior secondary schools in Lagos state formed the sample and quasi-experimental pre-test-post-test research design was used for the study. Chemistry Achievement Test and Questionnaire were used to collect data. The formulated hypotheses were tested using t-test statistical tool at 0.05 level while the raised research questions were answered using descriptive statistics. It was found out that students taught using Argumentative strategy achieved significantly higher than those taught using conventional method. Based on the findings, it was recommended among others that Chemistry teachers should adopt the use of Argumentative strategy in teaching chemistry. .

INTRODUCTION

Chemistry is one of the important science subjects taught at the Senior Secondary School (SSS) level of education in Nigeria. It is one of the core science subjects that students are required to pass at credit level in order to qualify for admission into tertiary institutions to pursue science-based programmes. In spite of this central and important position of chemistry among others science and related disciplines, studies revealed that, academic performance of students in chemistry at Senior Secondary School Certificate Examination (SSSCE) has consistently been very poor and unimpressive (Njoku, 2009). Statistics from the West African Examinations Council (WAEC) for many years consistently reveal a persistent poor achievement of Chemistry students in public examinations (WAEC Chief Examiner's report for 2003, 2004, 2006, 2007, 2008, 2010, 2011, 2012, 2013 & 2014)

Many factors have been suggested as contributing to this poor performance of students in science in general and chemistry in particular. Some of these factors include: inadequate laboratory equipment in chemistry (Eniayeju, 2010); poor teaching methods (Ogunwuyi, 2000); mathematical nature of chemistry among others.

A number of activity-oriented instructional strategies have been advocated for by curriculum designers and science educators to help improving students' performance in science. Examples of these strategies include guided discovery approach, demonstration method, discussion method and problem-solving for teaching senior secondary school chemistry as stipulated in National Policy on Education (FRN, 2008). Research findings had however, revealed that to date, a large proportion of science teachers, chemistry inclusive, still resort to the use of traditional/lecture method rather than the activity-oriented or student centered strategies advocated basically due to inadequate/unavailable instructional resources these strategies require for their effective application (Ogunwuyi, 2000; Kola, 2007).

Recently, with advance of teaching and learning science as inquiry, numerous studies have focussed on argumentation in science education (Osborne, Erduran & Simon, 2004; Eskin & Ogan-Bekiroglu, 2012) Argumentation as a teaching strategy has been considered relevant and fruitful in developed countries but no study is available on its effectiveness in Nigeria, especially in chemistry education. Argumentation is the process of making claims and providing justification for the claims using evidence (Toulmin, 1958). According to Osborne (2013), teaching students how to argue based on available evidence engages them in the scientific process and provides a better idea of how science actually works. When Argumentation is used, students encourage and support each other, assume responsibility for their own and each other's learning, employ group related social skills.

Another issue of contention in Nigeria today is the issue of gender both in our educational system and the society at large. In recent times researchers have expressed different views about gender and achievement especially in sciences hence, the issue has remain inconclusive.

The present study therefore, investigates the effectiveness of argumentative teaching strategy in facilitating conceptual understanding of chemistry concepts and helping students to develop argumentation skill in Nigerian chemistry classroom. Students' gender was built in as a moderating variable in the study.

STATEMENT OF THE PROBLEM

The problem of effective teaching and learning of Chemistry in Nigerian Senior Secondary Schools have become a sensitive issue that needs urgent attention. It has been observed that the issue is affecting the performance of students in both internal and external examinations adversely. It has also been discovered that the poor academic performance of students is related to the conventional method used to teach them by the teachers. Argumentation is a new approach of teaching which has been identified as a possible tool for promoting conceptual change in the developed world (Tippet, 2009). This study therefore, aims at investigating the effectiveness of argumentative instructional strategy on students' conceptual understanding of chemistry concepts in Nigerian classrooms.

RESEARCH HYPOTHESES

The following hypotheses were generated and tested in the study:

1. There is no significant difference in the students' conceptual understanding of chemistry concepts between students taught with argumentative instructional strategy and those taught with conventional method.
2. There is no significant difference in students' conceptual understanding of chemistry concepts using argumentative instructional strategy due to gender.

RESEARCH QUESTIONS

The study also provides answers to the following research questions;

1. What are the students' views about the effectiveness of argumentation as a teaching strategy for conceptual understanding of chemistry concepts?

2. Does students' gender influence their views about the effectiveness of argumentation as a teaching strategy for conceptual understanding of chemistry concepts?

RESEARCH METHODOLOGY

The study used pre-test, post-test Quasi-experimental design which involves experimental and control groups consisting of both male and female respondents. The population of the study comprised all the SS2 chemistry students in district IV area, Lagos State.

Two schools were randomly selected from Yaba Local Government Area from District IV of Lagos State. Each of the two schools was randomly assigned to experimental and control groups respectively and in each school intact class was used with total number of 120 students forming the sample size for the study. Chemistry Achievement Test (CAT) and Questionnaires on Students' Views of Effectiveness of Argumentative Instructional Strategy (QSVEAIS) were developed by the researchers and used to collect the necessary data on the subjects. The CAT consists of two sections; Section A sought bio-data information of the students while section B contained 30 multiple choice questions on kinetic theory of matter. The (QSVEAIS) also contained 10 items soliciting information on the views of the experimental group about the effectiveness of the instructional strategy used. Both instruments were validated by experts in item construction, CAT was tested for reliability (0.64) using Kuder Richardson formula 20 while the reliability (0.75) of the QSVEAIS was established using Croubach Alpha.

Procedure for Data Collection

The CAT was administered to the two groups before treatment which serves as the pre-test, after which the experimental group was taught the concept of Kinetic theory of matter using Argumentative instructional strategy and the control group was taught the same concept using conventional method for a period of two weeks.

After the treatment the CAT was administered again to both the experimental and control groups which form the post-test data and in addition, the questionnaire was also administered on the experimental group to obtain information on their views of the teaching strategy. In scoring the achievement test on kinetic theory of matter, correct response to the each question in the instrument was scored 1 point, while each wrong one was scored zero point and the maximum score on the test was 100 points. T-test statistical tool was used to test the hypotheses formulated and frequency counts and simple percentages were used to answered the research questions raised in the study

RESULTS AND DISCUSSION

Research Hypothesis 1: There is no significant difference in the students' conceptual understanding of chemistry concepts between students taught with argumentative instructional strategy and those taught with conventional method.

Group	N	Mean	Std. Deviation
Experimental group	60	52.1432	13.45345
Control group	60	51.4000	10.71068

Table 1: Descriptive statistics of pre-test score for the experimental and control groups

The result in table 1 shows that there is no significant difference between the mean score of the experimental group and the mean score of the control group, which implies that they have the same level of initial knowledge of the concepts under study.

Group	N	MEAN	SD	SE	Df	t-val	P	Remark
Experimental	60	60.67	10.97	3.90	118	3.5	0.02	Significant
Control	60	49.45	6.78	1.89				

Table 2: T-test analysis of post-tests of the experimental and control group

Table 2 shows there is significant difference between the experimental and control group ($t=3.5$, df: 118, $p<0.05$). Therefore, the null hypothesis is rejected.

Research Hypothesis 2: There is no significant difference in students' conceptual understanding of chemistry concepts using argumentative instructional strategy due to gender.

Gender	N	MEAN	SD	SE	Df	t-val	P	Remark
Male	37	61.49	10.83	6.64	58	6.4	0.03	Significant
Female	23	64.78	16.15	7.99				

Table 3: T-test analysis of students' conceptual understanding using argumentative instructional strategy based on gender

Table 3 show that there is significant difference in the conceptual understanding of the students in experimental group based on gender ($t=6.4$, df: 118, $p<0.05$). Therefore, the null hypothesis is rejected.

Research Question 1: What are the students' views about the effectiveness of argumentation as a teaching strategy for conceptual understanding of chemistry concepts?

Reference was made to Table 5 in answering this question.

S/N	Items	Agreed (A)	%	Disagreed (D)	%
1	I prefer the use of Argumentative strategy during class group work	33	55	27	45
2	I prefer contributing rather than listening during chemistry lesson	30	50	30	50
3	I like saying my views about what I know about the topic	37	62	23	38
4	Students should be allowed to show their creativity	45	75	15	25
5	I dislike memorization	57	95	03	05
6	I like to be actively involved in any hand-on activities	36	60	24	40

7	I like an interactive class, than the teacher explaining all through the course of the lesson	60	100	00	00
8	Lessons with argumentation give me opportunity to learn different ideas from my colleagues.	57	95	03	05
9	I get bored if the teacher does the talking through the lesson	47	78.33	13	21.67
10	The class would be lively if the teacher raise an argument for students to come to a claim or conclusion	31	51.67	29	48.83

Table 4: Views of experimental group on the effectiveness of the treatment

Research Question 2: Does students' gender influence their views about the effectiveness of argumentation as a teaching strategy for conceptual understanding of chemistry concepts?

Reference was made to Table 5 in answering this question.

DISCUSSION

From Table 2, the experimental group performed better than the control group which is due to the teaching method used to teach the experimental group. This finding is in agreement with that of Eskin and Ogan-Bekiroglu (2012) who found out that, the students taught with a strategy where argumentation was embedded in the instruction developed more correct and detailed reasoning of physics than those taught with conventional method. It is also in line with the submission of Sampson, Grooms and Walker (2011) who reported that engaging in argumentation and production of oral written arguments improve scientific knowledge and abilities. The study supports earlier findings that argumentative skills develop and that engagement in an argumentative discourse activity enhances that development (Kuhn & Udell, 2003; Felton & Kuhn, 2001; Kuhn et al., 1997).

s/n	Items	Male				Female			
		A	%	D	%	A	%	D	%
1	I prefer the use of Argumentative strategy during class group work	19	51.35	14	48.65	18	66.67	09	33.33
2	I prefer contributing rather than listening during chemistry lesson	13	39.39	20	60.61	17	62.96	10	37.04
3	I like saying my views about what I know about the topic	10	30.30	23	69.70	14	51.85	13	48.15
4	Students should be allowed to show their creativity	28	84.85	05	15.15	17	62.96	10	37.04
5	I dislike memorization	33	100	00	00	24	88.89	03	11.11

6	I like to be actively involved in any hand-on activities	26	78.79	07	21.21	10	37.04	17	62.96
7	I like an interactive class, than the teacher explaining all through the course of the lesson	33	100	00	00	27	100	00	00
8	Lessons with argumentation give me opportunity to learn different ideas from my colleagues.	33	100	00	00	17	62.96	10	37.04
9	I get bored if the teacher does the talking throughout the lesson	22	66.67	11	33.33	25	92.59	02	7.41
10	The class would be lively if the teacher raise an argument for students to come to a claim or conclusion	26	78.79	07	21.21	16	59.26	11	40.74

Table 5: Comparison of responses across genders

Table 3 revealed that female students achieved significantly higher than the male students when both were taught using argumentative instructional strategy. This shows that female students tend to argue better than male students. This finding is corroborated by Wilson, (1991) who has also reported similar findings in his research study.

From Table 4 also shows that all the students are of the opinion that argumentative teaching strategy will facilitate conceptual understanding of chemistry concepts. Although only 38.33% prefer to say their views about what they know on the topic, this is in line with the findings of Roberts and Kay (1997), who reported that traditionally, students' opinions and views have been under-represented and overlooked when it comes to discussing what students want and need in terms of learning and school experiences. Again, 100% say they would like an interactive class (item7), yet 50% prefer contributing (item2) while 50% prefer to listen. This is not surprising because in African culture, a child is not expected to exchange words or argue especially when an elderly person is involved or present in any gathering, in this sense 'argument' connotes rudeness or uncooperative attitude. This finding further lends credence to assertion by Okebukola (2005) who observed that most science teachers in Nigeria use predominantly the lecture method to portray the teacher as a fountain of knowledge and the students as passive listeners and note-takers. 60% likes being actively involved in any hand-on activities and 95% of the respondents also pointed out that chemistry lessons with argumentation provide them opportunity to learn different ideas about the chemistry concepts from colleagues.

But Table 5 shows that 60.61% of male students prefer to listen rather than contributing to the lesson being taught. This is in line with the findings of Goldin, Katz and Kuziemko (2006) who reported that high school female students now outperform male students in most subjects and in particular on verbal tests. Surprisingly, 62.96% of the female students dislike being actively involved in hand-on activities. This is finding is supported by that of Sampson and

Clark, (2008) who found out that female do not perform well in science because of their low level of confidence in hand-on activities and not their ability level. Taken together, these results imply that argumentation-based instruction used in this study, enhances students' conceptual understanding of chemistry concepts.

CONCLUSION AND RECOMMENDATIONS

Based on the findings from the study it is concluded that argumentative strategy can be used to enhance students' conceptual understanding of chemistry. The study also provides further evidence that the student-centered approaches are more effective in facilitating conceptual change and improving students' understanding than teacher- centered method. It is therefore, recommended that policy makers and curriculum planners should review senior secondary school chemistry curriculum in view to accommodate argumentation based science program for the students. Teachers are also encouraged to adopt argumentative instructional strategy to teach chemistry concepts especially where it is applicable for effective conceptualization and understanding of such concepts in chemistry. Both male and female students should be adequately encouraged and engaged through active participation during learning process when argumentative instructional strategy is used. Nigerian Government should put relevant and appropriate capacity building programs in place for the in-service teachers while such programs should be incorporated into the teacher education curriculum for pre-service teachers.

References

Eniayeju, A. A. (2010). Effects of cooperative learning strategy on the achievement of primary sixboys and girls in mathematics. *ABACUS: The Journal of Mathematical Association of Nigeria*, *35*(1), 1-9.

Eskin, H., & Ogan-Bekiroglu, F. (2012). Argumentation as a strategy for conceptual learning of Dynamics. *Research in Science Education, 43,* 1939-1956.

Federal Republic of Nigeria. (2008). *National Policy on Education*. Abuja: Federal Ministry of Education.

Felton, M., & Kuhn, D. (2001). The development of argumentative discourse skills. *Discourse Process*, 32, 135-153.

Goldin, C., Katz, L., & Kuziemko I. (2006). The homecoming of American college women: The reversal of the college gender gap. *Journal of Economic Perspectives 20*, 133-156.

Kola, A. J. (2007). Uses of instructional material for teaching and learning physics. *International Journal of Research in Education, 4*(1), 74-78.

Kuhn, D., Shaw, V., & Felton, M. (1997). Effects of dyadic interaction on argumentative reasoning. *Cognition and Instruction, 15*, 287-315.

Kuhn D., & Udell, W. (2003). The development of argument skills. *Child Development, 74*(5), 1245-1260.

Njoku, Z. C. (2009). Enhancing the relevance of chemistry curriculum delivery using science-technology-society (S.T.S) approach. *International Council of Associations for Science Education (ICASE)*, 48-54.

Ogunwuyi, A. O. (2000). *A causal model of teachers and students factors as determinants of achievement in secondary school integrated science*. Unpublished doctoral dissertation, University of Ibadan, Ibadan.

Okebukola, P. A. O. (2005). The race against Obsolesce: Enhancing the relevance of STAN to national development. Memorial lecture series 17. Science Teachers Association of Nigeria.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

Osborne, J. (2013). *Teach science through argument.* Stanford Report, April 9, 2013.

Roberts, R., & Kay, S. (1997). Students speak: How Kentucky middle and high school students view school. Retrieved March 12, 2009 from http://www_robbertsandkay.com/clients/students_speak.html

Sampson, V., & Clark, D. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education*, *92*(3), 447- 472.

Sampson, V., Grooms, J., & Walker, J. P. (2011). Argument-driven inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education, 95*(2), 217-257.

Tippett, C. (2009). Argumentation: The language of science. *Journal of Elementary Science Education, 2*1(1), 17-25.

Toulmin, S. E. (1958). *The uses of argument*. London: Cambridge University Press.

Wilson, M. (1991). (Ed.). *Girls and young women in education. A European perspective.* Oxford: Pergamon Press.

WAEC (2003-04, 2006-08, 2010-2014). Chief Examiner Reports. Retrieved from http://www.waecnigeria.org/

TEACHER EMPOWERMENT THROUGH ACTION RESEARCH

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A teacher of needlework was assigned to teach Environmental Studies (EVS) to IV and V Graders. Though she had studied science in school as well as college, she was faced with several challenges: she had been the Dining Hall Manager, later a needlework teacher - and now, being new to teaching, she had to recast herself as an EVS teacher. She had to confront students as well as peers who had stereotyped her as a needlework teacher. In addition, she was replacing an extremely popular teacher who had left the institution, and had to face the expectations of students that she would teach just like their previous teacher had. Above all, she had to manage a class of children who could easily see that she was too soft to be firm with them. This paper recounts how she undertook to carry out Action Research, framed and reframed her problem, found and implemented solutions that changed along the way. It also contains observations made by the facilitator of her action research, about the ways in which her approach, focus and practices changed, as her research unfolded.

ACTION RESEARCH AS A ROUTE TO TEACHER DEVELOPMENT

Several methods have been used for developing reflective teachers (Conderman & Morin, 2004). Journals (Powell, 1985), portfolios (Guba & Lincoln, 1985), self reports (Pak, 1985), collaborative diary-keeping (Brock, Yu & Wong, 1991), autobiographies (Gore, 1993), case studies (Chambers & Clarke, 1999), peer coaching (Costa & Garmston, 1994), group discussions (Fazio, 2009), peer feedback (Richards & Lockhart, 1991) and/or video- and audio-recording of classroom processes (Pak, 1985) are only some of the methods that have been successfully tried out. This paper describes how a teacher conducted action research and how her facilitator observed the ways in which the teacher-researcher was impacted by the whole process. It therefore contains the observations of both teacher-researcher and facilitator. Having conducted a successful research study (Raghavan & Sood, in press) where teachers of a semi-urban school showed enhanced reflection as a consequence of doing Action Research (Costello, 2011), the Principal Investigator[1] of that study (the facilitator in this) adopted action research as a way of enhancing reflective thinking in the teacher.

[1] The Principal Investigator of the cited study is now Founder Director of THINKING TEACHER, (www.thinkingteacher.in), an organization that engages with teachers of schools to develop reflective practitioners.

METHODOLOGY

The following method was adopted in this work:

- A one-day workshop was conducted by the facilitator to acquaint this teacher (and some of her colleagues) with Action Research
- This was followed with monthly meetings, as well as one classroom observation every month. The facilitator kept a record of her own observations of the classes that she observed. (During the class, the facilitator was a silent observer, and after the class, she shared her detailed observations with the teacher.)
- The teacher maintained regular documentation of her classes and e-mailed these to the facilitator.
- In every monthly meeting, the teacher and facilitator discussed the current situation and brainstormed about the way ahead.

This work was completed in a total time frame of six months (two of them being a period of summer vacation, and therefore, no action research or classroom observations.) Thus, the actual work was done in a period of four months. Analysis of observations, issues, strategies and their impact was done through discussions between teacher and facilitator. These were face-to-face (once a month), and over email and telephone a few times each month.

BACKGROUND

There were several stereotypes that this teacher had to confront, in her journey as a teacher. She was, initially, the Dining Hall Manager in this residential school. Having discharged her duties satisfactorily in this regard for some years, she was pleasantly surprised when the Principal asked her to teach needlework and craft. Trained as she was in Home Science (and in Science), this was relatively easy for her to do. What came as a bigger surprise was when the Principal asked her to teach Environmental Studies to Classes IV and V, and to complete her B Ed degree in parallel, in order to fulfil statutory requirements.

In the Principal's words, her reasons for this choice were: "*Ratna seemed to be doing her job as Needlework teacher very well. However, she seemed to be missing a certain intellectual stimulation in her job. In a residential school such as this, teachers need to feel an active part of whatever is happening in school, and Ratna seemed to feel that she was not in the 'thick of things'. Ratna has a science background, a highly methodical mind, and is very reliable and highly motivated to do her best in any job that she is given. Given all these factors, and the need for a science teacher in Grade IV & V, I felt that she would be the best person for the job and would do very well – with, may be, a little help initially*."

The teacher complied by investing considerable time and effort in acquiring the B Ed degree (before embarking on this Action Research), even as she taught EVS. However, this was not without struggle: the typecasting of a senior lady like her as being "better equipped" to handle "domestic tasks" like managing a kitchen (or teaching needlework) being only one of them.

FRAMING OF THE PROBLEM

As Schon (1983) points out, the framing of the problem is a critical step as it then lends itself to the development of strategies. The teacher began by framing her problem thus:

In my assigned class of heterogeneous learners (mix of IV and V[2]), how can I get all students to be completely engaged in EVS?

(The class strength was 23, with 11 from Class IV and 12 from Class V) The facilitator then led her through a process of analyzing her problem. Simply by posing questions such as the following*: What do you mean by „completely engaged"? How do you know that a student is/is not engaged? What do you think are the obstacles to being engaged*? The facilitator found that the teacher quickly realized that her core problem was one of classroom management. Indeed, this had become obvious to the facilitator in the very first observation of her class, but this analysis of the Action Research problem led the teacher also to conclude the same. (Interestingly, the facilitator had also observed another teacher's classes with the same set of children, and noted their rapt attention without any disruptive behaviour there. This was later acknowledged by this teacher as well.)

Thus, the reframed problem was as below:

In my class of heterogeneous learners (mix of IV and V), how can I bring about a harmonious atmosphere that lends itself to effective communication?

STRATEGIES TO ADDRESS THE PROBLEM

Before embarking on Action Research, the teacher had switched from one strategy to another in her desperation to learn how to manage a class. She noted: *"I was either shouting, or just keeping quiet, for whatever they did. I did not know how to be soft yet firm with them."* The facilitator's notes of their conversations ran thus:

She admitted candidly that she was new to teaching so that when she started teaching here, her classes were usually in chaos. Just calming the class would take five to seven minutes each time, and even thereafter, the classes would get so noisy that teachers from neighbouring classes would come and ask her how long it would take for the children in her class to settle down. This would repeat itself during evening prep. Although she tried several strategies (like thumping the duster on the table to catch the attention of noisy children), the restlessness did not abate. So in desperation, she searched the Internet to see how others had handled this - or indeed, whether they needed to handle this at all. To her relief, she found that this was one of the commonest problems faced by teachers on an ongoing basis. "It was not all about me," she sighed with relief. One suggested strategy that she found on the Internet did not work for too long, i.e. raising her arms up high so as to calm the children down. This would work only momentarily. So she again resorted to various means like shouting, being firm – in short, "beating around the bush" as she just couldn't zero in on a final solution.

Clearly, the teacher did not experience any of her learning objectives being met: instead, just getting the class to listen to her, and for her to communicate meaningfully with them proved to be a challenge in itself. She noted in her diary: *"Needlework needs a lot of organization and has a methodology. If I was able to teach that to the children, it is not very difficult to teach them EVS. It is just a little time-taking, and I may need a little guidance."* She now found that teaching EVS made the following demands (different from needlework) on her:

[2] Since this is a residential school that starts taking in students only from Class IV, the school has found it effective to mix these newcomers with Class V, in order to help them learn from each other and settle down better.

- A structured way of transacting content in EVS, unlike needlework where she could alter content and speed of coverage, as she went along
- A differentiated approach towards learners of varying levels, unlike needlework where all of them had been at the same level ("*None of them knew how to thread a needle*!")
- A firm grasp of EVS content so that she could then think about pedagogy: she was so comfortable in needlework, that she had experienced no problem in devising new approaches to deal with different children
- Delivery of content in a manner that held the attention of her students, unlike needlework where she had not been expected to deliver content in the same way

It never occurred to her, she now confessed, that she could share her dilemma with the children – by asking them *why* they were so unmanageable. *"Only after I began doing Action Research did I realize that this was an option,"* she admitted. *"You see, I was always thinking that I was the cause of the problem."* Her acutely felt disadvantage by being a popular teacher's replacement was also shared by her. *"This was explicitly thrown to me as a challenge by two of the kids,"* she confessed. *"It became more of a burden for me than I could bear. I was so enmeshed in the problem that I could not come out of the situation to look at it objectively."* Despite all this preoccupation with classroom management, however, she did manage to cover the prescribed content in the first term. She also noticed that the problem became acute only when the new entrants from Class IV joined those in Class V. *"I was new to teaching, so initially, I was more preoccupied with transaction of content. But soon classroom management became the core issue."*

As soon as she embarked on Action Research, the teacher employed an initial strategy of storytelling to hold the attention of her otherwise chaotic class, followed by an integration of the current lesson on *panchayati raj* (rural self government) into the management of her class. (Both the story-telling as well as the integration of the *panchayati raj* into classroom management had been suggested to the teacher as possible strategies, by the facilitator.) As she described the system of *gram panchayat*, she suggested to the class that they elect their own " *sarpanch*" (village head) and arrive at their own form of classroom management. The ensuing excitement amongst the nine- and ten-year-olds resulted in her acceding to their request to elect a new *sarpanch* every week, as every child wanted to be the „village" head. The teacher left it to each week's *sarpanch* to decide upon the corrective action to be taken against errant children. This sometimes resulted in harsh punishments being doled out by children to their fellows, something the facilitator came to know of – and sought to address – in the next month's visit. In the teacher's words:

They wanted me to take the responsibility of giving consequences for their misbehaviour. That did not work anymore, so the system had to be dissolved.

The facilitator observed that the teacher was resisting taking firm action against errant children, and now the students were turning the problem back to her. Using Tony Ghaye's (Ghaye, 1998) approach of building on the strengths of a teacher, the facilitator wrote as below to the teacher:

I have been doing some thinking as to how I can be of help to you in addressing your core issue. I suspect that we have focused solely on the problem and forgotten your core strengths: one of them being your loving and compassionate nature. Many teachers would envy you for the asset that you possess: not a single child is scared of you, I think! That is *a very great strength...In order to help you think this through, I am listing below some questions that I culled from an excellent book* (Ghaye, 1998).

Among the questions posed were the following: *1. What was your best day at work in the past month? What were you doing? 2. Why was it the "best day?" How far do you think you could re- experience it? 3. What was your worst day at work in the past month? What was going on? 4. Why did it drain or weaken you so much? What frustrated or bored you?*

This resulted in a change in strategy employed by the teacher, who now acknowledged the need to forge individual bonds with the children. She waited for the right opportunity and employed different strategies with each child, e.g. with some, she spoke to the parents, while with others, she observed their special interests and used those as entry points. For instance, she recorded one such case as below:

I made her participate in group activities - growing a patch of grains as a project, and she fared very well, as she was sincere and hardworking. Her patch of grains grew so well that it became a model for the others. That made me understand her strength.

With another boy, she employed a different strategy:

During one of his parents" visits, he was very scared that I would give a bad report about him. But I did not complain about him. That instilled respect towards me and he started responding differently. Earlier, he never bothered to listen. Now he tries to convince me, and if I reason it out, he responds.

Slowly, a turnaround began to happen in the class. The teacher recorded that her class was becoming manageable. She felt confident enough to direct a skit staged by this class in the school's assembly. During rehearsals, she forged stronger bonds with the children. The facilitator, in turn, noted that a focus towards content and pedagogy was beginning to rear its head:

So she is now reflecting on ways and means of balancing firmness with love, kindness with fairness, etc. I can also see the beginnings of a concern with pedagogy (her original Action Research problem) creeping in, now that class management is slowly getting resolved. I hope to see more of this emerge in the days to come, provided, of course, that classroom management truly does get resolved for her in a sustained manner.

During discussions, the facilitator found that the teacher was raising more questions of the type: "*How can I teach this better?*" in place of "*How can I get the kids to settle down and pay attention?*"

In turn, the teacher's notes ran thus: *"Now I can see clearly that children are enjoying the classes. The project of the Chinese dragon is going on parallelly. I will be starting Asia next week, and go to the countries, so that I will have time for all the countries planned. So far so good."*

SHIFT IN ACTION RESEARCH PROBLEM

By the third month, the teacher had reached a high level of comfort with her students, as they, too, had with her. She noted in her diary:

Now my main concern has shifted to the content of the lesson. I am so happy that from the non- cooperation level, they have come to a stage where they listen - or if not, at least sit quietly, without disturbing others.

Indeed, by the fourth month, only one student in this teacher's class could be seen to not participate at all, but this student did not interfere with the others" attention as he had, in fact, been doing in the past. (The teacher has decided to work with this student differently, and at a slower pace.) In turn, the facilitator recorded as below:

- From January, February to March, I can see a remarkable shift.
- R is much firmer with her students and there is far greater attention.
- The periods of attentive silence are now far longer than the noisy interludes. Previously, it was the reverse.
- I would say she has addressed about 70% of classroom management issues. She still needs to tackle the die-hards appropriately. (e.g. One boy blithely told her he didn't have his notebook, and when she asked him why, he shrugged airily and said – "I told you that I lost it three weeks ago". R left it at that.)
- Several questions were raised by children - all related to the subject, though some were tangential to the lesson. Till date, I have only seen kids ask irrelevant questions in her class. (*"Akka, why is he saying this/that...", or "Akka, why is she pulling her desk?"* etc.)
- Even today, she had a child walk into her class full twenty minutes after it started, and apparently, she did not feel free to take firm action/address the issue appropriately. The boy also smiled his way into class.

The electronic exchange between facilitator and teacher now began to gradually shift more to issues related to content and pedagogy. Slowly and surely, the Action Research Problem shifted back to the original issue:

In my class of heterogeneous learners (mix of IV and V), how can I get all students to be completely engaged in EVS?

The discussions between teacher and facilitator now veered around learning outcomes, lesson plans, activities and their alignment with learning outcomes, and assessments that tied the whole lesson together. The facilitator noted the enthusiasm and interest shown by the teacher in enlivening her lessons with contextual examples and activities. By the fourth month, there was a dramatic shift in classroom transaction, as noted by the facilitator:

It is remarkable how the discussion with R these days is mainly on pedagogy and content and hardly ever about classroom management. She has shifted a great deal from her original location.

Some extracts from the teacher's diary at this stage are as below:

I have grown a lot during this process. First of all, regular documentation helped me immensely. I knew day-to-day whether I was performing properly in terms of quantity and quality, if I was fair to every child, was I taking all the children into consideration, etc. I am very happy to note that I did not have a single incident where I felt sorry for my behaviour. The action research process really instilled a lot of confidence in me - in spite of my age - that I will be able do my job without constraints, as I knew I had continuous, unconditional help from the facilitator. The timely suggestions helped me to overcome problematic situations. Looking back, I don't see any strategy which failed... only a couple of children are still a little away, to be on board. But I am very happy to say I have won over most of *them.*

In addition, the facilitator's observations of a class in the fourth month was recorded (and exemplified) as below:

- *Questions were being raised by R about the likely cause of magnification (lesson was on this topic today)*
- *Children asked questions, some of them very good questions indeed.*
- *She made me think: and she certainly made many kids think! She was not in a hurry to provide the answer; instead she kept prodding them to think more and more*
- *She managed to elicit fairly good responses, albeit from the same boy over and over again*

Students asked questions like what would happen if they looked at an object through a flat glass slide (wherein they saw minimal distortion), and followed this with placing a drop of water on the slide and *then* viewing things through this. Would the image then be magnified? Instead of giving them the answer straight away, the teacher asked the students to try this out - and then, *take a guess* as to why the flat side of a slide did not magnify images but placing a drop of water on it did. Another student asked how things would look if viewed from the flat side of the slide with a drop of water on the *other* side. This led the teacher to talk about concave and convex lenses. The facilitator noted with interest the simple language used by the teacher to explain the bending of light, magnification of images by curved surfaces and apparent distortion of the image of a pencil standing in a glass of water. It was a new way of understanding these concepts for the facilitator, as she had been trained in Science and was accustomed to employing technical jargon. The facilitator experienced a fresh way of looking at the process of magnification of the bent pencil as well as apparent distortion of the immersed part, as she listened to the teacher transact this content in class.

Four months into the action research process, this teacher shared with amusement how she had been called by one of her colleagues to „manage" a class during the absence of their scheduled teacher. *"From one who was being told by neighbouring teachers to hurry up and get her class to settle down, this was certainly a new experience!"* she chuckled. On another occasion, the Principal heard students excitedly share with each other (over lunch) how much their EVS teacher had changed. *"Ratnakka has become strict - but I like it!"* During an informal exchange with more than one student of this class, the facilitator heard students say: "I like EVS classes, especially Science. I really like the way *akka* teaches…" When the new academic year began, the teacher shared as follows in her electronic exchange with the facilitator: For the past three days, class V children- who were in class IV last year- kept asking me: *"Akka, why don't you come for Science and Social for us?" So it is that children get used to a teacher, and take time to adjust to a new one."*

CONCLUSION

The framework of Action Research proved to be very effective for this teacher, despite her being new to teaching and her beginning to teach fairly late in life (she is a senior citizen). Simply by delving into the day-to-day issues that she faced in a systematic and sequential manner, this teacher overcame what initially seemed to be insurmountable issues. Stereotypes are inevitable in any community and fighting them is seldom easy. Coupled with her natural (and remarkable) tendency to disallow the taking of any opinion personally, this teacher made effective use of the Action Research framework to swiftly move out of the mould that many appeared to have cast her into. Also, her systematic approach brought her well out of the complex set of problems which she had initially felt enmeshed in. Today, her palpable enjoyment in teaching the subject (after her initial struggle to just communicate to her class) has brought her a long way from her original location. Doubtless, the persona of the teacher plays a huge role in the way that this process pans out, as seen by the experience of the facilitator who has been working with several teachers over the past year. It is, of course, not realistic to expect such dramatic results for every teacher in a matter of four months. Nevertheless, it is quite likely that this method could, in time, meet with success with other teachers who encounter similar issues.

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References

Brock, M. N., Yu, B., & Wong, M. (1991). Journaling together; collaborative diary-keeping and teacher development. Paper presented at the *International Conference on Second Language Teacher Education*, City Polytechnic of Hong Kong, April 1991.

Chambers, P. A., & Clarke, B. L. (1999). Using case studies for implementing reflective practice in in- service teacher education. Paper presented at *the TNTEE Lisbon Conference*, May 1999. Retrieved from http://tntee.umu.se/lisboa/papers/full- papers/pdf/F4PAChalmers.PDF

Conderman, G., & Moris, J. (2004). Reflect upon your practice. *Intervention in School and Clinic 40*(2), 111-115.

Costa, A., & Garmston, R. (1994) *Cognitive coaching: A foundation for renaissance schools*. Norwood, MA: Christopher-Gordon.

Costello, P. (2011) *Effective action research: Developing reflective thinking and practice (Continuum Research Methods).* NY: Continuum International Publishing Group.

Fazio, X. (2009). Teacher development using group discussion and reflection within a collaborative action research project. *Reflective Practice-International and Multidisciplinary Perspectives, 10*(4), 529-541.

Ghaye, T. (1998). (and later re-published in 2010). *Teaching and learning through reflective practice- A practical guide for positive action*. Britain: David Fulton Publishers.

Gore, J. M. (1993). *The struggle for pedagogies: Critical and feminist discourses as regimes of truth*. New York: Routledge.

Guba, Y. S., & Lincoln, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage

Pak, J. (1985) *Find out how you teach*. Adelaide, Australia: National Curriculum Resource Centre

Powell, J. P. (1985). Autobiographical learning. In Boud et al. (Eds.), *Reflection: Turning experience into learning* (pp. 41-51). London: Kogan Page.

Raghavan, N., & Sood, V. (in press). The reflective teacher: Case studies of action research. Orient Blackswan [under publication at the time of submission of this paper]

Richards, J. C., & Lockhart, C. (1991-92). Teacher development through peer observation. *TESOL Journal*, *1*(2), 7-10.

Schon, D. (1983). *The reflective practitioner: How professionals think in action.* London: Temple Smith.

MATHEMATICS AND SCIENCE ASSESSMENT FOR 12 YEAR OLD STUDENTS – THE ROMANIAN EXPERIENCE: INCREASING THE EFFECTIVENESS OF THE TEACHING-LEARNING ASSESSMENT PROCESS USING INFORMATION AND COMMUNICATIONS TECHNOLOGY

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To facilitate interdisciplinary standardized assessment, we implemented a national assessment program for 12-13 year-old students in Romania, using tests combining notions from mathematics and science. These tests are evaluated based on clustered codes. Each code presented in the encoding pattern is associated with a descriptor and is followed by a list of examples. The encoding pattern has been computed into an electronic application that lists each student's strong points and weak points in relation with the disciplinary competencies (mathematics, physics and biology) and the six interdisciplinary competencies that we specified. Using the list of strong and weak points expressed in action verbs, and detailed facts for each content assessed, teachers can develop individualized learning plans for their students.

BACKGROUND

We present a national assessment program that offers standardized information regarding students' knowledge and competencies and specific feedback for the teaching – learning – assessing process. To increase the effectiveness of this complex process, we have developed and implemented an interdisciplinary tool that prospectively identifies the areas where individual or collective adjustment is warranted.

Since 2014, in Romania we are employing a national assessment strategy (External National Assessment) for 2nd graders (8 – 9 years old), 4th graders (10 – 11 years old) and 6th graders (12 – 13 years old), complementing the national disciplinary exams already in place. We present an assessment of the 6th graders' ability to operate with and interconnect the content of mathematics and science (physics and biology) that they have already learnt. We are currently (2015) in the second year of applying this strategy; approximately 200,000 students were involved each year in this nationally-applied strategy for personalizing the teaching – learning – assessing process.

The results of this External National Assessment are available to teachers of mathematics, physics and biology, to students and their parents. Using the computer application developed, each student's results for each item are analyzed and an interpretation is provided on individual, class, school, regional, and national level. Teachers use the test's output to pinpoint the individual learning needs of students, to set learning objectives, adjust teaching strategies, initiate potential remedial activities, and plan learning activities.

The novelty behind these tests relies in their ability to provide a diagnostic assessment as well as a formative one. Through the use of these tools, teachers can identify particular skills, attitudes and aptitudes for each student, and make early decisions about future learning opportunities, thus providing personalized teaching assistance based on individualized learning programs.

CONSTRUCTING THE TEST

The tests were elaborated in several steps: devising the interdisciplinary competencies, projecting the specifications matrix, designing the test, elaborating the specific items and the encoding pattern (Streinu-Cercel & Cristescu, 2014). The tests were designed in accordance with the quality cycle: plan-do-check-act.

Six interdisciplinary competencies (IC) were derived from the general and specific competencies of the school's curricula in mathematics, physics and biology. We assess the following interdisciplinary competencies (Streinu-Cercel & Cristescu, 2014):

IC1. Identifying data, concepts, specific relations of mathematics/science in an interdisciplinary context

IC2. Processing the following types of data: quantitative, qualitative, specific structural mathematics/science contained in various data sources

IC3. Using concepts, algorithms and procedures of mathematics/science to locally or globally characterize a particular case

IC4. Expressing the quantitative or qualitative characteristics of a particular situation in the specific language of mathematics/science

IC5. Analyzing the characteristics of relationships, phenomena or processes specific to mathematics/science, based on real or hypothetical situations

IC6. Interpretation of problem-situations specific to mathematics/science by integrating knowledge from different fields

Competencies are stated in action terms – Bloom's cognitive levels (Bloom, 1994) –, as they cross-link stages of the teaching – learning – assessing process, categories of skills, and informational feedback, on skills and cognitive levels. In Romania, the mathematics curricula are designed on six competencies associated with Bloom's cognitive levels. Subsequently, the national evaluation in mathematics is based on six assessment competencies also associated with Bloom's cognitive levels. Taking into account the particularities of this national assessment strategy, cognitive levels of the interdisciplinary competencies are those from the school's curricula in mathematics (Streinu-Cercel & Cristescu, 2014).

Each test contains a total of 15 items of mathematics, physics and biology, introduced in a general context and three specific contexts, as shown in Table 1. The items are not specific to a particular discipline (for example, items of physics include mathematical calculus), but roughly there are five items for each discipline (CNEE, 2012).

General context					
Specific context 1		Specific context 2		Specific context 3	
Item 1.	Mathematics	Item 6.	Mathematics	Item 11.	Mathematics
Item 2.	Mathematics	Item 7.	Mathematics	Item 12.	Physics
Item 3.	Physics	Item 8.	Physics	Item 13.	Biology
Item 4.	Physics	Item 9.	Biology	Item 14.	Physics

Item 5.	Biology	Item 10.	Biology	Item 15.	Biology

Table 1: Test design

CALIBRATING THE TEST

In order to obtain accurate information at different levels (student, class, school, regional and national) the tests used in this national assessment program were calibrated using the Item Response Theory, which adopts explicit models for the probability of each possible response to each item. Through IRT the probability of each possible response is derived as a function of ability and some item parameters (Hambleton & Swaminathan, 2000). We have used IRT to obtain the likelihood of ability as a function of the actually observed responses as well as item parameters. The ability value that has the highest likelihood becomes the estimated ability (Partchev, 2004). The IRT model has to be true (correct) and the item parameters known. Calibration studies have been performed in 2012, 2013, and 2014 by giving the items to a representative number of tested students and computing their responses to estimate the item parameters.

We used the Three Parameter Logistic (3PL) model (Partchev, 2004) to correlate students' abilities in mathematics, physics and biology with their test performance. The item i is characterized by the parameters a_i, b_i and c_i and the probability of a random student having the ability θ to respond correctly to item i is given by:

$$P_i(\theta, a_i, b_i, c_i) = c_i + (1 - c_i)\frac{e^{a_i(\theta - b_i)}}{1 + e^{a_i(\theta - b_i)}},$$

where a_i is the item discrimination parameter, b_i is the item difficulty parameter and c_i is the probability of a correct response when true ability approaches $-\infty$ (Streinu-Cercel & Cristescu, 2014). Then, for each test we chose samples that were statistically identical (up to negligible random variation). The items of each test were applied on those samples and on data collected this way, both with an initial estimate of the ability level, were used to determine the probability of correct answer. The probability of correct answer was plotted depending on ability level and we determined the item's parameter values.

For each test, the likelihood function has been calculated based on the values already determined for the parameters of the items:

$$L(\theta) = \prod_{i=1}^{n} P_i^{u_i}(\theta, a_i, b_i, c_i)\left(1 - P_i(\theta, a_i, b_i, c_i)\right)^{1-u_i},$$

where $u_i \in [0,1]$ is the score on item i; $u_i = 0$ if the student answered incorrectly at item i and $u_i = 1$ if the student answered correctly at item i. For each student in the sample, the ability was set at the particular value that maximizes the likelihood function. We take $\theta^* = l\theta + k$, where l and k are constants, and we obtain a normal distribution of abilities for the students (mean of 0 and standard deviation of 1). The 3PL model can thus be adjusted to accommodate the linear transformation of ability by taking $a_i^* = \frac{a_i}{l}$, $b_i^* = lb_i + k$ and $c_i^* = c_i$. Since,

$$P_i(\theta^*) = P_i(\theta),$$

the probability of a correct response is invariant to these transformations. For these tests, the difficulty parameter b_i^* varied between -1.8 and $+1.3$.

For each test, we obtained the test characteristic curve by plotting the probability that a student with the ability θ will obtain a certain score to the test, using,

$$\xi(\theta) = \sum_{i=1}^{n} P_i(\theta)$$

(Streinu-Cercel & Cristescu, 2014). The tests were constructed to provide virtually identical curves, independent of item-specific context.

ENCODING PATTERN - COMPUTER APPLICATION ASSOCIATED

This national assessment program is based on a novel process for result interpretation. The tests are not graded, but are instead evaluated based on clustered codes. Thus, students receive individual feedback (translated into personalized learning plans) but clustered feedback is also provided at class, school, regional and national level, and each teacher can generate personalized teaching plans (Streinu-Cercel & Cristescu, 2014).

Each score in the encoding pattern has an associated descriptor. To ensure that the teachers (mathematics, physics and biology) that assess each test select the most appropriate evaluation code, we provide detailed examples.

We present as an example an item and its encoding pattern from one of the assessor's brochure:

Code	21	11	12	13	00	01	99

One diorama exhibits 60 birds, mammals and reptiles. The number of birds represents 30% of the number of exhibits, and the number of mammals is equal to the number of reptiles. Determine the number of reptiles presented in this diorama.

Total score

Code 21: complete and correct reasoning and solving. Correct answer: 21 reptiles

Examples:

- $\frac{30}{100} \cdot 60 = 18$ birds

$60 - 18 = 42$ and $\frac{1}{2} \cdot 42 = 21$, thus there are 21 reptiles

- $\frac{1}{2} \cdot \left(60 - \frac{30}{100} \cdot 60\right) = 21$ reptiles
- $100\% - 30\% = 70\%$, $\frac{1}{2} \cdot 70\% = 35\%$, that means that there are $\frac{35}{100} \cdot 60 = 21$ reptiles

Etc.

Partial score

Code 11: partially correct reasoning, calculations correct but incomplete

Examples:

- $\frac{30}{100} \cdot 60 = 18$ birds, $60 - 18 = 42$
- $30\% \cdot 60 = 18$ birds

Etc.

Code 12: partially correct reasoning, calculation errors

Examples:

- $\frac{1}{2} \cdot \left(60 - \frac{30}{100} \cdot 60\right) = \frac{1}{2} \cdot 60 - \frac{30}{100} \cdot 60 = 12$ reptiles
- $\frac{30}{100} \cdot 60 = 20$ birds, $60 - 20 = 40$

Etc.

Code 13: correct answer without justification. 21 reptiles

Zero score

Code 00: incomplete reasoning (correct statements) but not specific enough

Example:

- We can calculate the number of reptiles by subtracting the number of mammals and birds from the total number of exhibits

Code 01: other responses

Code 99: no answer

In Table 2 we present the encoding pattern for the item above that requires basic knowledge of percentage, ratio and proportion as well as basic calculus, with the correspondences among the codes associated to the item, the descriptors for each code and the positive/weak remarks that are used to generate personalized teaching plans.

Code	Descriptor	Positive remarks	Weak remarks
21	- complete and correct reasoning and solving the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus	- usage of percentage, ratio or proportion as well as basic calculus for correct and complete solving of the task	
11	- partially correct reasoning, calculations are correct but incomplete for the task that	- partially correct reasoning for the task that requires basic knowledge of percentage, ratio and proportion as	- the usage of percentage, ratio or proportion wasn't accurate enough to solve

	requires basic knowledge of percentage, ratio and proportion as well as basic calculus	well as basic calculus - correct usage of percentage, ratio or proportion, correct but incomplete calculations	the task
12	- partially correct reasoning, calculation errors for the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus	- partially correct reasoning for the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus	- calculation errors
13	- correct answer without justification for the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus	- correct answer without justification for the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus	- didn't present any steps in reasoning or calculation leading to the correct result for the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus
00	- incomplete reasoning (correct statements) but not specific enough for solving the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus	- correct general statements about percentage, ratio or proportion, but not specific enough for solving the task	- incomplete reasoning; the correct statements written about percentage, ratio or proportion weren't applied to the actual data of the problem
01	- didn't write correct statements about percentage, ratio or proportion		- didn't write correct statements about percentage, ratio or proportion
99	- no answer, no proof of attempting to solve the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus		- didn't show any attempts to solve the task that requires basic knowledge of percentage, ratio and proportion as well as basic calculus

Table 2: Encoding pattern for item no. 11: codes, descriptors, positive remarks, weak remarks

A computer application has been designed to extract from this encoding pattern strong points and weak points for each student in relation with each of the six interdisciplinary competencies, expressed in action verbs, as well as detailed facts for each content assessed. Based on this output, teachers (mathematics and sciences) can design an individualized learning plan for each student (Streinu-Cercel & Cristescu, 2014).

Each student receives a feedback sheet that contains two parts: the first part contains the codes designated after reviewing of her/his paper and the second part contains her/his strong points and weak points.

Strong points (+)	- identification in a table/diagram of quantitative data specific for Math & Sciences (Item 1, Item 12) - processing (comparison and/or calculation using integer numbers) of quantitative data specific for Math & Sciences (Item 2, Item 12)

	- identification of measurements in physics with the same unit (Item 3) - representation of an electrical circuit (Item 4) - association of life forms with their environment (Item 5) - adequate reasoning using information from the text in order to calculate the perimeter of a triangle (Item 6) - using of parallelism properties, properties of rectangle, isosceles and/or equilateral triangle together and/or properties of symmetry to deduce relations and to prove congruence of two triangles (Item 7) - calculations with rational numbers (Item 8, Item 14) - correct reasoning using the relation between the distance and the time of movement (Item 8) or between mass and density (Item 14) - identification of amphibians' adaptations (types of movement) to the environment (Item 9) - identification of type of breathing for four groups of life forms (Item 10) - adequate reasoning, analyzing data and usage of percentage, ratio or proportion as well as basic calculations for correct and complete solving of the task (Item 11)
Weak points (-)	- errors in analyzing the correct operating of an electrical circuit (Item 4) - errors in transformations of measurement units (Item 8, Item 14) - didn't prove the knowledge of evolutionary characteristics of studied life forms (Item 13) - indicates a living organism with an impact on environment without explaining its role (Item 15)

Table 3: Example of Part 2 of one feedback sheet regarding strong points and weak points

The computer application is user friendly. The list of possible codes is predefined and checkboxes are provided; thus, the teacher only needs to tick the codes for each student. The computer application automatically generates the list of strong/weak points. Once all the data regarding student's answers have been recorded, the application permits many types of data interpretation at different levels: student, class, teacher, school, regional and national. One of the important things about data analysis is that the application also enables extraction of data specific to any content and each competency. For example, if we are interested in the *IC.1 Identifying data, concepts, specific relations of mathematics/science in an interdisciplinary context* we can see if a student is able to identify data that he/she can use in mathematics tasks but he/she is not able to identify data that can be used in biology tasks; in this case, the area where further work is needed is not at the competencies level but at disciplinary level. On the other hand, if one student has issues on all contents with *IC.5 Analyzing the characteristics of relationships, phenomena or processes specific to mathematics/science, based on real or hypothetical situations*, the approach should be multidisciplinary.

The data that the computer application provides can be used at teacher's level if most of the students of one teacher are showing the same difficulties, at school level for deciding the strategy for teachers' professional development, and at regional and national level in order to implement educational policies.

Using the test characteristic curve and the distribution of test scores, we can also determine the students' ability in mathematics and science and compute their distribution among the school population.

The report summarizing the results of national assessments applied in 2014 at the end of the 2nd, 4th and 6th grades was published in 2015 (CNEE, 2015). The feedback from Mathematics and Sciences teachers from Romania was that the procedure is labor-intensive (reviewing tests, putting together individualized learning plans, remedial worksheets, etc.), but that, when correctly implemented, it can have a substantial impact on increasing the performance in students.

CONCLUSIONS

We have developed a state-of-the-art interdisciplinary tool that, associated with a computer application, can provide individual feedback for each student, as well as clustered feedback at class, school, regional and national level. By using clustered codes instead of classical grading systems, we are now able to provide personalized learning and teaching plans. This national assessment strategy can thus identify the areas where adjustment is needed to increase the effectiveness of the teaching – learning – assessing process.

This national assessment strategy has the potential to generate a database for remedial teaching-learning-assessment activities, as well as actions recommended specifically for each type of performance descriptor from the encoding pattern.

Given the formative nature of this assessment strategy, we expect that students who were evaluated in 2014 at the end of their 6th grade through this strategy will have better results at the end of the secondary school (8th grade), when they will pass their certificate assessment. These results will become available in 2016, and a statistical analysis will be performed at that point.

References

Bloom, B. S. (1994). *Bloom's taxonomy: A forty-year retrospective*. In K. J. Rehage et a. (Eds.), *Yearbook of the national society for the study of education, 93*(2). Chicago, IL: National Society for the Study of Education.

CNEE (2012). Ghid de elaborare a subiectelor pentru evaluările prin probe transdisciplinare, la finalul clasei a VI-a, www.rocnee.eu/Files/Ghid_evaluare_clasa_a VI-a.pdf

CNEE (2015). Evaluările Naționale la finalul claselor a II-a, a IV-a și a VI-a. Raportul administrării 2014, www.rocnee.eu/index100.htm, (pp. 173-211), Anexa 3B, 535-565.

Hambleton, R. K., & Swaminathan, H. (2000). *Item response theory – Principles and applications.* Boston: Kluwer Nijhoff Publishing.

Partchev I. (2004). *A visual guide to item response theory*. Friedrich-Schiller Universität Jena.

Streinu-Cercel G., & Cristescu B. (2014) Interdisciplinary (Mathematics, Physics and Biology) national assessment in Romania – personalized teaching and learning plans. In Union of Mathematicians of Macedonia (Eds.), *Proc. of the 5th. Congress of Mathematicians of Macedonia* (Section: History and Education of Mathematics and Informatics, pp. 98-107). Ohrid, Republic of Macedonia.

CLASSICAL-QUANTUM INTERFACE AT UNDERGRADUATE LEVEL: VISUALIZATION OF 'WAVEFUNCTION'

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Quantum Mechanics (QM) forms the most crucial ingredient of modern-era physical sciences course curriculum at undergraduate level. The abstract ideas involved in appreciating QM concepts are significantly difficult to visualize due to their counter-intuitive nature and lack of experiment-assisted visualization tools. In the heart of quantum mechanical formulation lays the concept of 'wavefunction' which forms the basis for understanding behaviour of physical systems. For example, squaring the modulus of 'wavefunction' (for a state) provides us the information about probability density which can be used for determining the probability of finding a particle in that state. At tertiary level, the concept of 'wavefunction' is introduced in an abstract and mathematical framework which opens up an enormous scope for alternate conception and improper visualization. In the present study, we attempt to explore and comprehend the visualization models constructed by undergraduate students for appreciating the concept of 'wavefunction'. We present qualitative analysis of a data obtained from administering a questionnaire containing 4 visualization based questions on the topic of 'wavefunction' to a group of 10 tertiary-level students of an institute in India which excels in teaching and research of basic sciences. Based on the written responses of students, all the 10 students were interviewed in detail to unravel the exact areas of difficulty in appropriate visualization of 'wavefunction'.

INTRODUCTION

Quantum mechanics (QM) forms the backbone of present-day physical as well as chemical sciences and its roots have now spread into domains of engineering streams especially in the area of communications. The fundamental concepts and formulations in QM are introduced at undergraduate curricula and in general, these concepts are presented in an abstract and mathematical framework to the students. It is apparent from previous researches in the area of physics education research (PER) that the students face difficulty in understanding various aspects of basic QM which includes probabilistic interpretation of particle's location (Bao & Redish, 2002), concepts related to probability density (Singh, 2001), measurement in QM as well as time-development of quantum states (Johnston, Crawford & Fletcher, 2007) and many more (Styer, 2008; Singh, 2008; Redish, Bao & Jolly, 1997). An innovative route for assisting students to appreciate quantum mechanical concepts could be achieved by equipping them to 'visualize' the problems in QM at the fundamental level (Ayene, Kriek & Damtie, 2011; Greca & Freire, 2014). In addition to its impact on students majoring in physics, visualization of relevant aspects of 'core-level' QM problems (such as 1-D finite and infinite potential well, spherically symmetric potential well, Hydrogen-atom problem) would be immensely helpful for students majoring in chemistry (Tsaparlisa & Papaphotis, 2009; Dangur, Avargil, Peskin & Dori, 2014). This could be easily derived by noting the fact that concepts related to orbitals, overlap of orbitals, allowed electronic transitions etc. is a straightforward manifestation of spatial distribution and overlap of eigenfunctions corresponding to identical or different eigenstates (Steinberg, Wittmann, Bao & Redish, 1999).

An important feature of QM lies in the technological difficulty in performing simple experiments which could illustrate underlying QM concepts. Although, there have been attempts made in this direction such as interference using correlated photons, the complexity and sophistication required to perform these experiments renders them impractical for an undergraduate teaching laboratory (Galvez et al., 2005). This results in escalation of difficulty level for students towards establishing a correlation with the classroom teaching with actual or real outcome. This, in turn, could lead to inappropriate visualization of basic QM concepts (Hiller et al., 1995). It has been often found that the visualized models for appreciating QM concepts strongly interfere with the visual frames existing with them for understanding topics in classical mechanics or electromagnetism (Hadzidaki, Kalkanis & Stavrou, 2000). At times, this results in over-simplification of problems and inappropriate understanding. For example, after years of experience in a seemingly deterministic world, reinforced by learning classical physics, students develop a strong deterministic view of the physical world (Paoloni, 2007). On the other hand, the domain of QM considers probabilistic representations to be fundamental to the understanding of physical world which is contrary to the deterministic ones. This may strongly interfere with the process of constructing a consistent mental model amongst students at undergraduate level. This interference of thoughts is an important source for development of alternate framework of concepts in QM (Cataloglu & Robinett, 2002). For example, the concept of 'wavefunction' or 'state vector' lies at the core of quantum mechanical formulation which is quintessential for obtaining probability, expectation value, uncertainty etc. An improper visualization of wavefunction in terms of its time evolution or physical interpretation could result in incorrect conception of quantum mechanical quantities. Styer, in his seminal work have shown that the students tend to exhibit varied misconceptions in interpreting 'wavefunction' or 'state vector' from the perspective of its definition and its importance in identifying particle's motion (Styer, 2001). In the present work, we explore the visualization models constructed by the undergraduate students and the physical interpretation of concept of 'wavefunction' or 'eigenfunction' of a state. Here, we primarily focus on the students' visual constructs of the concept of wavefunction and its interpretation in terms of applying them in physics.

OBJECTIVES AND METHODOLOGY

This is a qualitative study in which we have made an attempt to explore learners' mental models. In order to ascertain the students' visualization of quantum mechanical 'wavefunction', we chose question nos. 5, 6, 9 and 12 from Quantum Mechanics Visualization Instrument or QMVI[1] which is specifically designed for ascertaining students' visual construct of various QM related concepts (Cataloglu & Robinett, 2002). QMVI is in the form of multiple choice questions with five options out of which only one is correct. In order to identify the conceptual understanding, authors of QMVI have tried to construct questions which primarily involved visual representations of potentials, wavefunctions, energy eigenstates etc. with little or no mathematics. However, the students were needed to appreciate the relationships between various physical variables and their role in determining dynamics (both classically and quantum mechanically) of the system. It is worthwhile to note that content of QMVI substantially matches with QM curriculum adopted by a majority of institutions of higher scientific learning in India and in congruence with the syllabus prescribed by University Grants Commission (UGC), India. Q5, Q6, Q9 and Q12 of QMVI was administered in the form of written test to 10 students (S1 to S10) of National Institute of Science Education and Research (NISER) which is a government-aided institute excelling in teaching and learning of basic sciences. Due permission was obtained from the institution as well as the concerned teacher who was teaching Quantum Mechanics in that semester. Learners were also apprised of the test as well the objective of the study. Their permission was also sought for publishing their data.

At the time of administering QMVI, the students had already credited one course on classical mechanics (includes Lagrangian and Hamiltonian formulation), one basic course in QM (includes solution of Schrodinger equation for various potential functions, wave-packets, time-independent perturbation theory etc.), two courses on electromagnetism (includes static electricity & magnetism, boundary value problems, Maxwell's equations, dipole radiation, special theory of relativity etc.), level-1 course on statistical mechanics (includes basic thermodynamics as well as statistics of classical and quantum systems) and one basic course on condensed-matter physics. Written responses were analyzed question-wise with a focus on thinking and logic adopted by the students. Based on this preliminary analysis, all the 10 students were interviewed in detail so as to identify the existing mental models. The interview was semi- structured in nature which was primarily meant to uncover the method of reasoning adopted by the students which would distinctly elucidate difficult aspects of visualizing 'wave function'. Subsequently, the students' interviews were transcribed. The data of both – written responses as well as interviews was analyzed and presented together as they both formed a logical unit. The analysis was done from a constructivist perspective with an underlying assumption that each individual constructs his/her own knowledge based on their previous experience and knowledge. Therefore, there remains a possibility that the students' constructs could be significantly divergent from well-accepted knowledge of the present era. These divergent constructs are called alternate conceptions or misconceptions and our method of analysis essentially helped in delving into the possible reasons for such misconceptions amongst students' in the area of QM. Hence, the primary objective of this study is to identify and bring out the core issues encountered by the students in visualizing various aspect of the concept related to 'wavefunction'. Our analysis and outcomes indicate towards plausible pedagogic strategies which could be employed for providing a more conducive environment for learning abstract concepts in the subject area of QM.

DATA SUMMARY

The students' written response to Q5, Q6, Q9 and Q12 of QMVI is summarized in Table-1 below. Q5 of QMVI aimed at bringing out student's understanding of 'wavefunction' or 'eigenfunction' for a state or alternately 'state vector'. This question required the knowledge about calculation of 'probability of finding a particle' from the 'wavefunction associated with the state' in equally thick regions in real space. The written responses indicated that an overwhelming majority of students displayed appropriate level of understanding (see Table 1). One student (S7) who chose option (c) identified his mistake during the interview and attributed the choice to temporary lack of concentration. However, probing a solitary concept such as $|\text{wavefunction}|^2$ = probability density, may lead to an incomplete picture about student's comprehension on applicability of the concept of 'wavefunction' in different situations. This point is apparent in the subsequent questions Q6, Q9 and Q12 of QMVI. A noticeable point which emerged out from the interviews was that the students used the term 'probability' and 'probability density' interchangeably. Though, in majority of the cases, the students meant ‘probability density’, they instead used the term ‘probability’. This particular aspect could have been probed better if the interval (dx) in the region I, II and III in Q5, would have been unequal.

Q6 of QMVI focused on comprehending the relationship between ‘probability’ and ‘wavefunction’ for a hypothetical representation of wavefunction. Additionally, the question needed understanding of the concept of ‘normalization’ of wavefunction which is quintessential for describing physical reality. The written responses showed that 7 students (S1 and S3-S8) chose the correct option (a) and 3 students (S2, S9 & S10) chose option (d) which could be seen in Table-1. However, in the interview, S9 provided a correct description of the recipe for calculation of ‘probability’ after ‘normalization of wavefunction’ and acknowledged the mistake in his choice. Also, S10 adopted a similar route to obtain the probability but used the ‘|wavefunction|’ while carrying out the normalization, instead of ‘$|\text{wavefunction}|^2$’, thereby obtaining a numerical value given in option (a). The existence of an alternate conceptual framework of ‘wavefunction’ was evident in the response (both written and oral) of S2 who said “In order to normalize the wavefunction, the limits for integration or summation would be −2A to +3A (along y) and −2a to +4a (along x)”. This particular response by S2 exemplifies various interpretations made by students when they encounter the terms like ‘area under the curve’. Although the students are introduced to topics such as ‘functions and variables’ at the post-secondary or sophomore level, the understanding of ‘dependent’ variables such as fields and wavefunctions and ‘independent’ variables such as space & time in various contexts still remains a grey area amongst students.

Question no.	[a]	[b]	[c]	[d]	[e]
Q5	0 -	0 -	1 (S7)	0 -	9 ** (S1,S2,S3,S4,S5, S6,S8,S9,S10)
Q6	7 ** (S1,S3,S4,S5, S6,S7,S8)	0 -	0 -	3 (S2,S9, S10)	0 -
Q9	1 (S1)	1 (S5)	2 (S2,S10)	4 ** (S3,S6,S7, S8)	2 (S4,S9)
Q12	0 -	3 (S2,S5, S7)	2 ** (S1,S3)	3 (S4,S8,S9)	2 (S6,S10)
** - Correct response					

Table 1: Summary of students’ responses to Q5, Q6, Q9 and Q12 of QMVI. Figures in brackets indicate the student(s) who chose that option.

One of the major concepts targeted by QMVI includes ‘the correspondence between situations classical and quantum domain’ i.e. a physical interpretation of a quantum mechanical representation. Question numbers Q9 and Q12 were exclusively aimed to investigate this conceptual understanding. In order to obtain the correct answer for Q9, the students needed to appreciate that the 'amplitude of wavefunction' determines the probability of finding a particle and the extent of 'wiggle' or 'frequency of oscillation' of a wavefunction is dictated by its kinetic energy or velocity. In addition, Q9 emphasized on acknowledging the fact that probability of finding a particle is small in those regions where the particle velocity is high. Although, the written response for Q9 indicates that maximum number of students (S3, S6, S7, S8) chose correct option, other options were also given considerable importance by the students (see table-1). While options (a) and (b) were selected by S1 and S5 respectively, options (c) and (e) were chosen by 2 students each (S2, S10 – (c) and S4, S9 – (e)). In the interview, S1 admitted that he could not imagine a situation where 'quantum mechanical' quantities could be used for describing classical situations and therefore, he admitted that he had guessed the answer. When he was provided a few hints, he could relate the definition of probability using '$|\text{wavefunction}|^2$' and made an attempt to correlate the wavefunction to that of some very high excited state of 'harmonic oscillator' problem in QM. He then came out with option (d) as the answer which is the correct one. On the other hand, S5 promptly identified options (a) and (b) to be incorrect, during the interview. She mentioned that option (d) would be the correct one as the probability ($\propto|\text{wavefunction}|^2$) is more in regions where the velocity is least.

However, she could not appreciate the importance of 'change in wiggling' of wavefunction even after many hints and logical assists by the researchers. The response of S2, in the interview, distinctly elucidated an alternate and erroneous understanding that "*the wavefunction depicts the actual motion of the particle"*. Therefore, according to S2, the particle is undergoing an amplified oscillatory motion to the right. Moreover, she adds that the increase in amplitude is a signature of increase in velocity. Both the points mentioned by S2 are incorrect which clearly indicates possible misconceptions that students may hold in QM. S10 acknowledges the fact that the probability of finding the particle is more in regions where amplitude of wavefunction is large but he was unable to connect it to any physically observable movement/motion. He cited the reason as lack of information in the question such as potential, force or energy for appreciating the change in wiggling. Even after substantial assistance in terms of hints such as citing examples of wavefunctions encountered in certain potential distributions, he continued to argue that a comprehensive mathematical formulation was required to relate wavefunction to a physically observable quantity such as velocity or acceleration and that is the only approach to solve the problem.

However, he is unable figure out any route to develop such a mathematical relationship. In case of S4 and S9, the fact that 'wavefunction going to zero at infinite wall' in QM had strong impact which resulted in choice of option (e). Although, the amplitude of wavefunction goes to 'maximum' after the collision with infinite wall created considerable doubt in their mind, they were unable to correlate the wavefunction (in Q9) to any other plausible physical motion of a particle which remains consistent with the sacrosanct condition that 'wavefunction goes to zero at infinite wall'. Also, it is implicit from the respective interviews that the 'wiggle' in the wavefunction does not play any crucial role in determining particle's motion. Amongst the students who chose the correct answer, the reasons cited were similar, with a few resorting to some well-studied examples such as 'harmonic-oscillator' problem. However, during the interview, S6 casted a small doubt regarding his choice as he was unable to appreciate the pictorial representation of the wavefunction on extreme right. The doubt was essentially fostered by the idea that 'how can probability (or wavefunction) go to zero just before or after a maximum value?'

Q12 of QMVI required similar appreciation of 'classical-quantum connection' in a slightly different situation. It is interesting to note that framing of this particular question called for a 'text-to-visualization' approach instead of making a 'visualization-to-text' connection as it was in Q9. Since, the concept targeted was identical to that in Q9, it was quite obvious to anticipate that the pattern of responses would closely resemble each other. However, it was surprised to observe that the responses given by students (for Q12) brought out a substantially contrasting picture. Only two students (S1, S3) chose the correct answer and options (b), (d) and (e) where chosen by 3 students (S2, S5, S7), 3 students (S4, S8, S9) and 2 students (S6, S10) respectively (see table-1).

During interviews, S5 and S7 (who chose option (b)) admitted to have misunderstood the term 'H' which was actually the height from which the particle was dropped. They assumed 'H' to be the distance moved by particle starting from z = 0, according to the figures given in the question. After analyzing the 'amplitude' and 'wiggling' aspects of wavefunction again, both of them concluded that option (c) should be the correct option.

However, S2 reiterated an identical 'alternate' viewpoint as she did in Q9 i.e. *"the wavefunction depicts the actual motion of the particle*". According to S2, the particle, oscillates with smaller amplitude as it begins the motion and the amplitude increases when the velocity is high. Also, she mentioned that the wiggling should not change as the particle travels downwards as acceleration of the particle does not have any relationship with the 'frequency of oscillation' and hence, option (b). All the students (S4, S8, S9) choosing options (d) provided different reasons for their choice. S4 asserted that the problem could be viewed in 'classical mechanics' domain as well as in 'quantum mechanics' domain. Classically, either of the figures III or IV could depict the motion of particle but he could appreciate the significance of wiggling in determining the motion of particle. Upon scaffolding, he figured out the correct answer. However, he thinks, quantum mechanically, figures I and II (Q12) are the correct options as the probability would be maximum at the points where velocity is maximum. He noted this point while making a resemblance to the 'ground-state wavefunction' of a harmonic oscillator. S8 adopted an appropriate route by relating oscillation of wavefunction to kinetic energy of the particle but incorrectly related the argument of 'sine' or 'cosine' function to the frequency of oscillation. For example, he inferred that if 'k' is small in 'sin(kx)' where 'x' is a space coordinate, the frequency of oscillation would be more and vice versa. Due to this, he ended up obtaining an incorrect answer. On the other hand, S9 brought in the concept of 'convexity' from potential energy curves encountered in 'special theory of relativity'. According to him, the 'sharpness of change in the amplitude of wavefunction at the extreme points' gives the measure of 'convexity' and the sharpness of the increase is directly proportional to the convexity.

Although, it was not necessary to bring in the concept of 'convexity' of curve in the present context, it appears that S9 was strongly influenced by previous knowledge in the subject of 'special theory of relativity'. The response of S6 distinctly elucidated a bottleneck in appreciating a concept in QM in the realm of actual experiences made by the students. According to him, since the wavefunction exhibits many zeros (or zero probability) as it wiggles, this does not represent a practical situation of a particle falling from a height 'H'. Classically, the probability of finding the particle is not zero anywhere. When asked about the difference in approach for the Q9 and Q12, he said that he did not consider the zero-crossing of the wavefunction in Q9 as it was not evident from the figure. In the interview, S10 again, expressed his inability to correlate concepts in QM to situations in classical domain and re-emphasized that a mathematical framework is needed for this purpose, which he is unsure as of now.

DISCUSSION

Our effort was an attempt to delve into students' conceptualization of the fundamental concept of wavefunction in QM. Students' constructs of wavefunction were investigated through their visualization of these basic concepts and their interpretation both in quantum as well as classical realm using QMVI (Cataloglu, 2000). It was found through the study that students had made varied interpretations of the concept of wavefunction. Amongst the various interpretations, a significant fraction was found out to be alternate as compared to accepted interpretations within the discipline. The most important misconceptions revealed through the study are as follows:

- Wavefunction/eigenfunction depicts actual path of a particle
- Increase in amplitude of an oscillatory wavefunction/eigenfunction implies greater velocity of the particle in that region
- Collision with an infinite wall brings a particle to rest instantaneously
- Acceleration is not related to frequency of oscillation/wiggling for an oscillatory wavefunction/eigenfunction
- An oscillatory wavefunction cannot represent actual motion of particles

Through the interviews of each student, many noteworthy observations came to the fore. It was observed that many students could not correlate pictorial presentation to the physical concept it depicted. For instance, S10 in Q9 and S4 in Q12 could not connect wiggle of wavefunction to any physical concept. A clear implication for pedagogy is to make the connection between the physical concept and its pictorial or iconic depiction clear, strong and unambiguous. The teacher could explicate these connections by presenting to learners, varied perspectives of the same concept (physical, mathematical, pictorial etc.).

A significant revelation from this study was the lack of connection or alternate links between QM and classical mechanics. One noteworthy example is of S1 who in Q9 clearly expressed that he could not imagine a situation where quantum mechanical quantities could express classical system, which shows that he conceptualized QM and classical mechanics to be two independent systems rather than being two ends of a continuum. S2 in the same question perceived quantum mechanical systems from a complete classical lens which led to some crucial misconceptions. She expressed that the pictorial representation of wavefunction is the actual motion of particle and hence, the increase in amplitude should depict increase in velocity. Therefore, according to her viewpoint, figure in Q9 should depict an amplified oscillatory motion to the right. Such issues could be resolved pedagogically by distinctly and unambiguously pointing out the domain of application of concepts which are common to different subjects. In addition, it was observed that a few students used technical phrases such as probability, probability density and wavefunction interchangeably without paying due attention to physical meaning of these concepts. Therefore, it becomes paramount to the teachers to repeatedly lay emphasis on significance and depictions described by terminologies in a science classroom. Possibly, alternate implications due to improper usage of terminologies should be explained in conjunction with suitable demonstration. Also, a few students exhibited confusion in mathematical understanding of dependent and independent variables while carrying out wavefunction normalization.

In conclusion, we present our work where we have made an attempt to add qualitative dimension to the studies related to understanding of the concept of 'wavefunction' which is fundamental to the subject of QM. Via this study, we have been able to elucidate that the mental constructs of fundamental concepts are revealed explicitly as well as precisely when the students are required to provide reasons behind their written choices in the form of written as well as verbal explanations. Consequently, this study is aimed at helping physics teachers to design their pedagogy for a more meaningful learning environment for topic of QM, at the fundamental level.

References

Ayene, M., Kriek, J., & Damtie, B. (2011). Wave-particle duality and uncertainty principle: Phenomenographic categories of description of tertiary physics students' depictions. *Physical Review Special Topics - Physics Education Research*, *7*(2), 020113.

Bao L., & Redish E. F. (2002). Understanding probabilistic interpretations of physical systems: A prerequisite to learning quantum mechanics. *American Journal of Physics*, *70*, 210-217.

Cataloglu, E., & Robinett, R. W. (2002). Testing the development of student conceptual and visualization understanding in quantum mechanics through the undergraduate career. *American Journal of Physics*, *70,* 238-251.

Dangur, V., Avargil, S., Peskin, U., & Dori, Y. J. (2014). Learning quantum chemistry via a visual-conceptual approach: students' bidirectional textual and visual understanding. *Chem. Educ. Res. Pract.*, *15*(3), 297–310.

Galvez, E. J., Holbrow, C. H., Pysher, M. J., Martin, J. W., Courtemanche, N., Heilig, L., & Spencer, J. (2005). Interference with correlated photons: Five quantum mechanics experiments for undergraduates. *American Journal of Physics*, *73*(2), 127.

Greca, I. M., & Freire, O. (2014). Teaching introductory quantum physics and chemistry: caveats from the history of science and science teaching to the training of modern chemists. *Chem. Educ. Res. Pract.*, *15*(3), 286–296.

Hadzidaki, P., Kalkanis, G., & Stavrou, D. (2000). Quantum mechanics: A systemic component of the modern physics paradigm. *Physics Education, 35*(6), 386–392.

Hiller, J., Johnston, I., Styer, D. (1995). *Quantum mechanics simulations. Consortium for undergraduate physics software.* NY: John Wiley and Sons.

Johnston, I. D., Crawford, K., & Fletcher, P. R. (2007). Student difficulties in learning quantum mechanics. *International Journal of Science Education, 20,* 427-446.

Paoloni, L. (2007). Classical mechanics and quantum mechanics: an elementary approach to the comparison of the two viewpoints. *European Journal of Science Education*, *4*(3), 241–251.

Redish, E. F., Lei B., & Jolly, P. (1997) Student difficulties with energy in quantum mechanics. Presented 6 January, 1997 at the *Phoenix meeting of the AAPT.* Posted on the Web on 22 January, 1997. Retrieved from www.physics.umd.edu/rgroups/ripe/perg/quantum/aapt97qe.htm

Singh, C. (2001). Student understanding of quantum mechanics. *American Journal of Physics, 69*, 885–895.

Singh C. (2008). Student understanding of quantum mechanics at the beginning of graduate instruction. *American Journal of Physics*, *76*, 277-287.

Steinberg, R., Wittmann, M., Bao, L., & Redish, E. F. (1999). The influence of student understanding of classical physics when learning quantum mechanics. *Proc. of Research on Teaching and Learning Quantum Mechanics* (pp. 41–44.). Boston: NARST Annual Meeting.

Styer, D. F. (2008). Common misconceptions regarding quantum mechanics. *American Journal of Physics*, *64*, 31–34.

Styer, D. F. (2001). Quantum revivals versus classical periodicity in the infinite square well. *American Journal of Physics*, *69,* 56–62.

Tsaparlisa, G., & Papaphotis, G. (2009). High-school students' conceptual difficulties and attempts at conceptual change: The case of basic quantum chemical concepts. *International Journal of Science Education*, *31*(7), 895–930.

CONSTRUCTION OF GEOMETRY PROOFS: A REGRESSION ANALYSIS OF KNOWLEDGE STRANDS

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The development of proofs in geometry continues to be problematic for many students. Battista (2007) argued that we need to address this issue by examining the relative role of general processes and task-specific knowledge in the development of proofs by students. The present study is driven by the assumption that development of geometric proof constitutes a problem-solving activity the understanding of which requires the untangling of knowledge components that drive the process. Our literature review resulted in the identification of three knowledge components that are relevant to geometry proofs: Content Knowledge of Geometry, Metacognitive Skills (general processes) and Mathematical Reasoning. As expected, regression analysis indicated that Content Knowledge of Geometry to be the most important predictor of success in the construction of proofs. We also found that Metacognitive Skills and Mathematical Reasoning to be playing a significant role in the process of proof development. Taken together, the results suggest that solution of geometry proof problems are inherently complex and involve a robust interplay between students' general and task-specific knowledge components during the search in the problem space. Our work also contributes to the on-going debate about the role of general skills in mathematical problem solving.

INTRODUCTION

Many students are reluctant to solve problems in geometry that require them to develop formal proofs, and, when they do decide to tackle them, their performances have been shown to be unsatisfactory (Herbst, 2002). This continuing malaise with proofs with geometry was evident in a study reported by Martin, McCrone, Bower and Dindyal (2005) which showed that students experienced difficulty in constructing proofs and that further studies about how individual students understand and generate proofs is an important line of inquiry.

Harel and Sowder (2007) showed that some students develop and activate 'proof schemes' when they are required to draw logical inferences. The notion of scheme or schema suggests that students' knowledge is multidimensional and structured. Harel et al.'s analysis is an important starting point for research that explores the kind of knowledge, understandings and reasoning processes that could drive and govern the process of construction of proofs. We suggest that content-specific information and general processes constitute significant components of proof schemes, and the investigation of the relative impact of these three knowledge components is an important area of inquiry.

THEORETICAL CONSIDERATIONS

Domain Specific Knowledge and Metacognitive Skills

The role of domain-specific knowledge and metacognitive skills in learning and problem-solving performance has been the subject of considerable interest in recent years (Zohar & Peled, 2008). Within geometry, and specifically, geometry proofs, Hanna and Barbeau (2008) identified different strands of mathematical knowledge. Such knowledge could be viewed as domain-specific or general. Domain-specific knowledge consists of concepts, principles, conventions and principles that are unique to that domain. Metacognitive (general) skills, on the other hand, refer to a cluster of skills that indicate one's knowledge and control of one's own cognition.

Sweller (1989) argued that rich domain-specific knowledge plays a prominent role in mathematical understanding and problem solving in comparison to general processes while Lawson (1989) suggested that both these strands of knowledge interact and complement each other. In a recent study, Bertholda, Nückles and Renkl (2007) showed that more effective learning is evidenced when students are taught to apply both cognitive (domain-specific) and metacognitive prompts. Thus, there are competing views on the relative role of these two knowledge variants not only in the solution of geometry proof problems but mathematical problems in general.

Development of Geometry Proofs

The construction of geometric proofs can be seen as a problem-solving activity where students draw on a body of domain-specific or content knowledge. For example, Euclidean geometry consists of a coherent body of content knowledge that includes understanding the characteristics of objects such as point, angle, triangle and shapes as well as knowledge of use of axiomatic reasoning. In addition to this content-specific knowledge, students need to utilise a range of general skills during the course of their search for the proofs. A feature of non-algorithmic approach to geometry proof problem solving is the difficulty of finding a starting point or a method for approaching the problem (Healey & Hoyles, 1998; Riess, Kleime and Heinze, 2001). Cognitive processes such as planning have a role in directing the search for strategies (Schoenfeld, 1992). As a control process, metacognition orchestrates the solution process.

Reasoning skills play two key roles during the solution of geometry proof problems. Firstly, reasoning facilitates the construction of logical arguments. During the course of development of proofs, the solver develops a series of well-connected arguments that are based on the process of reasoning. Van Hiele's levels (1999) provide useful framework for analysis of reasoning patterns that are involved in geometry proofs. According to this model, at the level of Formal Deduction (van Hiele's Level 4), students draw on their formal deductive abilities to the solution process. Students working at this level have acquired knowledge of geometric concepts about basic plane figures, geometric relationships, and use them to understand proof situations. A student who reasons at Level 4 understands the notions of mathematical postulates and theorems and can write formal proofs of theorems (Senk, 1989). While there is little doubt about the role of reasoning in proof development, how specific these processes anchor the construction proofs in the domain of geometry is an area that has received less attention.

Purpose and Research Questions

Based upon the above review of literature, the principal research question addressed in this study was 'what is the relative contribution of knowledge of geometry concepts, metacognitive skills and mathematical reasoning skills in supporting the solution of geometry proof problems?' The study aimed at examining the predictive value of three independent variables (*Metacognitive Skills,* MS; *Geometry Content Knowledge,* GCK; *Mathematical Reasoning Skills*, MRS) on the dependent variable (*Proof-Type Geometry problem-solving*, PTG). PTG represents a measure of students' outcomes to solution of geometry proof problems.

Participants

Participants in this study were Year 11 students from Sri Lanka (n=166). Year 11 students in Sri Lanka study mathematics that was based on a common curriculum that includes that key strands of Number, Algebra and Geometry. The participating students were enrolled in four high schools within the metropolitan areas of Colombo and Kandy. Within each school, the students were enrolled in a single mathematics class.

Tests and measures

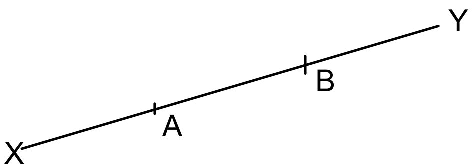
Tests were developed to assess students' PTG, MS, and GCK. Students' MRS scores were based on their performance in a common examinations conducted at the end of Grade 10 for all students in Sri Lanka. These examination included problems in geometry and algebra with a strong emphasis on working mathematically and reasoning skills.

Test development and scoring procedures

The items for the tests were selected from a pool of resources such as textbooks, examination papers and research papers. A number of items were modified for the purpose of the study. The items were reviewed by a group of six senior mathematics teachers (including one teacher from Australia) and a curriculum expert from the Sri Lankan Department of Education. Each test was piloted with a group of 15 students from a school that did not participate in the final data collection phase of the study. The duration for each of the tests was as follows: PTG – 80 minutes; MS – 80 minutes; GCK – 60 minutes.

Proof Type Geometry Problem Solving (PTG) Test

Five geometry problems of varying levels of difficulty were selected and modified for this test. All problems were well-structured proof problems. Our decisions to select or modify these problems were guided by a) richness and range of embedded geometric knowledge, b) opportunities to explore representations (MS) and c) multiple reasoning steps involved in the development of proofs. Figure 1 below is one of the problems that appeared in this test. The proof for this problem involves students to use a sequence of reasoning moves (MRS) to represent the problem in terms of appropriate equations. In so doing, students need to activate geometry content specific knowledge items such as equality and segments (GCK).



The line AB has been extended to either side so that AX = BY. Prove that AY = BX.

Figure 1

Metacognitive Skills (MS) Test

The MS test contained five non-routine problems. The written test was constructed so that students could present evidence related to four general processes of problem solving: (a) *analysis,* (b) *representation,* (c) *planning* and (d) *use of knowledge retrieval*. These four general processes emerged to be significant from our review of research on problem solving. Figure 2 is one of the problems that appeared in this test.

You are to organise a tea party for the class at the end of the year. How would you find out the food-item preferences of your classmates?

Figure 2

Scoring rubric for PTG and MS

The scoring procedures for PTG and MS were based on the same rubric. However, we focused on different parts of the rubric in order to generate the scores for PTG and MS. In developing the scoring rubric we aimed to include dimensions of levels and cognitive processes. The criteria for scoring were developed from geometry proof problem perspective. The scoring rubric included features of a two-dimensional matrix: process and level. The processes were: *analysis*, *representation*, *planning* and *use of knowledge retrieval*.

Geometry Content Knowledge (GCK) test

Geometry proof problem solving requires the activation of *Geometry Content Knowledge*. The GCK test was designed to measure students' acquisition of rules and declarative knowledge components that were required for the solution of five geometry proof problems of the PTG Test. This knowledge was broadly classified into 15 components because these were considered to be the content requirements for the solution of the five geometry proof problems that were the focus of the present study. Figure 3 shows one of the items that appeared in the GCK test.

Provide two pieces of information conveyed by the diagram.

ABC is a triangle

AB = AC

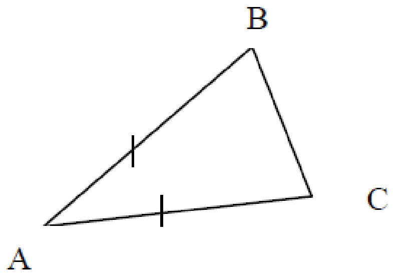


Figure 3: GCT test item

Student responses to Geometry Content Knowledge test was scored as: 1 - correct response;

0 - incorrect response.

Test administration procedures

A 2-hour session was conducted to practise answering the MS test. The problems used in the practice session were not similar to the test items in the final MS test because the aim was to practise written presentation of general problem solving. In order to avoid possible practice effects of the training session on performance in MS, the practice session was followed by the PTG test instead of MS. In order to avoid possible practice effects of the PTG on GCK, PTG was followed by the MS test instead of GCK. In order to avoid possible practice effects of the GCK on PTG, GCK was administered last. Students' regular classroom teachers administered all tests during their mathematics lessons.

RESULTS AND ANALYSIS

Correlation Analyses

Pearson correlation coefficients indicated that GCK is the independent variable that was most strongly related to geometry proof problem-solving performance. The other variables (MS and MRS) were also significantly correlated to PTG. This suggested that while GCK could be the major predictor of geometry proof problem-solving performance, students' general metacognitive skills (MS) and their reasoning processes (MRS) carried significant load in the regression model.

Regression analysis

To test our principal research question (What is the relative contribution of knowledge of geometry concepts, metacognitive skills and mathematical reasoning skills in supporting the solution of geometry proof problems?) a stepwise regression analyses was conducted. The Multiple Regression coefficient (R) is an important statistic in the regression analysis. It is the square root of the coefficient of determination or the correlation squared (R2), which is the total proportion of variation of the dependent variable explained by dependent variables. The results of the analysis are shown in Table 1.

Variables Entered	Variables Removed	R	R^2	Adjusted R^2	Std. Error of the Estimate
MRS MS GCK	-	.852	.726	.721	5.34

Dependent Variable: PTG; c Predictors: (Constant), GCK, MS, MRS.

Table 1: Model summary

According to the above model, 72.6% of variation in PTG was explained by the three variables: MRS, MS, and GCK. The adjusted R2 is an estimated value to use as the population estimator, as small samples tends to overfit. The difference between R2 and adjusted R2 was not large indicating the strength of the prediction. Analysis of variance showed that R2 was significant ($F3, _{162} = 143.440$, $p < 0.001$). Since the above R2 represents a collective effect, it could not be used to explain the variations in terms of the contribution from each independent variable. We, thus, computed regression coefficients for each of the independents. The unstandardized coefficients for the independent variable (all significant at $\alpha = 0.05$) allowed us to generate the following regression equation:

$$PTG = -6.399 + .939\ GCK + .314\ MS + .122\ MRS$$

DISCUSSION AND IMPLICATIONS

The aim of the study was to examine the relative contribution of students' *general processes* vs *task-specific knowledge* as they attempted to solve problems in the domain of geometry that involves the construction of proofs. Three knowledge components were hypothesized to be relevant for proof construction: *Geometry Content Knowledge, General Processes and Mathematical Reasoning Skills.*

The regression analysis suggested that all three knowledge components were involved in predicting students' success in solving a given set of geometry proof problems. In doing so, we found that *Geometry Content Knowledge* (GCK) was most influential in aiding students generate appropriate proofs. Both *General Processes* (MS) and *Mathematical Reasoning Skills* (MRS) made significant contributions to the activation and utilization of *Geometry Content Knowledge* by the students during the course of solution search. About 67% of the variance in the measures of performance in the development of proofs could be attributed to *Geometry Content Knowledge*. This suggests that improving *Geometry Content Knowledge* could have a significant positive impact on students' success in generating geometry proofs. The overwhelming impact of students' prior geometric knowledge evidenced in the present study is consistent with that reported by Senk (1985). In that study, which involved the participation of 2567 students from the United States, Senk obtained a value of 0.67 for Pearson correlation coefficient between geometry proof problem solving and students' content knowledge of geometry. This further demonstrates the importance of acquisition and use of a robust body of *Geometry Content Knowledge* schemas in geometry proof problem solving.

Studies have shown that domain knowledge is not a sufficient condition for the application of that knowledge during the course of solution search. For instance, Lawson and Chinnappan (in press) found that students who can be shown to have acquired the necessary geometry knowledge failed to utilise that knowledge during problem solving when it would have been appropriate to do so. Thus, it would seem that there are other knowledge components that work in concert with GCK.

Content knowledge related to geometry problem solving includes geometric concepts, knowledge about geometric relationships and visual representations of such relationships via appropriate diagrams. Reiss et al. (2001) argued that the above components need to be organized into meaningful schemas in order to foster accessibility. Geometry proof problems have a unique structure and the solution of such problems requires, firstly, an intuitive understanding of the given context and what the solution could be. This intuitive understanding, we suggest, involve students entertaining potential moves that would be productive.

Let us consider the second variable: *General Processes*. During the solution attempts, students, almost always, need to translate problem information into an appropriate diagram. This process of *representation* involves the translation of geometric information in the problem situation from one form to the other. Skills in diagrammatic representation are not confined to converting text information into diagrammatic form. They are also required to generate goal-directed new information with the aid of general processing skills. For example, during the *planning* process, students need to identify key steps of proof development that could not be generated by algorithms. For example, in Figure 1, in order to prove that segments AY and BX are equal, the student had to plan to solve a sub-problem in finding the different segments that could be used to represent AY and BX. This process shows the role of planning in geometry proof building processes. The solution process related to the proof in Figure 1 also exemplifies the role of another GPS - *use of knowledge retrieval*. Retrieving appropriate knowledge and accurate use of those retrievals are in turn influenced by general skills. This process enabled students to access and retrieve the required theorems and geometric concepts, and to use them in generating new information in a goal-directed manner. In order for students to activate and use their prior knowledge in a goal-direct manner, we argue, they will have to call upon a second layer of skills which are *general or metacognitive* in nature.

We have indirect evidence here for the interplay between content knowledge and general processes as students attempt to develop proofs. The results h are consistent with findings of Hilbert, Renkl, Kessler and Reiss (2008) that studying examples of heuristics could help students' ability to solve geometry proof problems. Our results are also consistent with those of Yang (2012) in that metacognitive processes need to work in concert with cognitive processes in assisting students make sense of geometry proof problems.

How can we explain the role of the third predictor variable (Mathematical Reasoning Skills) in proof development? We have argued that domain-specific knowledge (GCK) as well as general processes (GPS) play a key role in directing and controlling the flow of given and new information within the problem space that is relevant to the construction of proof. However, what are the processes that aid students in the generation of new information from given information? It would seem that the use of reasoning skills plays a critical role here in this phase of the solution process. During the course of construction of proofs, students go through an iterative process in which relevant given information is used to drive the reasoning process and vice versa. The outcome of this process is the generation of new moves and sequential information production that feed off each other. Taken together, it would seem that the proving of a given statement or geometric relationship in a diagram can be expected to be dictated by the context-relevant content knowledge, general processes and reasoning..

An emerging issue here is domain-general or domain-specific nature of deductive reasoning that was activated during the construction of geometry proofs in the present study. Mathematical Reasoning (deductive reasoning in this case) might have both the attributes as students could be expected to activate such skills in the solution of non-geometric problems or, indeed, in solving geometric problems that do not involve proofs. Future studies could focus on the domain-specificity or otherwise of mathematical reasoning in the solution proof-type problems in general, and geometry in particular.

We set out to examine the relative impact of domain-specific and domain-general knowledge in the production of proofs for a series of geometry problems. The results of this study suggest that geometry proof development is a complex problem-solving activity that is underpinned by an ongoing interaction between *general processes* and *task-specific knowledge*. Of greater significance of this study is that we did pull out three core strands of knowledge that provided deeper insight into knowledge-related issue raised by Battista (2007). We suggest that further research is needed to untangle the relative role of these knowledge components and processes, and their interactions with a variety of geometry and other mathematical problems that involve the construction of proofs.

Our regression analysis of the four knowledge components could lead to the assumption that the development of formal geometry proofs follows a linear path. In adopting the regression model, we were driven to explore and highlight the relative contribution of content, general processes and reasoning on success in proof generation. In so doing, we do not underestimate the complexities underpinning proof development (Hanna, 2000) and do not claim that having these knowledge and skills is sufficient for students to become competent proof developers. These knowledge components interact and the paths of this interaction are far from linear.

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References

Battista, M. T. (2007). The development of geometric and spatial thinking. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning, Vol 2* (pp. 843-908). Charlotte, NC: Information Age Publishing.

Bertholda, K., Nückles, M., & Renkl, A. (2007). Do learning protocols support learning strategies and outcomes? The role of cognitive and metacognitive prompts? *Learning and Instruction, 17*(5), 564-577.

Hanna, G. (2000). Proof, explanation and exploration: An overview. *Educational Studies in Mathematics, 44*, 5–23.

Hanna, G., & Barbeau, E. (2008). Proofs as bearers of mathematical knowledge. *ZDM: The International Journal on Mathematics Education, 40*, 345–353.

Harel, G., & Sowder, L. (2007). Toward comprehensive perspectives on the learning and teaching of prooof. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning, Vol 2 (pp. 805-842).* Charlotte, NC: Information Age Publishing.

Healy, L., & Hoyles, C. (1998). *Justifying and proving in school mathematics.* London: Institute of Education, University of London.

Herbst, P. G. (2002). Engaging students in proving: A double bind on the teacher. *Journal for Research in Mathematics Education, 33*(3), 176–203.

Hilbert, T. S., Renkl, A., Kessler, S., & Reiss. K. (2008). Learning to prove in geometry: Learning from heuristic examples and how it can be supported. *Learning and Instruction, 18*, 54-65.

Lawson, M. J. (1989). The case for instruction in the use of general problem solving strategies in mathematics teaching: A comment on Owen and Sweller. *Journal for Research in Mathematics, 90,* 21-25.

Lawson, M. J., & Chinnappan, M. (in press). Knowledge connectedness and the quality of student and teacher mathematical knowledge. In E. A. Silver and P. Kenney (Eds.), *More lessons learnt from research* (pp. 272–277). Reston: National Council of Teachers of Mathematics.

Martin, T. S., McCrone, S., Bower, M., & Dindyal, J. (2005). The interplay of teacher and student actions in the teaching and learning of geometric proof. *Educational Studies in Mathematics, 60*(1), 95-124.

Reiss, K., Klieme, E., & Heinze, A. (2001). Prerequisites for the understanding of proof in the geometry classroom. *Con. Proc. 25th International conference in Psychology of Mathematics Education*, pp. 96-109.

Schoenfeld, A. H. (1992). Learning to think mathematically: problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 165–197). New York: MacMillan,

Senk, S. (1985). How well do students write geometry proofs? *Mathematics Teacher, 78*, 448-456.

Senk, S. L. (1989). van Hiele levels and achievement in writing geometry proofs. *Journal of Research in Mathematics Education, 20*(3), 309-321.

Sweller, J. (1989). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 257-285.

van Hiele, P. M. (1999). Developing geometric thinking through activities that begin with play. *Teaching Children Mathematics, 5*(6), 310-315.

Yang, K. L. (2012). Structures of cognitive and metacognitive reading strategy use for reading comprehension of geometry proof. *Educational Studies in Mathematics, 80*(3), 307-326.

Zohar, A., & Peled, B. (2008). The effects of explicit teaching of metastrategic knowledge on low- and high-achieving students. *Learning and Instruction, 18*(4), 337-353.

EXPLORING THE TRANSIENT PHENOMENA OF ELECTROMAGNETIC INDUCTION

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The main objective is to demonstrate that coil-magnet system with a data-logger becomes an exemplary experimental model system to teach science as well as the method of science. We first describe a task which involves designing, constructing and conducting quantitative experiments by students with a focus on collecting, representing and analyzing large, real-world data sets. Second to establish the coil-magnet as an exemplary model system which allows for easy parameter manipulation, and third to make a case for the use of computers for data collection and constructing graphs to bring out salient features of scientific investigation.

INTRODUCTION

The phenomenon of electromagnetic induction was discovered by the brilliant work of Faraday (Faraday, 1832), in which empirical data was gathered with careful design and experimentation and analyzed to arrive at path breaking conclusions. It is often demonstrated qualitatively in the school classroom in many different ways, e.g., Chapter 8 of Class 8 (MSBSHSE, 2011a) and Chapter 5, Class 10 (MSBSHSE, 2011b), Chapter 13 Class 10 (NCERT, 2012). The demonstrations can be fun and enjoyable, for example, see the section on activities of electromagnetic induction on Arvind Gupta's excellent website Toys from Trash (Gupta, 2015), which is incidentally an inspiration for this study. But most of the demonstrations are qualitative in nature and in some cases the complete analytical description of the phenomena may involve calculus, which can be demanding for school students, for example, see (Kingman et al., 2002).

In some cases the transient nature of the phenomena prevents one from making any quantitative studies of the same, for example firing of a LED attached to a coil, when a magnet is passed through it. Even when we vary the number of turns, or diameter or length of the wire the effects we notice in this setup are not visibly very different. To make the effects visible we introduced an electronic data-logger connected to a computer to the traditional coil-magnet setup. Could this addition transform a demonstration setup into a complete experimental setup? Amrani and Paradis (2005) and Bonanno et al. (2011) used data-loggers in the study of electromagnetic induction. In our study we extend this approach so that it also provides sufficient scaffolding to learn electromagentic induction, and also for the method of science for school students. We seek to demonstrate in this case study the pedagogical potential of the setup for learning the content as well as the method of science.

The Students: The study was conducted with two students who had just appeared for class 10 exams, and were part of the study for a week. They were from an urban Indian school with English as medium of instruction. One of the students was well versed with the use of computers and had experience in hobby electronics. The other student had not used computers much and was not aware of electronics. The interactions with the students were in the form of semi-structured interviews taken before, during and after the activities and were video recorded. The students already had a knowledge of the Faraday's law of electromagnetic induction, Ohm's law and Newton's laws of motion. At the end of a week the students presented their work to other students and mentors. During the interviews the students reinforced each other's answers, often citing examples to support and clarify each other.

To begin with the students were shown a simple demonstration of electromagnetic induction by passing a magnet through a copper coil. An LED attached to the terminals of the coil lights up when the magnet is passed. A paper tube is passed through the coil to facilitate the magnet movement through the coil. A schematic of the set-up is shown in left of Figure 1. The students were asked to explain this phenomenon, which they did correctly. The students were asked probing questions to elicit their conceptual framework.

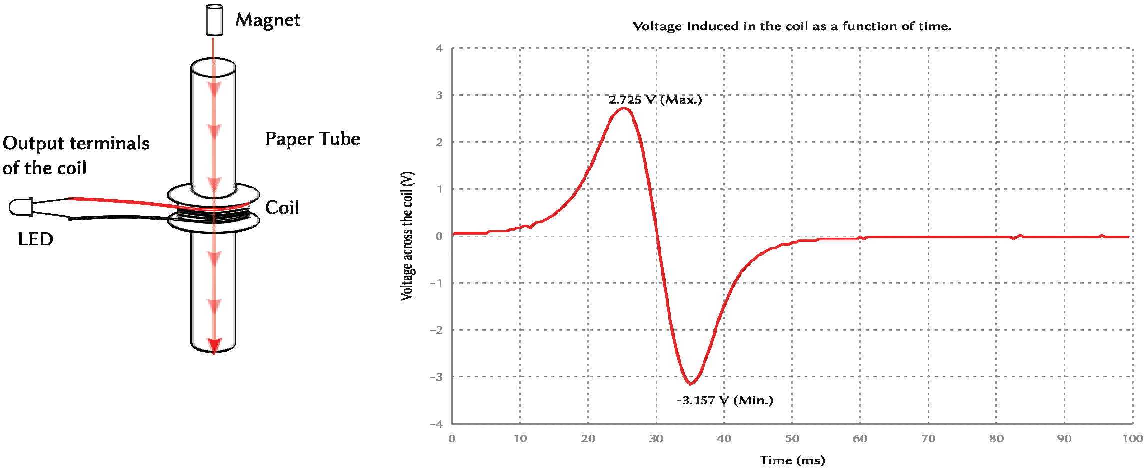

Figure 1: *Left*: A schematic drawing of the basic setup of the demonstration. We can attach LED to the output terminals of the coil. The LED lights up if the emf generated in the coil is above the threshold voltage. *Right:* A typical curve plotted using the data-logger which shows emf generated in the coil as a function of time, when magnet is passed through it.

CAPTURING, VISUALISING THE PHENOMENON THROUGH A DATA-LOGGER

The students were then asked to attach a digital multimeter to the coil to read off the voltage generated by passing the coil. The multimeter registers a surge in voltage and in a fraction of a second returns to zero. This being a transient phenomenon, which takes a fraction of a second, voltage cannot be measured using a multimeter. To address this issue we used a data-logger, *expEYES* to capture the phenomenon (Kumar, 2011). expEYES is non-proprietary device with millisecond and millivolt resolution. The cost of the current version of device is about Rs. 2000 (< USD 35). The software interface for the device has many in built programs, and can be reprogramed. The expEYES kit displays a graph and saves the data into a text file once the experiment is performed. The data has two columns, time and the corresponding voltage across the coil. This data can be used to plot the graph with any other graphing software.

The students were introduced to use of expEYES and to the specific programme in the software interface which can capture the required phenomenon. When our experimental setup of the coil and magnet is attached to expEYES instead of a LED, we can not only measure the peak of the voltage but also observe the waveform of the phenomenon. The output from the data logger is in the form of voltage across the terminals of the coil along with a time stamp. A plot of typical output voltage as a function of time, resulting from passing of the magnet through the coil is shown in the right side of Figure 1. The graph consists of a total of about 100 voltage readings in 60 *ms*. The graph clearly shows *two* peaks of voltages, which cannot be noticed through either the LED or multimeter.

The availability of data and the possibility to plot it as graph opens up the possibility for more inquiry. How does this curve explain electromagnetic induction? Why were there two peaks? What are the different parameters in this setup that will affect the induced voltage? The students were asked to seek answers to these questions by designing experiments.

Prior to the experiments the students gave explanation of the two peaks along the following lines: The first peak is due to the approach of the magnet *towards* the coil, while the second peak is due to the magnet moving *away* from the coil. The students also noted that the peak voltages in the first and the second peak are not same.. They reasoned with help of Newton's laws of motion since the magnet is falling under gravity it gains speed with time. Hence the speed of the magnet is greater when it goes away from the coil.

DESIGN, CONSTRUCTION AND INVESTIGATION

What parameters affect the induced voltage in the coil and how do they affect it? For this purpose the students were asked to design experiments to test their hypotheses. Three major categories of the parameters were finalised after prolonged engagement with the researcher: coils, magnets, speed of approach. Table 1 shows the different variations of these parameters, their variations and designs and constructions required for testing the hypotheses regarding these.

Parameter	Variation	Design/Construction	Hypothesis
Coils	Number of turns	250, 500, 650 with 30 gauge wire	Induced voltage will increase with number of turns.
	Diameter of wires	30, 35 and 41 gauge wires with 250 turns	Induced voltage will increase will diameter of the wire.
	Diameter of coil	0.75, 1 and 1.5 inch, with 35 gauge wire and 450 turns.	Induced voltage will decrease with diameter of the coil.
Magnets	Reversing polarity	Using magnet in obverse and reverse directions.	The induced voltage will change polarity.
	Magnet strength	Using magnets in three different configurations.	Induced voltage will increase with magnet strength.
Speed	Straight drop	Moving the coil along the paper tube.	Induced voltage will be largest for lowest position of the coil.
	Slant drop	Slanting the paper tube along a scale.	Induced voltage will be largest for the straight drop.

Table 1: Parameters and their variations, design for the experiments with the hypotheses to be tested.

Students constructed a total of nine coils for the experiments. The construction of the coils was found to be engaging and enjoyable. They were asked to explain and document how they made the coils in detail.

EXPERIMENTS, RESULTS AND ANALYSIS

For each set-up experiments were repeated multiple times. The students were instructed to use a non-proprietary graph plotter (*gnuplot)*, is a versatile plotting programme with many features included for analysis (William & Kelley, 2014). *Note:* The graphs presented here in Figures 2, 3, and 4 have been redrawn and labelled for clarity. The data used in these graphs is from students' experiments.

Experiments with Magnets

Change in orientation of magnets: The basic question that was addressed in this part was: *Will changing the orientation of the magnet cause any change in the induced voltage?* The LED glows in both cases, but graphs obtained in the two cases present a dramatically different case (Figure 2. *Left*). We not only see the reversal in the waveforms (red and blue curves), but also note they are almost symmetric. In terms of conceptual understanding, this explains the '− ve' sign in the law, which says that the induced voltag opposes the change in the magnetic field.

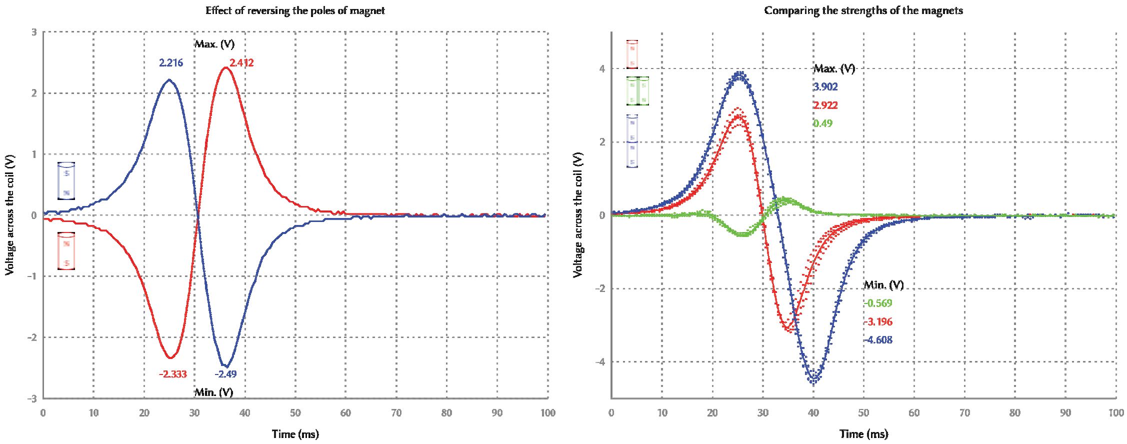

Figure 2: *Left:* Effect of inversion of magnets. In this the two graphs were obtained by inverting the magnet. *Right*: Comparing strength of magnets. The pole to pole configuration provides the maximum induced voltage, while side-by-side the least.

Magnet Strength: The students repeated the experiments with s*ingle magnet (red curve)*, t*wo magnets attached pole to pole (blue curve)*, t*wo magnets attached side by side (green curve)*. The results are shown in the right side of Figure 2. The hypothesis that the induced voltage would increase as the magnet strength increases was tested as well.

Experiments with Coils

In case of coils the students constructed nine coils and performed experiments using the same magnet. . Some of the coils can be seen in the bottom right of Figure 3.

Number of turns in the coils: Students constructed three coils with 250, 500, 650 turns with gauge 30 wire. The results from these experiments are shown in the top left of Figure 3. In this case the hypothesis that the induced voltage is directly proportional to the number of turns was also verified.

Diameter of wires: Students constructed three coils with 30, 35 and 41 gauge with same number of turns. The results are shown in the top right of Figure 3. In this case the students hypothesized that induced voltage is proportional to the thickness of the wires. They argued that in thicker wires the resistance would be lesser than in thinner wires, and hence thicker wires will have more induced voltage. But the results of the experiments were against their hypothesis.

Diameter of the coils: Students constructed three coils with 0.5, 0.75, 1.5 inches with 250 turns of 30 gauge wire. The results are shown in lower left of Figure 3. In this case the hypothesis that induced voltage is inversely proportional to the diameter of the coils was tested.

Experiments with Speed

Straight Drop: For the straight drop students did the experiments by moving coil relative to the paper tube by equal amounts. The results of this experiment are shown in left of Figure 4. This confirms the hypothesis that the induced voltage is directly proportional to the speed of the magnet.

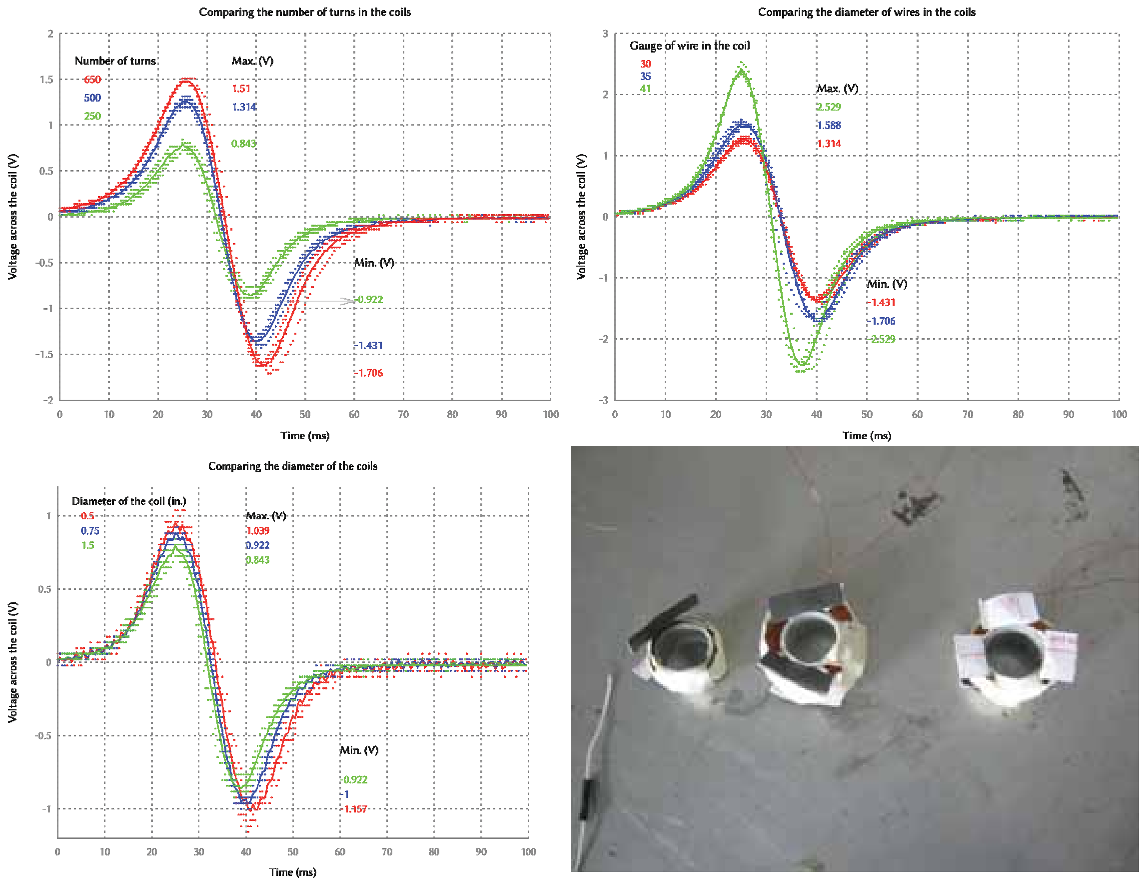

Figure 3: Results of experiments with coils. *Top Left:* Comparing number of turns in the coil. More turns (650) produce more induced voltage. *Top right:* Comparing diameter of the wires of the coil. Thinner wire produces more induced voltage, this was against the hypothesis made

by the students. *Bottom Left:* Comparing diameter of the coils. Smaller diameter produces more induced voltage. *Bottom Right:* Some of the coils made by the students.

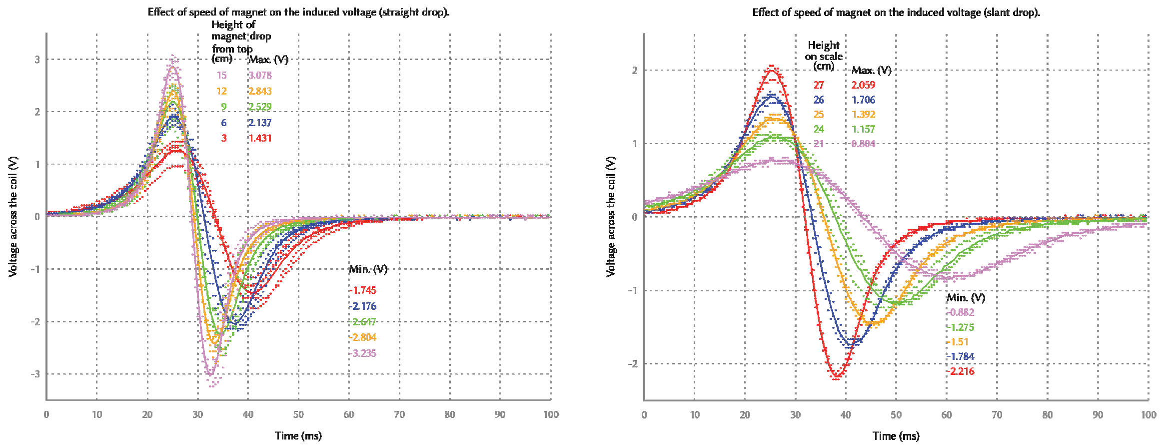

Figure 4: Results of experiments with speed.

The induced voltage is directly proportional to the speed of the magnet. *Left:* The results from the straight drop method. Notice how the voltage peak intensifies (pink graph) as speed increases. *Right:* The results from the slant drop show the spread in the voltage peak as the speed decreases (pink graph).

Slant Drop: For the slant drop the students tilted the paper tube to form an incline at different angles. The results are shown in right of Figure 4. The hypothesis is confirmed again in this case.

DISCUSSIONS

Real-World Data and Use of Computers

The electromagnetic induction can be seen in a variety of applications in everyday life and hence is a close-to-life context in which investigations were carried out. The task gave students a better understanding of basics of the phenomenon under study and experience in collecting real-world data which is an important skill (Curcio, 1987). In the task students collected and handled large data-sets, arising from repeated experiments. The use of technology in the form of a data-logger and computer for plotting data opened an avenue for collecting and analysing large real-world data. Without use of computers tools the experiments were almost impossible to perform. Though there are works which report use of data loggers, for example see (Wood & Sebranek, 2013), they differ from our work in the sense that construction and design of experiment by the students was not part of their study.

A single observation from the data logger had 100 data points and was instantly displayed while taking the observations. With multiple readings each of the graphs have thousands of data points. Using computers to plot such large data sets becomes essential. So this task gave them experience in collecting real-world data, which included many trials and errors during experimentation. As this happens in any science lab, we consider this as a good exposure to the nature of science. The concept of dependent and independent variables, and controlled experimentation was concretely presented in this engagement.

Coil as an Exemplar Model System

The coil with different parameters can be seen as an exemplary model system for the study. Historically what was pendulum to the classical mechanics, coil was to the electro-dynamics. It forms a bridge between the theoretical learning from the textbooks and the real-world applications of the phenomenon. It provided a low-cost, easily manipulable system in which different parameters can be changed and the effects of the change can be easily observed. This was made possible by the use of data-logger, but the entire construction process can be carried out easily with minimal raw materials and tools. The construction of a variety of coils based on the designs by students added another dimension to the investigation. The students could relate to what and why they were doing. The design of the activity created a base for any further investigations that students might do in the future.

Multiple Representations

The entire task can be seen as an exercise in multiple representations. Multiple representations are required in tasks that involve decision-making and problem-solving skills (Ainsworth et al., 1997). The phenomenon (the magnet passing through the coil) itself is a concrete and experiential one. The students can perform the phenomenon and experience the lighting of the LED when the magnet passes through it. The phenomenon can be described verbally, explaining the cause and effect. The table of numbers containing the time and voltage across the coil from the data-logger is an abstract representation of this same phenomenon. And when these same numbers are visualized in the form of graphs it is yet another abstract representation of the same phenomenon. The task of changing the parameters concretely during the design of the experiments and observing the resulting change in the form of graphs enables one to move between representations. At the end of the task the students were already familiar in reading information directly from graphs, analyzing and inferring from them. In case of scientists interpreting the graphs the movement between abstract and concrete is not just one way, but appears to be simultaneously from concrete to abstract and from abstract to concrete (Roth, 2006). Providing students with meaningful opportunities where they have to deal with multiple representations is helpful in developing ability to move between abstract and concrete representations.

Developing Graphicacy

Students usually face problems in comprehending and constructing graphs. The ability to read and make graphs forms one of the core competencies in doing science. One of the intended aims of this task was to develop opportunities for *graphicacy*, which has been defined as an "ability to understand and present information in the form of sketches, photographs, diagrams, maps, plans, charts, graphs and other non-textual, two-dimensional formats" (Aldrich & Sheppard, 2000). The representation of large data sets by graphs, provided the students a platform by which they could answer many questions, while gaining new insights into already known facts. The students had the exposure to develop the skill of reading graphs and relating the features on the graphs to physical phenomenon that they represent. This goal was inherent to the design of the task. The design of the task was such that the abstract representation of graphs and change in them, always had a concrete analogy which the students could relate to (the parameters that they had changed). Thus students could learn the skill in a context they were familiar with and was close-to-life.

Graphicacy does not have an emphasis even though it is an important skill in science, mathematics and everyday life. In *Critical Graphicacy* Roth et al. show that textbooks do not provide students with enough opportunities to read scientific texts critically (Roth et al., 2005). In the context of Indian school textbooks graphicacy is a neglected area (Dhakulkar & Nagarjuna, 2011). Neither there is any emphasis given to seeing it as a interdisciplinary skill which needs continuous nurturing through exposure of students to activities which involve graphs. Activities like this can build upon prior knowledge of the students, allow students to design experiments, collect data, and test hypotheses take them to a different level, in terms of qualitative and quantitative investigations, will perhaps help fill this gap.

Method of Science

The students while performing these experiments followed a path which started with their prior knowledge, led to forming hypotheses and test them by designing experiments.

The selection of parameters and hypotheses regarding them were informed by prior knowledge of the students. This led to designing of experiments and constructions required to execute them. The measurements aided by the data logger and graphical representation of numerical data was done with computers. The analysis of graphs led to answers to questions concerning the hypotheses. In some cases the hypothesis was validated by the experiments, while in other cases the hypothesis was proven to be incorrect. This led to new knowledge about the phenomenon under observation. In some cases a new insight about known facts (for example, effect of inversion of polarity of magnet) and new knowledge emerged (for example, the second peak being slightly larger than the first). Thus the students were able to design experiments, investigate the relations between the variables and test their hypotheses. At the end of the investigation the students presented their findings to other students in the project camp. During this presentation they could talk about the phenomenon by presenting the graphs and could explain the ideas about the design of experiments. Thus this activity also had reporting element as well.

Schematically the process can be represented as below and more or less follows the method of scientific experimentation:

Prior Knowledge + Reasoning => Hypothesis => Design => Construction

=> Measurements => Graphical representation => Analysis => Inferences => Test of Hypothesis + New Knowledge/Insights => Reporting

Considering the richness of the coil engagement, which brings to the foreground the several desired goals of science education, we recommend such use of technology. As Papert says "*the kind of knowledge children most need is the knowledge that will help them get more knowledge*" (Papert, 1993). We hope that this activity fulfils this aspiration.

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References

Ainsworth, S. E., Bibby, P. A., & Wood, D., (1997). Information technology and multiple representations: New opportunities – new problems. *Journal of Information Technology for Teacher Education 6*(1).

Aldrich, F. K., & Sheppard, L. (2000). 'Graphicacy': The fourth 'R'? *Primary Science Review*, *64*, 8-11.

Amrani, D., & Paradis, P. (2005). Faraday's law of induction gets free-falling magnet treatment. *Physics Education 40.4*, 313.

Bonanno, A., Bozzo, G., Camarca, M., & Sapia, P. (2011). Using a PC and external media to quantitatively investigate electromagnetic induction. *Physics and Education 46*(4).

Curcio, F. R. (1987). Comprehension of mathematical relationships expressed in graphs. *Journal of Research in Mathematics Education, 18*(5), 382–393

Dhakulkar, A., & Nagarjuna, G. (2011). An analysis of graphs in school textbooks. In S. Chunawala, and M. Kharatmal (Eds.), *The epiSTEME Proceedings, Volume 4* (pp. 127-131). Mumbai, India: MacMillan.

Faraday, M. (1832). Experimental researches in electricity, *Philosophical Transactions of the Royal Society of London, 122,* 125-162.

Gupta, A. (Accessed June 2015). Toys from trash (http://arvindguptatoys.com). The website has instructible videos and booklets for making low-cost / no cost toys with variety of themes.

Kingman, R., Rowland, S. C., & Popescu, S. (2002). An experimental observation of Faraday's law of induction. *American Journal of Physics*, *70*(6), 595-598.

Kumar, A. (2011). *Experiments for young engineers and scientists: User manual (Ver 2.0)*, Inter-University Acceleratory Centre, New Delhi. Project website is at the URL (http://expeyes.in)

MSBSHSE (2011a). *Science Class 8, Maharashtra State Board of Secondary and Higher Secondary Education. Pune,* Chapter 5, 49-60.

MSBSHSE (2011b). *Science and Technology Class 10, Maharashtra State Board of Secondary and Higher Secondary Education. Pune,* Chapter 5, 49-60.

NCERT (2012). *Science Textbook for Class 10, National Council of Educational Research and Training, New Delhi,* Chapter 13, 223-241.

Papert, S. (1993) *The children's machine: Rethinking school in the age of computer*. NY: Basic Books.

Roth, W.-M., Pozzer-Ardenghi, L., & Han, J. Y. (2005). *Critical graphicacy*, Volume 26 of Science and Technology Education Library. NY: Springer

Roth, W-M. (2006). On the relation of abstract and concrete in scientists' graph interpretations: A case study. *Journal of Mathematical Behavior*, *25,* 318–333.

William, T., & Kelley, C. (2014). gnuplot 4.6 An Interactive Plotting Program. Retrieved from http://sourceforge.net/projects/gnuplot

Wood, D., & Sebranek, J. (2013). Electromagnetic Induction with Neodymium Magnets. *The Physics Teacher*, *51*, 344-345.

TEACHING CHILDREN "HOW DO WE SEE?"

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The purpose of this research was to develop a scientific way of thinking amongst students, by encouraging them to think and express in a logical & scientific manner. Generate their answers & cross check them based on the available information/Knowledge that they possess. Challenge the limits of their information with the common understanding or general knowledge. Here I attempted to break the myth that is well practiced and accepted. Conclusion: After the action research was over, it was observed that there had been a change in the thought process of the students not only in the science classes but otherwise too. Its impacts were noticed in History classes & in their attendance too. On certain festive days the increase in the attendance was shown & when asked, the students tried to come up with a question basically to understand the logic behind it. This change could be only a start if nurtured could lead to a larger & longer series of changes.

BACKGROUND

Grade 7 science books do have a lot of content related to the science but one of the objectives of science teaching is to develop a scientific temperament in the students which many of the science books present it in for of an activity to be performed. The major objective becomes to conduct the activity rather than developing a scientific bent of mind. Most of the experiments in the books become only a thing for validation of the pre-stated fact. Very less chance exists to disagree, redesign, re-conclude and improvise the experiments. Here the attempt was to understand the root of the issues with which children come and how this belief of the students could be challenged so that the process of logical thinking becomes more important than the conclusion.

METHODOLOGY

Case study.

OBSERVATIONS

Day 1, Monday, July 29, 2013

Today, I had 3rd period in class 6th & the topic was: to introduce transparent, translucent & opaque objects. I was a co-teacher with Mrs. Shakuntala. The class started with our assumption that the students had some exposure to these terms as they had already been discussed by the chemistry teacher, Mr. Mohit Sharma, and he had told us that these students were familiar with these three terms. So we were quite relaxed. The class began with our asking for examples, prior to which they were asked to state the definitions - as they have understood from their previous classes. The students came up with the definition of transparent as "the objects through which we can see clearly." Examples were air, glass, filter (Net), Mirror, Sari, etc... The next one was opaque & its definition was given as "the objects through which we can't see" examples were – House, stone, Brick, Paper, Book, mirror, iron, metal, etc… & for the translucent category the definition was “the objects through which we can partially see”. The examples were “Butter Paper, oil Paper, dirty water & fog/ cloud.”

By listening to the above discussion, I was a bit disturbed, as the base line of their definitions was clearly shaky, being based totally on vision & not on the property of transmission of light. (Eaton, Anderson & Smith, 1984).

So I thought, if this is how they have understood the optical property of the substance, they need to be checked on their understanding of vision. I wanted to know what the students thought about vision. To formulate it simply, I asked them to explain how they see things. Everyone was ready to state his/her own understanding of how (s)he was able to see anything. I sensed that they were certain they knew this because it is something which seems so obvious, that hardly anyone ever thinks about the depth of the process that is involved in the transfer of an external body to our own field of perception (vision). Many interesting points with examples came up, and as the question was asked, I invited the students to answer one at a time.

First, J (names with-held for confidentiality) said: “I know, light from our eyes moves out to the object, falls on it & this is how we are able to see that particular thing.” So this was considered as one point to which others could either agree or disagree.

Secondly, V said that she disagrees with J, as in her opinion, “some light from our eyes travels towards the surface & then it returns to our eye - which enables us to see the object.”

Further, there were some students in the class who didn’t agree with either of these viewpoints, but said that these two theories are incorrect. Instead, they proposed that “Nothing goes out; only the outer light enters into the eyes.” This was Vi’s point of view.

So I called for a vote after counterchecking that there was no other stand of anyone else in the class.

Now the condition was that each student had to either support one of the 3 groups or state their own theory (if they had any). They were also free to say that they don’t have any idea. So leaving all three choices open, I asked them, one after the other, what their stand was.

Of 27 students who were present (out of a total of 29), 6 were in support of J. 18 students were in favour of Va, & the remaining 3 were in support Vi.

The next thing that I asked was how they knew that there is light in the eyes. I asked this of the group who said that the eyes emit light & also of those who said that there is a two-way process for vision. Here, the entire class had the same idea despite differences in their approaches. In this respect, the entire class seemed to be united with the idea of having a **मणि** or gem - that’s what they called it. It was accepted throughout the class that there is something like *mani* in the human eyes.

Here I feel that the mistake not theirs, as it was very clearly pointed out by many of the students that they have heard - from their elders - that when a person has lost his vision due to some accident, it is said that “उस की आंखों की रोशनी चली गई है। This literally translates to “The light has gone out of their eyes.” So this implies that there was some light in the eyes which has been lost due to that particular accident.

Is it a careless mistake? But it may not be a mistake too, because that’s the way Hindi is spoken. When I thought about it, I also found many idioms in Hindi, like “आंखों का तारा” &

“आंखों का नूर” (translated to “star of my eye” or “Light of my eye” – rather like the English idiom “apple of my eye”) which clearly gives an indication that eyes have got some type of in-built source of light. Thus, we have here a myth that is well carried and practiced. (See Lowe, 1986).

Now my basic problem is how to help the students arrive at the correct conclusion. Right now, I don’t have any idea as to how I am going to take it forward but all that I know is that one day (later or sooner) they will explore it on their own. But as Newton said “Nothing moves on its own”, so I think I also need to push them. How? That is what I have to think about now.

* * End of Day 1 * *

Day 2, Tuesday, July 30, 2013

I was working on finishing the monthly report for the month of July as it was to be dispatched by today evening & was a bit busy in collecting the data, photographs & typing them. At that time Mrs. Shakuntala stepped in & told me that the entire class was calling me (as I am the co- teacher with her). This in itself came as a surprise, because prior to this, they had never done so. I was also excited as now it had become my responsibility to take their interest forward (since I knew why they were calling me). I was also excited because last night, between sleep, I had planned my next set of actions, & was eager to implement these. I intended to inquire about the Mani factor by conducting interviews. I was also aware that because of this, the class should not miss the main topic which was about TRANSPARENT, TRANSUCENT & OPAQUE substances. Keeping a balance was important. Everyone was painted by a brush stroke in the hue of PHYSICS, I could see it as I had had prior experience of it. This colour is impossible to define in terms of frequency, wavelength & other characteristics, but it resembles something like excitement, enthusiasm & everyone chattering in class only about vision: “How , what , who told you , & how does he know it?” This was the chattering heard. Now I knew it was the perfect time to hit the nail. But before I could have asked them anything, however, they started asking me who was right. I told them every one was correct because they told me what they knew or felt, & since it was their own observation who was I to judge it? “No, what we mean is - which group is correct?” While this was being asked I noticed that Va - who had earlier given the theory that light from the eyes goes out &, in turn, some light from outside enters into the eyes – was quiet.

So I left the question unanswered & asked her what had happened. “Why are you so quiet?” I asked.

She said: “I know that I was wrong” & as she admitted this, I could see a lack of conviction in her admission clearly written on her face.

“How? How do you know it?” I asked her.

“My father told me.” (Her father is a doctor).

“OK that may be so, but how do you see it? That’s what really matters.” I countered

To which she responded that she still believed that what she had told was correct, but since she trusts her father & he is well educated, so what he has told her may be the only truth.

I let that rest. Now all the other students started asking the same question, “Which group was correct?”

I said: “I don’t know.”

Here they started arguing: “But how you can say thus?”

I tried to explain but before I could, they came up with logic that I might have learned it during my own schooldays. I made them silent & told them that what I had learned should not become a barrier for them to think, & it’s not that everything is always written in books, there are certain points which we have to think & develop our own understanding about. Had it not been so, I pointed out, no new inventions or discoveries would have been possible, because then everyone would have looked into books for the final verdict.

Then I pointed to Va and said: “Science is always changing, & that’s the nature of the subject. If something doesn’t change it’s not science, it’s History (to my understanding), because history won’t ever change - what has happened has happened. If Gandhiji was born on 2nd of October, it will never change to 31st of December. So what was correct a couple of years ago in Science may not be the same for the rest of the generations to come. These changes may or may not be visible in our life span, but they can always be challenged. So whatever your father said - it’s you who need to analyse, check & make your own understanding. I don’t want to say we should not trust our elders, but you must have a scientific approach to keep your understanding alive - otherwise it is others’ understanding that is running through you!”

I don’t know how far they understood this lecture, but they were mesmerized. So I came back to my point to ask what the Mani is all about. I anticipated that there would at least be a couple of answers & was ready to note these down. But to my surprise all the answers were the same. The entire class had a common understanding of the term Mani : “It is something which is very shiny, It’s at the center of the eye.” (See Reviews of *The British Medical Journal, 1*(2769), 200).

“But can we see it OR have you seen it or just heard it through someone?” I asked.

“We have seen it.”

“Can you help me also to see it?” I asked.

“Yes!” the class said. “If you stand in front of a mirror & look very carefully at the center of your eye (inside the black circle) you will see a still smaller shinier object that looks like glass, and is black in colour.” They continued: “It looks different from the outer black circle…..” and thus, they went on explaining.

Now Va was also looking relaxed & was discussing the topic with others. I said I have also seen it, ah, so that’s mani.

“Yes!” they all replied.

“OK…that may be so, but we need to check it in the class, & think about something which can prove the point that you made yesterday or the point to which you agreed yesterday. We will share our findings, experiences & demonstrations in the class on Friday. Will this time be enough?”

“Yes!” the class said.

We resumed our usual topic of transparent, translucent & opaque objects. I gave them a task - to think about the possibilities of the behaviour of light that falls on a surface. What all could possibly happen to light? The class was divided into 5 groups, where every group member was asked to present his/her idea. The entire class came up with three basic ideas:

1. The light can pass through the substance.
2. The light can't pass through the substance at all
3. Some of the light could pass through the substance.

So here, we didn't have any names for these three categories. I suggested that we now play a point game wherein I will write some names & they need to analyze them based on their statements as No: 1, 2 or 3. "You will get one point if you guessed it right & others could counter your arguments & if it's acceptable to the rest of the class they will get +2. If it's not agreed to, by the rest of the class, they will get -1. Simple rule - none of us will be winner or loser. It's just for fun."

Amidst much excitement, the game started, and I first wrote air & the red group said No.1 None of the groups came forward to counter this, "So it means that we all agree with this?" I checked.

"Yes!" came the resounding answer.

"OK, so we move to the next one - water…"

Again, the red group said No.1, but this time, the blue group came up with the point that it is not always No.1, it could be No.2 or No.3 also. This was a surprise for the rest of the groups because during their chemistry classes, they had seen it as a clear transparent substance, & I think, they were also told this by the teacher (I need to check it with the teacher). Interestingly, the supporting argument that the blue group gave was based on their daily observation from their surroundings. They asked – "How about the pond water these days (monsoon)?" Moreover, S asked: "Where will you put the ditch water? Will you not accept it as water?" The others agreed to this & they got +2. By now, other groups also realized that transparency depends on the level of purity, so they started shouting that even in the case of air it should hold valid.

I was confused - not just because I couldn't decide whom to give points to, but because the speed at which they learned this concept was in sharp contrast to the many years that it had taken me to grasp! Now there was a race of judging everything based upon this parameter.

The next object was paper for which one group (green) said it is No.2 whereas the orange group said it is No.3. Several supporting arguments were advanced but no one was ready to give up their stand.

So I stepped in & said: "Ok we will see this in the class."

I then brought an A-4 size sheet of paper & kept it against the light & kept my fingers behind the sheet. Then I asked the class: "Can you see my fingers? How many are they?" They were able to count & answered correctly.

Next thing I did was to add 20-25 sheets of A-4 size paper & repeat the same exercise, to which they replied: "No, we can't see through these." (Still, they didn't say *light can't pass through it* but that's OK.)

And a discussion immediately erupted across the class. This was the end of the period, so before leaving, I reminded them of the task that they were supposed to do for the next class.

* * End of Day 2 * *

Day 3, Monday, August 5, 2013

The class was unable to find the answer to the question & was also held up. Today the topic of Transparent, Translucent & Opaque (See Ashbrook, 2009) continued as there was a basic shift in the level of understanding of the class from the previous definition - where they had said "Transparent objects are the objects through which we can see", " Through which we can partially see and "through which we can't see". Now a basic shift had occurred - that the Transparent objects "are the objects which allow the light to pass through them (Here the direction of the light in still under question)", "Allow the light to pass through them partially" OR "do not allow any light to pass through them".

I am happy with this transformation. I don't recall, in my own experience, whether these two definitions were different from each other at any time.

What I can recall is that I just mugged up the definition & kept on reciting it as & when asked. I feel that now I understand the difference between the two, to most people they may still seem the same. But it's a great change that I have felt. Still I am unable to bring the whole thing onto a platform such that the students may see the entire process clearly.

What should be done? Since last week I have a feeling that I need to interview the students separately, so that the idea of one may not influence other. Though in the class they all have discussed this issue many times, but still, I have a feeling that it may give me a direction to work further. So, I said: "I would like to talk to all of you but individually, & not in class."

This was quite a difficult task as it took a lot of time but there were many things that I got from the children. A, who was a supporter of J (the child who had said that the light moves out from the eye, falls on the object & that is how we are able to see the objects) said: "I know for sure that light is in our eyes because my uncle who is now blind told me, & even my mother confirmed it." I was surprised, so I asked: "What did they tell you? & how do they know it?"

He told me the story that a couple of years ago, in his family they had had a land dispute. His uncle who was involved in it - & till that time was OK - lost his sight during a fight when he got hit with a stick over his head.

"पर चोट लगने की वजह से उनकी आंखो की रोशनी चली गई। मम्मी और मामा दोनों यही बोलते है।"

(Translation – *"But because he got hit on the head, the light went out of his eyes. That is what both my mother and uncle say."*)

It seems very clear that his belief is based upon the sound rationale that only if something is already present inside can it be lost. Otherwise, they would have said that something inside the eyes has been damaged.

One of the students, PB, who supported V, said during the interview that there is sufficient amount of light in our eyes & I have seen it too. During a dark night you can also see the eyes of the cat, they shine like fire.

I asked her: "But what about our eyes - why don't they shine?"

She had a very strange theory for this - she said in meat there are certain things (whose names she didn't know) which give light to the eyes. So all carnivorous (this term I am using, because she said meat-eaters) animals have got shiny eyes. But cows & other herbivorous animals don't have this, because they eat grass.

Some others who had said that nothing goes out from the eyes (like Vi) had no clue as to why they had said so. I was more interested in talking to the students who had come up with the idea of light as an external factor & suggested that it enters into the eyes.

While talking to them also, I discovered that they too had no clue as to why they had said so. Now I too was at a loss as to what to do, so as to enable them to get the right idea on their own.

I have to think but the thought that I had needs to be discussed with someone. Will it be advisable to share about the anatomy of the human eye? Because this is not included in their syllabus. My personal feeling is that the human mind is quite capable of understanding much more then we expect it to. Maybe the problem is from our side - we don't give - or we hesitate to give - knowledge. But on the other hand, my idea is not to impart knowledge; I am working on the creation of knowledge.

How to push them in the right direction? Here also I have a doubt - now what we are terming 'correct' may not be the absolute truth, so who knows? This may just be one of the most commonly believed facts, based on the tiny amount of knowledge that the human race currently has.

I feel totally stuck. At a dead end - because without the proper understanding of the prior concepts how can they reach a final conclusion? And even if they do so, it will be just an assumption. It's not as easy as I had initially thought it would be ……….

* * End of Day 3 * *

CONCLUSION

The approach adopted here in the classroom for a certain topic was just a way to develop a temperament of the scientific inquiry in a student, regarding which our constitution also talks. This approach holds good for most the subjects & all the topics. The beauty of it was that students developed a way of life. It can't be said that with this single time activity scientific temperament will be developed but it definitely will sow the seed of enquiring the things regarding why they are as they look to be. This brings a major shift in the way the child visualises the word around him, making an individual a critical thinker.

References

Ashbrook, P. (2009). The early years: Does light go through it? *Science and Children, 46*(7), 16-18.

Eaton, J. F., Anderson, C. W., Smith, E. L. (1984). Students' misconceptions interfere with science learning: Case studies of fifth-grade students. *The Elementary School Journal, 84*(4), 365-379.

Lowe, E. J. (1986). What do we see directly? *American Philosophical Quarterly, 23*(3), 277-285.

NCERT. (2006). Position paper national focus group on aims of education. Retrieved from http://www.ncert.nic.in/new_ncert/ncert/rightside/links/pdf/focus_group/aims_of_education.pdf

Unknown . (1914). Review of "the anatomy and histology of the eye; The anatomy of the human eye illustrated by enlarged stereoscopic photographs by Arthur Thomson. *The British Medical Journal, 1*(2769), 200.

DEVELOPING A CURRICULAR FRAMEWORK FOR ECOLOGICAL SENSIBILITIES: EXPLORING THE ACTIVITY OF URBAN FARMING AS A CRITICAL AND RELEVANT INTERVENTION

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Current environment education curricula focus on presenting facts about the environmental crisis, and providing awareness. This awareness model does not lead to environment-oriented behaviour because of lack of possible interactions between information, critical pedagogy and pro-ecological behaviour. Community farming presents an interesting alternative approach to developing environment-oriented behaviour focusing on embodied, situated and dynamic interactions with elements of nature. The article chalks out urban gardening as an activity that creates an embodied understanding of nature that is distinct from that created through conventional environmental education alone.

INTRODUCTION

> "The volume of education has increased and continues to increase, yet so do pollution, exhaustion of resources, and the dangers of ecological catastrophe. If still more education is to save us, it would have to be education of a different kind: an education that takes into the depth of things." —E F Schumacher

The above words bluntly describe the gap between our collective knowledge of ecological degradation and our actual behaviour towards the environment. This gap can be understood as arising from a set of cognitive problems.

1. *Lack of direct cause and effect relations:* Most ecological problems are not immediately perceived; for example, repercussions of using excessive pesticides and fertilisers in farming are not seen or felt immediately. Often groups of people who feel the brunt of ecological degradation are not the same group that caused it. For example, people apprised of pollution, ozone hole, climate change etc. still can lead a consumerist life style, and go about their everyday activities without feeling the brunt of these problems. On the other hand, people (and other living beings) suffering the consequences of the consumerist lifestyle are more often than not removed from sphere of influence or action.
2. *Cognitive load:* Engaging in pro-environmental behaviours decidedly means going against the current of established practices, and thus exerts a cognitive load on the individual, who has to disengage from 'default' and instead deliberate over choices. Pichert et al. (2008) show that many environmental choices depend over what is the default option available to an individual, because of the difficulty in performing trade-offs and reconcile conflicting objectives (such as save money on cheap fuel or go for greener options). As creatures of habit, sticking with the default seems to allow one to bypass an otherwise stressful decision.

3. *Invisibility:* The invisibility of the production/consumption process, description of problems that mostly seem out of individual control or wouldn't be impacted by solitary action. Eg: one person opting for public transport or not throwing garbage indiscriminately when problems are described on global scales of climate change or land pollution. In such cases, the 'locus of control' seems far removed from the individual, thus prompting questions like, "what difference would my actions make?" The accompanying feeling of apathy and resignation forms what may call a negative feedback loop and provides added rationale for sticking to default habits.

These are only a few of the cognitive reasons why, despite having pro-environment intent, translating these attitudes into desirable behaviour is not easy. To address these cognitive issues, the problem-spaces need to be local, relevant and solutions must empower individuals to take further action (Chandrasekharan & Tovey, 2012). These elements have been put into practice through various movements, the most recent and promising being 'The Transitions Initiative' (Hopkins, 2008) which emphasises on community issues in form of "engaged optimism" by firstly convincing people that their actions will result in an enhanced quality of life. A positive outlook makes a problem much more interesting rather than daunting and can help sustain an action despite the cognitive load involved. The usual avoidance associated with conflicts is mitigated by peer involvement which helps create new norms, practices and goals.

To develop an educational curriculum that will lead to environment-oriented behaviour, students need to develop a relational thinking that views the world as a seamless web of relations and processes that affect one another constantly. This recognition would need introduction of new components in the curriculum that integrates facets of geography, science, politics and history and feeds into community life. The immediate surroundings would become an important starting point for entering various disciplines, and the success of a course would be seen in terms of community participation.

Educational Implications

In India, over the past few years, environment education (EE) has been made a mandatory part of all subjects from class I to XII. This is based on a sound rationale since an environmental approach draws from various interdependent disciplines. However, experts and practitioners have highlighted a number of constraints, the main being lack of opportunities and space for synthesis of learning that should take place between different subjects which tend to become compartmentalized as the grade progresses. Another road block exists in the form of lack of a common course at XI and XII level in order to infuse the core content of EE. Nevertheless, the perspectives on inclusion or exclusive space for environmental education are secondary without an unequivocal stand on recognition of nature's value. This recognition will in turn determine how environmental problems are conceived, what kinds of answers are sought, and more importantly, what will count as an answer.

Jackson (2004) describes problematic aspects of conventional textbooks, particularly giving disproportionate attention to the concerns of urban minority in terms of pollution and wildlife conservation. Secondly, the content in the books tend to convey that environmental "problems" can be solved by purely technical measures. There is also a perceptible silence over social, economic and political determinants and consequences of these problems and projected solutions. More pertinently, these problems are usually described on huge scales and thus put beyond the child's reach in terms of nuanced understanding or ability to take action. As a result, education creates a body of superficially informed disempowered individuals because they are unable to see their role in any significant manner.

To address these issues, he argues that environmental phenomena must relate to locale specific problems existing within communities so that students can acquire the capacity to deal with them effectively. This implies a need for creating region specific learning resources that is designed by articulating problems faced by native population residing in the area.

Current textbooks fall short of recognizing the multitude of realities in immediate environment, and thus fail to create tangible linkages between students and their surroundings. There are many such instances across different grades that indicate an urban perspective, which is unable to question the cultural model on which the society is functioning.

Further, in an attempt to maintain a "neutral" stance as scientific perspective supposedly has, the content turns out to be confusing, contradictory and even incoherent in certain cases. For example, the grade 5 textbook mentions pesticides to be a serious health hazard, yet states that farmers need to use them in small quantities to kill pests. Apart from being contradictory, the use of ambiguous terms like "small" renders the content useless to gain any critical perspective. Further a fatalistic tone, such as "need to", "have to" suggests that there are no alternative options when in fact increasing movements to switch to organic farming are under way.

A more serious implication arises in absence of clear definitions or realistic solutions. The onus of solving these issues is shifted to global policies or technological innovations, both of which are beyond the reach of common individuals who bear the direct brunt of ecological imbalance. One is then forced to think how such a perspective could prove to be of any value when it comes to taking responsibility and action in immediate locality.

A detailed analysis of class VII science textbook has been done to understand ways in which environmental sensibilities have been infused in the curricular content as stated in the National Focus Group Position Paper on Habitat and Learning (2005). Specifically, the frames of reference for reviewing the textbooks consisted of implied message through usage of specific images and terms, attempts to sanitise the content by silences over controversial topics, and ways in which environment has been perceived in different chapters. I propose an alternative approach by elucidating gaps in those chapters that can be addressed through making gardening a central activity in development of critical ecological sensibilities.

Chapter title	**Issues to be addressed**	**Farming activity**	**Learning outcome**
Nutrition in plants	No activity connecting to importance of soil, diversity in growth patterns	Planting different varieties of plants in various conditions to observe patterns of growth	Learning about interdependence of soil, plants and insects, and food webs.
Nutrition in animals	No activity to observe modes of nutrition. No space for experiential knowledge. Unconnected with	Observe the insects and animals in garden along with what they eat. Grow different vegetables and learn about how	Learning about waste being a socially constructed concept since everything in nature becomes food for some organism;

	nutrition of food items consumed daily	they are cooked.	Nature of food and ideas of wholesome nutrition
Fibre to Fabric	Lack of discussion on effort of converting plant or animal fibre into cloth; also negligible mention of environmental impacts	Growing of few cotton plants and harvesting the cotton bolls to spin a yarn	Understanding about resource dependency and labour involved in making consumable products.
Soil	No practical activity to accompany the theoretical information provided about soil components	Make compost. Compare growth of plants in different soil types. See effects of fertiliser/ pesticide	Appreciating the complexity of soil constituents and how it is necessary for growth. Learn about various natural cycles.
Reproduction in plants	Theoretical discussion limited to reproductive parts of plant	Save seeds of different plants and compare their shape, size, colour etc. Examine the variety of flowers and pollinators	Understanding interdependency of insects and plants through pollination. How use of pesticides and fertilisers affects insects. Diversity in modes of reproduction
Water: A precious resource	Discussion limited to knowledge about water cycle and water scarcity	Using different methods of watering plants. Measuring amount of rainfall and growth of plants in monsoon. Making birdbaths in the garden	Learning about water utilization and how weather plays a crucial role in water cycle. Discussions can be enriched through local case studies
Forests: our lifeline	Activities mentioned can't be done without access to a garden. Mere discussion is of little value.	Plant variety of tree saplings and observe their growth	Appreciation of the time it takes for a tree to grow and how ecosystems emerge around trees.

Table 1: Alternative approach

Urban Farming: An Embodied Approach to Environmental Education

The alternative to the existing model of environment education is an imagination of rootedness of human life, within 'here and now', as part of an enriching experience; this can only be realized by practiced values and ethics, embedded in a harmonious relationship with environment. The challenge is to create avenues of 'embeddedness' that allow for development of ecological sensibilities in an enacted fashion. Urban farming is an intervention that provides the possibility of such an enactive environmental education.

Specifically, a garden by virtue of what it contains provides for many functional possibilities, termed as affordances by Chemero (2003), to understand principles and ideas about environment by working in the given space. Theories of situated cognition reaffirm the importance of context in learning through participation within a community (Rogoff, 2003).

The idea of community farms is not new, and has been an important part of Gandhian Basic Education. In fact, Anand Niketan, a *Nai Talim* school at Wardha has made farming an integral part of school activities. The students are however, already from agricultural communities and don't face the distancing from environment, as seen in urban places. As part of an earlier research, 5 students between ages 11-13 from the school were interviewed to understand their perception about environment and sustainable practices. For a comparative analysis, 5 children from an urban settlement were also interviewed1. Those living in urban areas (in Delhi) could at most recollect names of three trees in their locality (Neem, Peepal, Gulmohar). Most had a few plants at home but except one child, none took care of the plants personally. All of them mentioned having plants and trees at school but they were taken care of by the gardener employed for the job. Most felt disinterested in participating in "environment-activities" which is considered an extra-curricular subject by them. Even the ones interested mentioned eco-club activities like debates, drawing competitions and related projects as being related to the environment. All of them had very poor knowledge about their immediate locality in terms of energy usage, water consumption, plant diversity and food source.

In contrast, students from Anand Niketan were well aware of trees and plants found in local areas. Interestingly, none of them felt they were doing anything special *for* the environment by growing vegetables at school or home, taking measures to save water, keeping weather records or learning skills to lead a life with minimal dependence on outside resources. Rather their answers indicated that they saw direct relevance of these activities in their life, in other words, they didn't see a distinction between their own well-being and the ecosystem they are a part of. One could assume that they had internalized concepts of interdependence and resilience through various activities at school. During cooking, they usually use the vegetables grown in the school garden and are well aware of the efforts and time taken in growing them. The teachers also facilitate discussions over aspects of nutrition, and the act of cooking itself is done as a group activity so students come to realise by experience the importance of each sub-activity and the outcome (that is eaten by all of them) is dependent on these tasks being done well. The emphasis, thus very naturally shifts from competition to collaboration and coordination. The school premises are cleaned by both teachers and students without exception unless anyone is seriously injured or ill. The activity has led students to take a certain ownership about the place and ambience. They are intuitively aware of their rights and responsibilities. So, issues pertaining to garbage disposal, waste management, pesticide usage and water availability are not in the sphere of theoretical knowledge but active engagement with tangible outcomes. It remains to be seen whether a similar intervention would change

[1] Field study titled *An exploration of ecological sensibilities in school education— analyzing its reflections in the NCERT science textbooks, and understanding some initiatives and practices* carried out as part of MAEE at TISS

perspective among urban students. The argument is that, community gardening, as an intervention could be introduced in urban settings in order to promote 'whole systems thinking', defined by Sterling (2001) as an "extension of perception, a quality of connection in our conceptual thinking, and integration in our planning and actions towards healthy systems." Broadly, a garden provides a rich platform for contextualization and integration of ecologically relevant concepts along with avenues to experience change brought about by one's own efforts. The combined approach is essential for development of ecological sensibilities.

Urban Ecology Education in Action

Following is a short description of few activities that can be done to bridge the gap between mere awareness and pro-environmental behaviours mentioned in the previous sections. These activities are also important to help students feel and view natural systems as constituting of mutually interacting entities and connected by complex, non-linear relationships. This view is argued as essential to be able to view the dominant reductionist paradigms in critical light. Implications for cultural perception and behaviour about ecosystems are expected to emerge from the nature of interactions between the environment and individual. Activities under the broad theme of gardening provide ample space for such meaningful interactions and connections that are difficult to make when dealing with fragmented chapters. Depending on the age, the same activity can be explored at different levels of complexity and criticality.

Making Compost: Students will be initiated into a discussion of waste; how it is generated; where is it disposed; would waste be around in absence of human population. Next, the concept of compost as a process and principle will be discussed. Students will use waste from school premises to experiment with different kinds of composting techniques. They will also be encouraged to make compost at home. The discussions and activities will help students analyse waste through a constructive lens and about independence of organisms to ensure a healthy ecosystem.

Planning for gardening: Students will be asked to visit some public gardens and nurseries to identify and plan the kind of plants they would like to grow. They will be encouraged to plant vegetables and will thus have to decide the months suitable for growing, learn to grow seedlings, make beds, plan placement of shrubs and vines, and learn about water requirements. The planning involved can be used to initiate discussions around phenology, climate change and food miles.

Incorporating organic farming principles in garden: Students will be taken to organic farms and asked to observe what they can. This will be followed by discussions around approaches for growing plants without chemical fertilisers and pesticides. Students will learn to prepare natural remedies to keep plants healthy and analyse how different insects and weeds are part of a garden, and can contribute to growth of their plants. These activities can be linked to problem of monocultures, industrial farming and importance of growing local food.

Cooking harvested vegetables from garden: Students will participate in cooking the vegetables they grow in the garden and in the process discuss various aspects of nutrition, energy needed for cooking, alternative sources of fuel and so on. They can be encouraged to learn local cuisines, and gain some understanding of history and geography of the area as a parameter leading to food choices. This brings to fore the question of food miles, environmental impacts, self-reliance, economics of crop production and right to food, especially for those below poverty line. Equally important is the issue of organic food, its relevance, the nature of pollutants in food and what can be done in order to eat healthy food.

Assessing Impact of Urban Gardening in Ecological Education

While there has been a lot of emphasis on ecological literacy, based on knowledge and awareness about ecological problems, relatively less has been discussed with regard to *environmental competency*, which would look at their ability to take action based on identification and analysis of local environmental issues. They should further be able to propose, evaluate and justify suitable actions. Their decisions and actions can be reasonably thought to be influenced by the knowledge, experience, sensitivity and disposition accrued by exposure to gardening and related discussions. The idea of embodiment should be reflected in the extent to which students view themselves as part of the environment and respond in light of this understanding. Their responses could be assessed using ethnographic methods in which the researcher would spend extended time observing and analyzing their activities and thought through interviews.

References

Chandrasekharan S., & Tovey, M. (2012). Sum, quorum, tether: Design principles underlying external representations that promote sustainability. *Pragmatics and Cognition, 20*(3), 447-482.

Chemero, A. (2003). An outline of a theory of affordances. *Ecological Psychology, 15*(2), 181-195.

Hopkins, R. (2008). *The transition handbook: From oil dependency to local resilience* (p. 17). Totnes: Green books.

Jackson, M. G. (2004). Towards an authentic Indian environmentalism. *Southern African Journal of Environmental Education, 21.*

NCERT (2005). *National focus group on habitat and learning.* New Delhi: NCERT.

Pichert, D., & Katsikopoulos, K. V. (2008). Green defaults: Information presentation and pro-environmental behaviour. *Journal of Environmental Psychology, 28*(1), 63-73.

Rogoff, B. (2003). *The cultural nature of human development*. NY: Oxford University Press.

Schumacher, E. F. (1995). *A guide for the perplexed*. London: Random House.

Sterling, S. (2001). *Sustainable education: Re-visioning learning and change*. Schumacher Briefings. Schumacher UK: CREATE Environment Centre.

EXPLORATION OF STUDENTS' PHYSICS PROBLEM SOLVING APPROACH USING LATERAL SCAFFOLDING TECHNIQUE

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Inculcating general and domain specific problem solving skills has continued to hold the interest of researchers. In the context of problem solving in Physics, influencing factors are many and the interplay among them is complex thus rendering the understanding of the problem solving process hard. One way of attempting to understand this is to enable a student to navigate through a particular problem that shall allow the researcher to decipher at least a subset of the influencing factors. In this paper, we report the investigations of the reactions and responses to a Physics problem. During the problem solving process, lateral scaffoldings were provided. Which scaffolding does a learner use and when and how does he/she use them unearths influencing deterring factors. Analysis of the results suggest an instructional approach that may require a directed approach to the strengthening of skill sets and that when embedded in a well-designed Physics problem may develop robust problem solving skills.

INTRODUCTION

Education is the process by which an individual is encouraged and enabled to fully develop his or her potential; it may also serve the purpose of equipping the individual with what is necessary to be a productive member of society. Through teaching and learning, the individual acquires and develops domain knowledge and skills, which are the chief contributors for the development of students' problem solving abilities. The last two decades mark an important phase in the recognition of the transition from 'learning stage' to 'facilitate the learner stage' in the realm of problem solving in Physics (Madsen et al., 2015; Kontur et al., 2015; Barniol & Zavala, 2015; Zuza et al., 2015). In the present context, the literature cited discusses students' strategies for solving specific types of Physics problems (Larkin et al., 1981; van Heuvelen et al., 1991; Hake, 1998).

Research results indicate that students resort to hunting for the relevant equation as the important first step while solving a problem (Larkin, 1980; Frank, 1987; Mayer, 2003b). Not being able to recall the equation could be one of the major reasons for not solving the problem. It has also been observed that mathematical skill or the lack of it can be a major contributor not only in not being able to formulate a conceptual framework into a mathematical coherent structure, but also in not being able to reach the end of the solution while solving a problem (Leonard, Dufresne & Mestre, 1996; Hu & Rebello, 2014; Pretz et al., 2003). The inability of a student in translating verbal information into a coherent conceptual framework can be a major deterrent in reaching the said goal (Bunce & Heikkinen, 1986; Larkin & Reif, 1979; McDermott & Larkin, 1978; Singh, 2007; Polya, 1957). This issue gets compounded when the problem involves usage of Physics from different domains (Larkin et al., 1980; Cohen et al., 2000; Frank et al., 1987). Our own research substantiates these observations (Hegde & Meera, 2012; Hegde & Meera, 2011). Another aspect investigated by researchers in this field is the efficacies of an attempt by students to solve a

Physics problem in a group (Heller et al., 1992). It is in this context that we investigated the role of some of these issues in Physics problem solving by contriving the problem discussed below.

METHODOLOGY

In our study, we have adopted a two phase approach. We have obtained and analysed responses to Physics problems designed in Multiple Choice Question (MCQ) format and followed it up with semi-structured interviews to probe in detail the students' Physics problem solving methodologies. Three hundred students from undergraduate level were presented with a set of Physics problems in the MCQ format. Options for each question were designed with clear objectives. The students' responses were analysed. In this paper, we discuss the results of investigation of a selected representative problem. The responses to the MCQ test provide us with pointers that have been used in the design of interview protocol. The design of the interview protocol is the critical aspect of this study. The interview protocol is designed with appropriate scaffoldings so as to bring out the microstructure of their knowledge representations. The interview stage involves validation interview as the first step which serves the purpose of identifying whether a question conveys the meaning the interviewer intends to present to the student. Based on these inputs, the questions were reformulated wherever necessary and the scaffoldings were fine-tuned. These processes laid a foundation for the data interviews. Each student has been interviewed in a specially set up studio. We have interviewed ten students with this problem. The interviews were recorded using a video camera and electronic writing pad. Scaffoldings were given to ensure progression towards solution to the problem. The recordings have been transcribed and analyzed.

The students who participated in the study are in the age group of nineteen to twenty one years and are students of an undergraduate program. All the students studied Physics as one of their subjects. The problems presented ensured that the students had received formal class room instruction on the relevant topics.

Design Considerations for the Question

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic $\gamma = \left(\frac{7}{5}\right)$ gas at the same temperature 300 K. The piston of A is free to move, whereas that of B is fixed. The same amount of heat is supplied to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise the temperature of B is

(A) 30 K (B) 18 K (C) 50 K (D) 42 K

For the solution of this problem, the following aspects of Physics learning are intrinsically relevant.

- Interpretation of 'piston is free to move' and 'piston is fixed'.

More often than not, we express the language of Physics and Physics instruction in terms of colloquial representation. However, the question that needs to be addressed is about the acceptance of such a practice amongst the student community unless and otherwise conveyed properly. Does 'free to move' imply constant pressure and 'fixed' imply constant volume.

- Relating Q and ΔT through $Q = nC\Delta T$.

The mathematical connectivity between heat supplied and the temperature difference/rise appears in different contexts in heat and thermodynamics. The choice of appropriate equation is an important step in such a case.

- Relating C_P and C_V through $\gamma = \frac{C_P}{C_V}$.

An important hindrance to learning is attributed to the choice of a symbol which can represent different physical quantities in different contexts. In this case, γ is used to represent the ratio of specific heats; however the same symbol can stand for or gamma radiation or coefficient of cubical expansion or in fact for anything! The recognition of accepted symbols in a given context is an important way of bridging the conceptual platform and mathematical structure.

Stage 1 –Pilot Study

In the pilot study, the question was presented in the MCQ format, as given below.

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic $\gamma = \left(\frac{7}{5}\right)$ gas at the same temperature 300 K. The piston of A is free to move, whereas that of B is fixed. The same amount of heat is supplied to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise the temperature of B is

(A) 30 K (B) 18 K (C) 50 K (D) 42 K

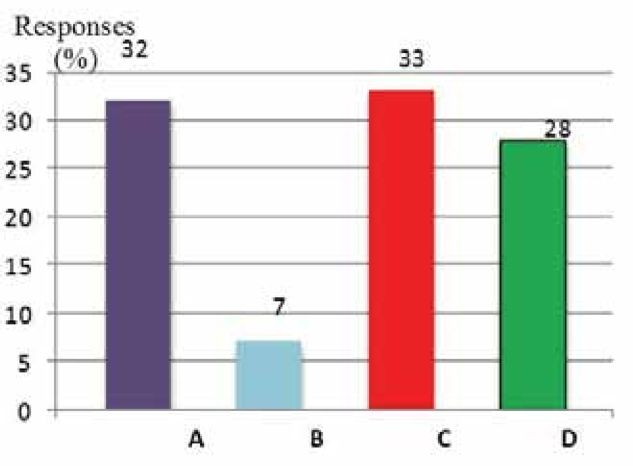

Figure 1: Students' responses

We observe that twenty eight percent of the students chose the correct option. The nature of distribution of the responses does not establish any clear dominant aspect of difficulty in solving this problem. The analysis of the MCQ responses presents us with several tasks. The important one is the necessity to investigate the difficulty in interpreting the colloquial statement into a coherent Physics concept. In addition to this, the role and mode of mathematical processing when multiple variables are involved also needs to be probed.

Stage 2 – Personal Interview

Design of Interview Protocol

The scaffoldings provided during the interview play an important role in the usefulness of interview proceeds. Research findings show that students rarely have a tendency to look for the underlying physical principles while solving a problem (Hegde & Meera, 2012; Hegde & Meera, 2011). Therefore, presenting the relevant physical principle to the problem solver is a weak scaffolding. The strong tendency for a student is to hunt for the relevant equation. Any help in this direction is, therefore, a strong scaffolding. In the design of the interview protocol, the weakest scaffolding was provided first. The categorization of a scaffolding as a weak scaffolding or a strong one is not really absolute. The sequencing order of the scaffoldings was generated taking into account the analysis of MCQ responses and also of validation interview results.

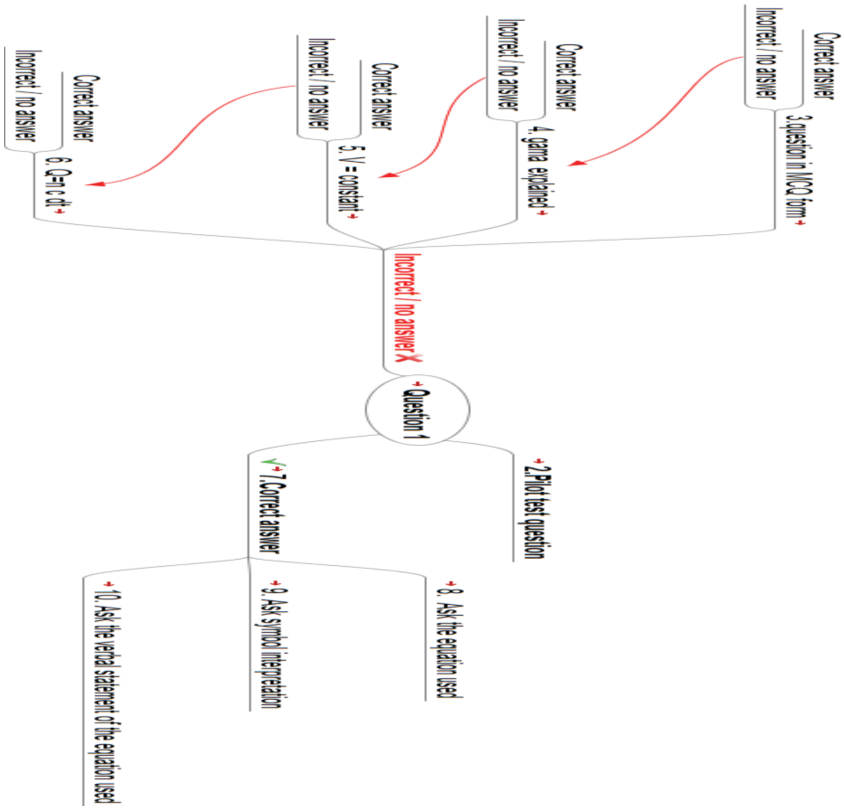

Figure 2: Mind map representation for scaffolding strategy management

As depicted above, the problem statements were structured in different versions to enable the student to use the corresponding scaffolding.

Version 1: Question in the Open Ended Format

To begin with, we presented the question in the open ended form as given below.

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic gas $\left(\gamma = \frac{7}{5}\right)$ at the same temperature. The piston of A is free to move, whereas that of B is fixed. The same amount of heat is supplied to the gas in each cylinder. The rise in temperature of the gas in A is 30 K. Calculate the rise in the temperature of the gas in B.

Of the ten students, one student could solve the problem successfully.

The students' responses revealed the lack of understanding between different relational aspects of specific heats of an ideal gas. The two chief relations between the specific heat at constant pressure C_p and that at constant volume C_v are $C_p - C_v = R$ and $\frac{C_p}{C_v} = \gamma$. These two equations govern most of the conceptual interconnections in the context of ideal gas laws and thermodynamics.

The excerpt below from one of the interviews highlights the lack of a coherent knowledge structure.

> "…the gas is diatomic, …however, the heat does not depend on that gamma…"

Such an observation from the student community is not rare. Clearly, a mismatch between the proper conceptual framework and the mental models carried by students needs to be addressed. Unless the link between the nature of the gas (read atomicity) and the heat absorbed is established during instruction, the required skill sets cannot be instilled.

Version 2: MCQ Format

For those students who could not solve the problem successfully, we rephrased the question in MCQ format.

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic gas $\left(\gamma = \frac{7}{5}\right)$ at the same temperature. The piston of A is free to move, whereas that of B is fixed. The same amount of heat is supplied to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise the temperature of the gas in B is

(A) 30 K (B) 18 K (C) 50 K (D) 42 K

Of the nine students who received this scaffolding, only one could use the MCQ format to solve successfully.

Version 3: Scaffolding Explaining γ

For those students who could not solve the problem successfully, we rephrased the question to include the definition of γ .

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic gas ($\gamma = \frac{C_P}{C_V} = \frac{7}{5}$) at the same temperature. The piston of A is free to move, whereas that of B is fixed. The same amount of heat is supplied to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise the temperature of the gas in B is

(A) 30 K (B) 18 K (C) 50 K (D) 42 K

Of the eight students who received this scaffolding, two students used this scaffolding to solve the problem successfully.

The meaning of physical processes in colloquial representations is one of the major bridges in establishing a robust and appropriate mental model in students. The following piece of interview transcript suggests the lack of connect between colloquial usage of physical processes.

"…the piston is free to move in the first case, but it is not in the second case; how does it help?....I am not getting it…"

These requirements came from almost all the students who attempted this step. A conscious and deliberate effort is needed to establish a link between language of physical processes and their representations in terms of everyday life and can be of use in establishing a speedy problem solving ability in students.

Version 4: Scaffolding Explaining the Meaning and Consequence of Fixed Piston v/s Movable Piston

For those students who could not solve the problem successfully, we rephrased the question to include the meaning of 'piston is fixed' and 'the piston is movable'.

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic gas. The ratio of specific heats of a diatomic ideal gas is $\gamma = \frac{C_P}{C_V} = \frac{7}{5}$. Both the cylinders are at the same temperature. The piston of A is free to move (the pressure of the gas in A is constant), whereas that of B is fixed (the volume of the gas in B is constant). The same amount of heat is supplied to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise the temperature of the gas in B is

(A) 30 K (B) 18 K (C) 50 K (D) 42 K

Of the six students who received this scaffolding, two students used the scaffolding to solve successfully.

Version 5: Question with Maximum Impact Scaffolding i.e., Equation for Heat Absorbed Given

For those students who could not solve the problem successfully, we rephrased the question to include the equation connecting heat supplied to the change in temperature.

Two cylinders A and B fitted with light and smooth pistons contain equal amounts of an ideal diatomic gas. The ratio of specific heats of the ideal gas is $\gamma = \frac{C_P}{C_V} = \frac{7}{5}$. Both the cylinders are at the same temperature. The piston of A is free to move (the pressure of the gas in A is constant), whereas that of B is fixed (the volume of the gas in B is constant). The same amount of heat is supplied to the gas in each cylinder. The heat supplied during a thermodynamic process is given by $Q = nC\Delta T$. If the rise in temperature of the gas in A is 30 K, then the rise the temperature of the gas in B is

(A) 30 K (B) 18 K (C) 50 K (D) 42 K

Of the four students who received this scaffolding, three students could use the scaffolding to solve successfully.

The remaining one student had difficulty in bringing C_P and C_V into the mathematical formalism.

Equation hunting has been known to be an impediment in problem solving. However, given the equation in a slightly altered form – which eliminates the need for random equation hunting process —can a student build up on it and generate the equation needed becomes the most important question. In our research, we got no strong correlation to support the above said expectation. As one of the students said during the interview,

> "…you have given $Q = nC\Delta T$ But there are C_P and C_V .… How to connect them to temperature change?....."

This was one of the persistent questions from students. The mathematical skill to reconstruct the equations to suit the altered context is not a natural learning outcome; it needs a deliberate restructuring during instruction.

Exploration of strategies by those students who solved the problem correctly during individual interviews

We wanted to investigate not only the above said parameters, but also the approach by successful solvers. We wanted to investigate further by exploring the knowledge structure used for solving the problem. We began by exploring it with a question as given below:

> "Which equation is used in arriving at the answer?"

We ask this question because we hypothesize that a novice would approach a problem by the process of random equation hunting.

All the six students who received this question could answer it. As expected the equation for heat supplied in terms of specific heat capacity was the answer given by the students.

In the next step, we asked the students if he/she can identify the meaning of the symbols used.

We asked this equation because an equation in mathematics is a functional representation using symbols; in an equation in Physics, symbols represent physical quantities. In Physics a given symbol represents different physical quantities in different contexts (many to one transformation). Four students could answer it. However, for two students, ΔT meant the temperature difference (as in heat conduction) rather than temperature rise/fall.

In the next step, we asked the students if he/she can verbally state the physical law that is represented by this equation used while arriving at the answer.

We are interested in knowing the students approach to translate the mathematical equation into the statement of a physical law. The students could translate the mathematical equation into the statement of a physical law. The response of three students was

> "…heat is proportional to temperature change…."

In this problem, the temperature rise depends on the external conditions under which heat is supplied for the same amount of heat supplied. This issue remained unexpressed in the knowledge structure carried by students.

RESULTS AND DISCUSSIONS

The investigations reveal a methodology for examining the parameters which act as deterrents while solving a Physics problem. The existing and practiced instructional strategies often concentrate on building a conceptual framework along with the relevant mathematical rigor. However, often a student fails to construct his/her ideas beyond definitions and statements of laws which get exemplified in the context of problem solving. This investigation probes in detail the microstructure of student thought processes in the course of problem solving. The semi-structured interviews along with appropriately designed scaffoldings bring out the exact nature of the difficulties which otherwise do not get exposed. These lead us to the following conclusions.

As a first step in problem solving, it is logical to identify the physical principle applicable to the situation. However, the weak association of students' conceptual framework of the physical principles acts as a major deterrent in problem solving. Most often than not, the physical terms in the problem statement act as a trigger for the search of an equation and the inability to do so may hinder the problem solving completely. The weakness students' possess in connecting the symbols to the physical quantities can be attributed to a tendency to look at an equation in Physics not as a relation between physical quantities but merely as a mathematical equation. Another important parameter which can play a significant role in limiting the problem solving abilities is the lack of mathematical manipulation skills. This brings to the front a possible approach to strengthen problem solving skills which instead of solving numerous problems, addresses strengthening of skill sets. The problem for this need to be appropriately designed and directed effort to develop the necessary skills can then be the focus.

A factor whose influence cannot be undermined in the studies of this kind is the role of domain vulnerability of the problem solver in the problem context. A student who is already unclear of concepts in a domain of Physics may not get much help from scaffoldings. The scaffolding in such cases may not instigate the student towards a solution. Another limitation, here, is the non-uniqueness of scaffoldings, which cannot be sequenced. The absence of such a hierarchical structure may render a set of scaffoldings (generated for a question, designed for a learner) unusable in some other context. This being a possible limitation of the probing methodology, a learner independent but system dependent unique scaffoldings can hardly be designed. However, our investigations reveal similar constraints in learning even in the context of problems in other domains (Hegde & Meera, 2012; Hegde & Meera, 2011) suggesting the generality of the usefulness of the technique illustrated in this paper.

References

Barniol, P., & Zavala, G. (2015). Force, velocity, and work: The effects of different contexts on students' understanding of vector concepts using isomorphic problems. *Phys. Rev. ST Phys. Educ. Res. 10*, 020115.

Bunce, D. M., & Heikkinen, H. (1986). The effects of an explicit problem-solving approach on mathematical chemistry achievement. *Journal of Research in Science Teaching 23*(1), 11-20.

Cohen, J., Kennedy-Justice, M., Pai, S., Torres, C., Toomey, R., DePierro, E., & Garafalo, F. (2000). Encouraging meaningful quantitative problem solving. *Journal of Chemical Education, 77*, 1166-1173.

Frank, D. V., Baker, C. A., & Herron, J. D. (1987). Should students always use algorithms to solve problems? *Journal of Chemical Education, 64*, 514-515.

Hegde, B., & Meera, B. N. (2011). Multiple choice questions and interview as a combined tool for unravelling students' cognitive process in Physics. In S. Chunawala and M. Kharatmal (Eds.), *Proceedings of the Fourth epiSTEME 4 – International conference to review research on science, technology and mathematics education* (pp. 132-136). India: McMillan.

Hegde, B., & Meera, B. N. (2012). How do they solve it? An insight into the learner's approach to the mechanism of Physics problem solving. *Phys. Rev. ST Phys. Educ. Res. 8*, 010109.

Kontur, F. J., Harpe, K. L., & Terry, N. B. (2015). Benefits of completing homework for students with different aptitudes in an introductory electricity and magnetism course. *Phys. Rev. ST Phys. Educ. Res. 11,* 010105.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six thousand-student survey of mechanics test data for introductory Physics courses. *American Journal of Physics, 66*, 64-74.

Heller, P., Keith, K., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics 60*(7), 627-636.

Heller, P., & Hollabaugh, M. (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. *American Journal of Physics 60*(7), 637-644.

Hu, D., & Rebello, N. S. (2014). Shifting college students' epistemological framing using hypothetical debate problems. *Phys. Rev. ST Phys. Educ. Res. 10*(1), 010117.

Larkin, J. (1981). Cognition of learning Physics. *American Journal of Physics, 49,* 534 - 541.

Larkin, J. H., & Reif, F. (1979). Understanding and teaching problem-solving in Physics. European *Journal of Science Education 1*(2), 191-203.

Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science 208*(4450), 1335-1342.

Leonard, W. J., Dufresne, R. J., & Mestre, J. P. (1996). Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems. *American Journal of Physics 64*(12), 1495-1503.

Madsen, A., McKagan, S. B., & Sayre, E. C. (2015). How Physics instruction impacts students' beliefs about learning Physics: A meta-analysis of 24 studies. *Phys. Rev. ST Phys. Educ. Res. 11*, 010115.

Mayer, R. E. (2003b). *Learning and instruction*. New Jersey: Merrill Prentice Hall.

McDermott, J., & Larkin, J. H. (1978). Re-representing textbook physics problems. *Proceedings of the Second National Conference of the Canadian Society for Computational Studies of Intelligence.*

Polya, G. (1957). *How to solve it, 2nd ed.* NJ: Princeton University Press.

Pretz, J. E., Naples, A. J., & Sternberg, R. J. (2003). Recognizing, defining, and representing problems. *The Psychology of Problem Solving 30*(3).

Singh, C. (2007). Problem categorization in teaching and learning. Presented at the *American Association of Physics Teachers 2007 Summer Meeting.*

van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based strategies. *American Journal of Physics, 59*, 891-897.

Zuza, K., Almudí, J-M., Leniz, A., & Guisasola, J. (2015). Addressing students' difficulties with Faraday's law: A guided problem solving approach. *Phys. Rev. ST Phys. Educ. Res. 10,* 010122.

CHEATING DETECTION IN LOW STAKES TESTING

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An underlying assumption of a low-stakes test has been that mass cheating is not prevalent. Because the test gives feedback to stakeholders, such cheating could adulterate the data collected and feedback given to all stakeholders involved. Also, such instances of mass cheating could hint that the test is no longer perceived as a low-stakes test. The purpose of this study is to develop an algorithm-based system to detect mass cheating cases and investigate possible reasons, if detected, in ASSET.

This study will develop an algorithm and use it to detect possible cases of mass cheating using response data collected from ASSET. The outcome of this study, within our organization (Educational Initiatives Pvt. Ltd.), will be to analyse such cases, using a robust algorithm and supporting them with qualitative insights.

INTRODUCTION

What is cheating?

Cheating is any deceitful or fraudulent attempt to evade rules, standards, practices, customs, mores, and norms to gain an unfair advantage or to protect someone who has done so. Cheating includes, but is not limited to (Jones, 2001/ 2011):

- Giving or receiving information during an exam ("exam" includes tests, assessments, and quizzes, whether delivered in a classroom setting or on line.)
- Using unauthorized material (like notes) during any exam; unauthorized dissemination or receipt of exams, exam materials, contents, or answer keys in written or digital form.
- Taking an exam or writing a paper for another student—or asking someone to take an exam or write a paper for you (this includes sharing work and/or writing group-produced answers on take-home and on-line exams unless explicitly permitted by the instructor). This is also called "impersonation."
- Submitting the same paper—or different versions of what is substantially the same paper—in other courses or in subsequent attempts to pass a course.
- Sabotaging, misrepresenting or fabricating written work, sources, research, or results as well as helping another student commit an act of academic dishonesty or lying to protect a student who has committed one.

For this research our findings mainly focus on cheating happening through a teacher where he/she reads out the answers in class or teaches through the test or asks a 'bright' student to solve the paper and read out the answers in class during the test.

WHAT IS ASSET?

ASSET (Assessment of Scholastic Skills through Educational Testing), developed by Educational Initiatives (EI), is a low-stakes, multiple choice-single response type and benchmarking test. It gives critical feedback to students, teachers and school management about the learning levels of students and also entire classes.

Rather than testing rote learning, through multiple-choice questioning, it focuses on measuring how well skills and concepts underlying the school syllabus have been learnt by the student (ASSET Website). Students of classes 3-10 are tested in English, Maths and Science, Social Studies and Hindi.

Basic Assumptions and Caveats

1. Cheating happens to secure a gain in performance. W. C. Fields, acting in the movie You Can't Cheat an Honest Man, opines, "If a thing is worth winning, it's worth cheating for." (Cook, in Cook & Sacerdote, 2003)
2. Only mass cheating is under the purview of this paper. The main objective of this paper is to identify cases of mass cheating where students receive external help from a teacher or an evaluator or students mark answers that the 'best' student reads out, etc.
3. Sections with at least 15 students are part of this study. Although, theoretically, cheating among a smaller number of students can be caught, we have restricted ourselves to sections with at least 15 students which helps strikes a balance between large sections and smaller sections.

Based on the performance and patterns in responses received via ASSET, the algorithm developed will help us identify sections of classes where cheating is suspected. The algorithm uses three criteria. To identify cheating cases one or more criteria should be met.

This algorithm was tested on four rounds of ASSET performance data. In each round, approximately 300 schools' performance data was looked at to ascertain if cheating had occurred.

The Three Criteria

Criteria 1 - Number of questions in each class where the performance of the class is greater than the national average by 30%. In other words, more the number of questions with 'high' performance, more likely cheating.

Criteria 2 - Number of questions in each class where the performance of the class in low performing questions (questions with performance less than 50%) shows a 90% match in responses chosen. Meaning, the more similar the responses in low performing questions, more likely cheating.

Criteria 3 - Average score compared to previous round shows a significant jump of 20 percentile points. Drastic improvements compared to previous performance is considered to be an indicator of cheating in the current round.

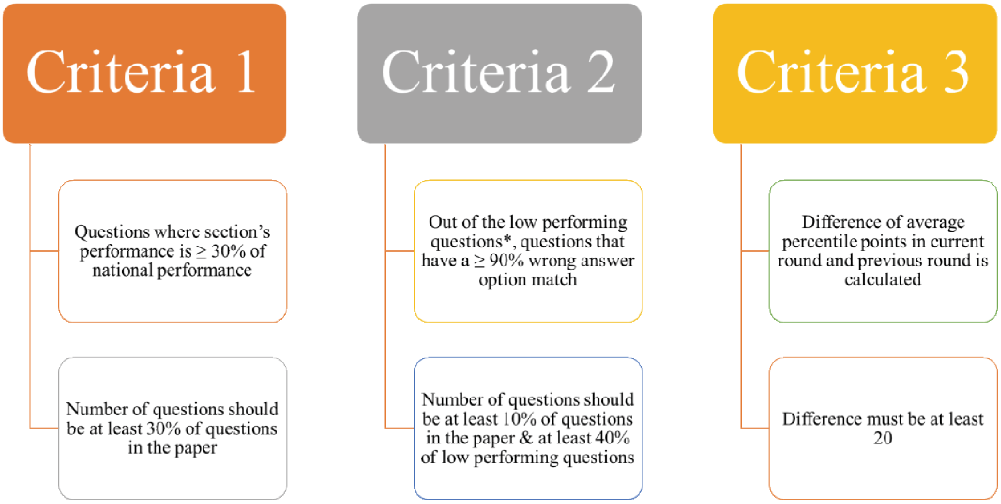

Figure 1: The three criteria are represented in the image above

METHOD

Characteristics of a Cheating Section:

1. Extremities in performance of questions in the test, i.e., performance in most questions are very high or very low.

% of SECTION students answering correctly	91	9	91	83	0	85	89	89	20	93	87	85	83	83	85	85	78	83	80	89	2	85	78	76

Sample 1: This shows how the performance of almost all questions is closer to 0 (lowest) or 100 (highest) (each box from left to right represents % score in questions)

2. Similar answering patterns seen

	Question No. →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
No.	Student ↓ Correct Answer →	C	D	C	B	C	B	D	B	A	D	C	D	B	A	B	A	D	A	A	B	C	A	A	C	D	A	C	B	C	D	B	D	C	A	C
36	[redacted]	✓	B	✓	✓	D	✓	✓	✓		✓	✓	✓	✓	✓	*	✓	A	✓		✓	*	✓	✓	B	*					C			D		✓
37		A	B	✓	D	B	✓	✓	✓	C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	B	✓	✓	✓	✓	A	C	B	C	✓
38		✓	✓	✓	✓	D	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	*	✓	✓	✓	✓
39		✓	B	✓	✓	D	✓	✓	✓	C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
40		✓	B	✓	✓	D	✓	✓	✓	C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
41		✓	B	✓	✓	D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
42		✓	B		C	B	✓	✓	✓	C	✓	✓	✓	✓	✓	C	✓	✓	✓	✓	✓	A	✓	B	✓	✓	B	✓	✓	✓	✓	✓	✓	✓	B	✓
43		✓	B	✓	✓	D	✓	✓	✓	C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
44		✓	✓	✓	✓	D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	D	✓	✓	✓	✓
45		✓	B	✓	✓	D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
46		✓	*	✓	✓	D	✓		✓	B	✓	*	*	✓		*	D	A		✓	✓	*	D	*	D	A		A	✓			C	*	*		

Sample 2: The above sample shows very similar answering patterns by the students indicating that a teacher/student could be reading out the answers (student names hidden in this sample)

3. Unusually high scores in the round that cheating happened.

Unlike gains associated with true learning, however, one expects no persistence in the artificial test score gains due to cheating. Thus if the children in cheating classrooms this year are not in cheating classes next year, one expects the full magnitude of the cheating-related gain to evaporate (Jacob & Levitt, 2002)

***The algorithm*:** The responses from students across the country in the ASSET tests administered are collected and scored. Post this, a log file can be created on demand in an internal system developed by EI's IT personnel. Thereafter, checks are made to see if above said criteria are met. Such cases are those where cheating is suspected and are filtered.

Checks:

Criteria 1 (where the performance is significantly greater than national performance): If the number of questions with high performance exceeds 30% of the total questions in the paper, it is flagged.

Criteria 2 (similar answering patterns in low performing questions): Number of questions with a 90% match should be at least 40% of all the low performing questions in that section[1].

Criteria 3 (drastic and sudden improvement in performance): The jump in the average percentile points in the current round compared to the previous round if greater than or equal to 20 points is flagged as suspicious.

The final output from this exercise is a list of schools and specific classes and sections within that school that are flagged as suspicious. There are two levels of suspicious cases – level 1 (greater levels of suspicion) and level 2 (moderate levels of suspicion).

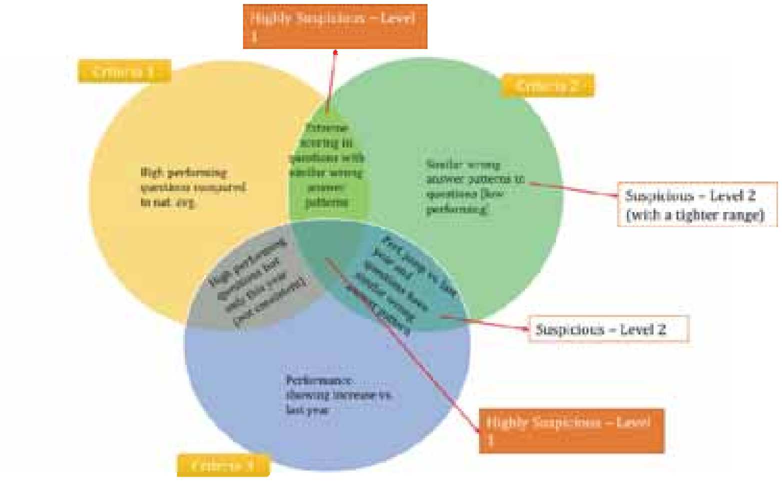

Figure 2: The figure above shows which cases fall under level 1 and 2 respectively.

1 The number of questions that satisfy these criteria should make up at least 10% of the questions in the paper.

RESULTS

Performance data from the December, 2014 round of ASSET was collected. A total of 9890 sections data was fetched. These sections belonged to classes 3 to 10 from 260 schools.

Out of these 9890 sections, 20 sections have been deemed to cheating cases – 14 in level 1 and 6 in level 2.

These 20 sections belong to a total of 11 unique schools.

Section	Student Count	Question Count	Benchmark	Criteria 1	Criteria 2 checked	Criteria 2 matched	Criteria 3 student check	Criteria 3 percentile difference
Section 1	33	30	147	15	4	3	Null	Null
Section 2	32	40	138	18	9	4	30	48
Section 3	34	40	152	17	7	4	33	-11
Section 4	34	45	118	14	19	9	31	-5
Section 5	27	40	127	18	11	10	22	34
Section 6	27	40	111	12	18	12	24	19
Section 7	32	60	131	30	14	10	30	33
Section 8	30	60	118	25	21	13	25	20
Section 9	30	45	115	14	19	8	25	34
Section 10	31	45	117	15	17	7	29	33
Section 11	43	50	132	24	6	5	43	42
Section 12	30	45	127	19	16	10	29	-8
Section 13	24	35	140	18	10	10	17	62
Section 14	31	40	123	14	15	6	30	33
Section 15	17	30	115	0	5	3	Null	Null
Section 16	40	40	103	2	7	4	37	-30
Section 17	43	40	129	11	7	4	43	-2
Section 18	26	40	73	5	25	22	Null	Null
Section 19	26	45	97	10	26	18	Null	Null
Section 20	27	40	123	9	8	5	20	25

Table 1: Showing the cases of cheating filtered and how they fare of each criterion

DISCUSSION

Individually, the criteria used do not fully substantiate cheating. But when corroborated, they substantiate cheating. Criteria 2 (similar wrong answer patterns) is believed to be the most compelling of the three. Criteria 1 and 3 help in supplementing and affirming the suspicion. Identifying similar answering patterns using strings of responses suffers from a drawback – the process is complicated. Simply identifying number of questions where such similarities are seen are not limited to blocks of questions showing similar responses patterns. Even if the cheating pattern in the test is sporadic, it can be identified here. This research would be incomplete without conducting a retest on a sample set of students suspected to have cheated. For the retest, the same paper will be administered again under supervised conditions (based on a forthcoming publication).

The overall perception of low stakes testing is challenged in this research.

> Another kind of standardized testing, in which the results only matter somewhat for teachers and students, is commonly referred to as low-stakes. On the scale of testing, this is

better. It holds teachers and students collaboratively rather than competitively accountable for student outcomes, and uses test scores to guide things like professional development and budget allocation (Save our Schools blog page, 2012).

A low-stakes, benchmarking test like ASSET focusses on testing concepts and skills and providing feedback on the learning gaps identified through this test. Students need not prepare for the test as it assess them on what they have learnt and understood so far, rather than recall facts. In such a test or any other low-stakes test, if cheating is brought to light, it is interesting to find out if the stakeholders of this test know the true meaning and purpose of a low-stakes test.

High-stakes testing is also not free from the obstructive issues of cheating.

> As school systems across the country have raised the stakes associated with standardized testing, cheating on these tests has become a tempting option for some teachers and administrators. The investigation for the Chicago Public Schools by Brian Jacob and Steven Levitt (2003) has documented cheating by 5 percent or more of the teachers.

CONCLUSION

The basic results of the analysis of the data points to mass cheating being prevalent in a low-stakes test.

Our first goal in the coming months is to administer retest and compare data with the first round of tests. The process will then be finalized and ongoing after every round of ASSET (which is currently conducted twice a year; in August and December)

As a long term goal, this algorithm and understanding can be extended to other similar tests.

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References

Cook, P. J., & Sacerdote, B. (2003). Comments. In *Brookings-Wharton Papers on Urban Affairs 2003*(1), 210-218. Brookings Institution Press. Retrieved November 10, 2015, from Project MUSE database.

Jones, L. R. (2001 & 2011). *Academic integrity & academic dishonesty: A handbook about cheating & plagiarism.*

Jacob, B. A., & Levitt, S. D. (2003). Catching cheating teachers: The results of an unusual experiment in implementing theory. In *Brookings-Wharton Papers on Urban Affairs: 2003* (pp. 185-220) US: Brookings Institution Press.

Save our Schools Blog (2012). Retrieved from www.saveourschoolswisconsin.wordpress.com/2012/06/12/high-stakes-low-stakes-no-stakes-the-testing-dilemma/

ASSET Website (n.d). Retrieved from www.ei-india.com/asset

TENTATIVENESS OF SCIENTIFIC THEORY: WHAT DO HIGH SCHOOL STUDENTS BELIEVE

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Nature of Science (NOS) is an important component of scientific literacy and as such is considered as significant for school going children. A minimum level of understanding of the character of science is considered as essential for all students to make them scientifically literate. One of the principles included within the broader concept of NOS is that scientific knowledge including scientific theories are tentative in nature and that the scientific theories are more a creation of the scientists' rather than mere discoveries. This paper presents the findings related to school student's beliefs and their justifications regarding tentative nature and constructed versus discovered nature of scientific theories. The findings from this qualitative study suggest naïve understanding of nature of scientific theories among the participants. It is also suggestive of need for initiatives to enhance students' understanding of nature of science.

INTRODUCTION

Scientific literacy is considered as important for every individual and for all nations and school education has a key role in achieving the goal of scientific literacy for all and Nature of Science (NOS) is unanimously considered as a vital component of scientific literacy (AAAS, 1993; NRC, 1996; Lederman et al., 2002; Bell, et al., 2003; NCF, 2005).

NOS reflects the epistemological beliefs inherent to scientific knowledge and its development and refers to the description of the values and assumptions underlying science and scientific process, understanding of which is supposed to influence the way individual applies scientific knowledge (Driver et al., 1996), facilitates students` understanding of science content knowledge (McComas, 1998), their ability to effectively deal with socio- scientific issues (Kolsto, 2001) and in intelligently interpreting popular science reports (Norris & Phillips, 1994). The school science curriculum is, therefore, expected to cater to the needs of the majority of the students along with the need to prepare individuals for career as future scientists. National Curriculum Framework (2005) also acknowledges that understanding of NOS is an important goal of science education.

NOS, however, is a contested term that has been defined differently by different people. Mc Comas (1998) defined NOS comprehensively including the sociological, philosophical and cognitive perspectives into the definition. A more general and practical definition given by Lederman et al., (2002), defined NOS in terms of the values, assumptions and limitations of scientific knowledge. Irrespective of the contest in defining NOS at a higher level, there is a considerable degree of agreement among the different stakeholders regarding the different principles that are included in the umbrella term of NOS and that are important as well as comprehensible by school going children (Lederman et al., 2002). One of the significant principles of NOS is that scientific theories (ST) are tentative in nature although they are reliable to a great extent (McComas, 1998; Abd-El-Khallick, et al., 1998). STs are considered as the ultimate goal of science that provides the explanatory and predictive powers to science. It is accepted to be a scientists' construction and that further modification or changes are not untenable in future. Several studies have been conducted to ascertain the students understanding of the scientific theories as absolute or tentative and whether it is discovered or constructed in nature.

However, no empirical study was located in the Indian context that investigates and explored the school going students' views on different aspects of NOS in general and the tentative versus absolute and discovered versus constructed nature of scientific theories in particular. The observation was considered as significant on the ground that school science curriculum includes learning of several scientific theories and that exploring students' views will provide insight into any effort to develop informed understanding of NOS among the students. The present study was thus carried out to answer the following research question: *What are the students views regarding nature of scientific theories and what justifications are held by the students' in favour of their views?*

METHOD

In accordance to the purpose of the study a qualitative approach was used to answer the research questions.

Participants

The participants for the exploratory study were science students in first year of their two year precollege course in science stream. Twenty-eight students, with high achievement in science at the secondary level, from four schools in the city of Varanasi affiliated to Central Board of Secondary Education were purposively identified as participants for the present study. All the schools used a mixed language approach for instruction and followed the text-books prescribed by NCERT during their secondary level education.

Data Collection

Data collection method involved collection of written response on a Science Reflection Questionnaire (comprising of six open-ended questions) as well as semi-structured interview data in accordance to the procedure detailed by Creswell (2003) and as advocated for by the previous research studies (Lederman & O`Malley, 1990). All the data were collected during the first quarter of 2008.

Credibility and trustworthiness of the data was established through member check method (Lincoln & Guba, 1985) and through triangulation of data from the questionnaire and from the interviews (Denzin, 1970). Finally, Scott's pi estimate of inter-coder reliability was calculated involving two independent coders and was found to be 0.82 which was considered as satisfactory (Shoemaker, 2003).

Data Analysis

The qualitative study followed inductive data analysis procedure (Creswell, 2004) that implies an iterative process for identifying patterns in response and for categorization and coding of the data. The entire data from questionnaire and semi-structured interviews were analyzed to identify explicit notations pertaining to nature of scientific theories. These identified notations were then inductively analyzed to identify students' reason or justification and categorize the same.

FINDINGS OF THE STUDY

The findings of the present study are presented as follows:

Finding 1

The entire twenty eight student in the present study accepted that scientific theories are discovered in nature. However, the only fourteen students were able to provide any reason or justification in support of their belief thus reflecting understanding of any sort, naïve or sophisticated.

A majority of the students (n=11) believed that the changes and/or modifications in STs are due to the **technological advancements**. Advances in technology leads to more sophisticated observations that leads to discovery of new facts and henceforth caused change in existing theory. The following transcript from the students' interview is exhibitive of their views:

Interviewer: You believe that scientific theories can change. What reason do you have to think so?

Vijay: Many of the theories can change …. In past the scientist lack in Technology and scientist's give theory by what they can see and they can know. But modern day technology helps in better instruments to see and observe.

Interviewer: You have cited Rutherford in your written response to support your belief. Can you explain that in light of what you said here?

Vijay: Rutherford experiment gave a new atomic structure…….he made an experiment [that was possible] because he had sophisticated instruments to do his experiment.

Similarly another student used the lessons from biology class and presented the discovery of microscopes as a technological advancement that led to new knowledge in science and yet another student cited the invention of telescopes as the reason behind change in scientists' ideas and theories. Thus these students believed that development of technology helps the scientists to know many new things that were earlier unknown and that technological advancement in science lead to development of more sophisticated instruments that enabled the scientists to do experiments at a much more sophisticated level. Thus, the scientists come to know of several facts/evidences/ideas that were unknown earlier. The new facts that scientists comes to know with the help of new technology causes the scientists` to change many of their ideas and theories.

Three of the students discussed about the mismatch between the theory and observation as the leading force behind the change in scientific theories or ideas and also included the role of technological advancements in theory change in their discussion. This subset of three students believed that scientists` develop explanations for different things. However, when the existing explanations do not apply to several of the observed facts, the scientists` try to study the phenomenon with alternative thinking and come up with new explanations that can explain the observed facts. One student explained in her written response that *often the old theories are proved wrong….. they do not support many facts and scientists do more experiments to make a theory and show other facts as true.* Further these students were also able to cite examples from their science classrooms to explain their views. The context of atomic structure was cited by two of the students whereas one student cited the context of Lamarck's theory. One of this subset of students expressed that *Rutherford did not agree with Thomson and proved him wrong…He gave a new model that showed why alpha particle was deflected in the Rutherford experiment*. These students also used the justification of technological advancement as a reason for change and modification in scientific ideas.

Thus only these three students clearly understood the explanation function of science and were able to synthesize the idea of new observations and facts leading to deficiency in the explanatory power of ST and thereby leading to modification or change in ST.

Finding 2

Of the 28 students five students believed in the constructed nature of ST, whereas seven (7) students believed that STs are discovered and sixteen (16) students were unable to discuss the issue at all. The students affiliated with the construction view believed that science explains natural phenomena and many times the scientists creativity is important in coming up with an explanation of those phenomena. They further believed that the scientists need to be creative and imaginative while developing their theories. One of the student explained in his written response that *when the scientist observed the vapours coming out he must have been very creative and tried to link different things together…that the energy of this vapour can be used to develop an engine….so I think that scientific theories are created more so.. S*imilar explanations were also provided by other students commonly drawing their reasons from the works of Newton, Priestly and Rutherford. The reasons provided by the students reflected their informed understanding with respect to scientific theories in comparison to other students.

Seven of the students believed that scientific theories are discovered rather than constructed. The scientists try to uncover the facts and relationships that are already there, existing in nature. Thus one student believing in the discovered nature of scientific theories wrote that *"scientists work for truth and truth is always there in nature. Scientist work and they discover it...like the laws of reflection was already there but scientist first gave the two laws"*. However these seven students do not outright reject the role of creativity in science. They believed that scientists are highly creative. However, while explaining creativity in science the students commonly cited the case of technological inventions where the creativity is important. For example one of the participant wrote that [*scientist] also use their Imagination and Creativity at many times in making new things for the society.* The following transcript reflects the students' views on creativity of scientists in science:

Interviewer: You have explained that scientists are creative. Can you please cite some relevant example to support your view?

Swati: Scientist invent when something new is given by him… we say that airplane was invented and bulb was invented by Addison because they used their imagination to develop so many new things.

The rest of the students (sixteen) did not comment on the constructed or discovered nature of scientific theories. However they all agreed that creativity is important in science and at the same time delimiting the role in case of technological inventions. Thus, the analysis of students' written response and interview data revealed that a majority of students' views on the nature of scientific theories (with respect to discovered vs absolutist dimension) are far from being sophisticated. Thus, they could not extrapolate their understanding of imagination and creativity to the different theories. They believed that all the theories are about the natural phenomenon that already exists in nature and the scientists search for them. Therefore, they find out or discover the theories.

The pattern of students' response further illustrates their lack of understanding about theory and it`s difference from other scientific knowledge (scientific law in particular) as was evident from the frequent mention of different laws and facts in place of theories in their response.

For instance at many occasions they cited different laws, (such as law of reflection), in their monologues related to scientific theories assuming that both kind of scientific knowledge are same.

DISCUSSION OF FINDINGS

No exploratory study could be identified in the Indian context for comparison and discussion. However, the findings from the present study were not in contradiction to the findings reported by different researchers across the globe. Perhaps the misconceptions regarding different aspects of NOS, including those related to ST has a globally common pattern. The present study revealed that a majority of the participants of this study could hardly discuss their position with respect to the different aspects of nature of ST. The students believed that the tentativeness of ST were mainly due to the discovery of new facts and evidences. They also frequently mentioned of the betterment of technology as the leading factor behind the discovery of new facts and evidences. Similar finding was reported by several researchers in different countries (Kang, et al., 2004; Solomon et al., 1996).

Another significant finding of the study was that a majority of the students could not discuss at all about the invented vs discovered nature of scientific theories. Among those who responded on this aspect, a majority of them accepted that ST is discovered rather than invented or created by the scientists. Such beliefs are a clear indication of the students' inability to associate the scientists' imagination and creativity with other aspects of development of scientific knowledge. Such finding is not an exception since great significance is attached with the word 'discover' in the studies of students epistemological beliefs (Larochelle & Desautels, 1991). The high frequency of students adhering to the belief that ST discovered implies that these students have no understanding of the explanatory nature of science. Rather the students exhibit an understanding that centres around the idea that science is description of natural events or phenomenon. The majority of the students failed to realize that the imagined and created ideas are integral part of the scientists' effort to develop scientific theories and laws. Similar findings were reported by Tsai (1998) wherein he concluded that students, both having dynamic view regarding tentative nature of scientific knowledge as well as having a static view, considered ST as discovered rather than invented. Literature on students' understanding of NOS suggests that early adolescents find it difficult to identify creation of explanations and their subsequent testing, as central to science (Solomon et al., 1994; Carey et al., 1989). Thus although the subjects of this study mentioned about imagination and creativity with respect to Newton they failed to identify the created nature of ST.

CONCLUDING REMARKS

The conclusions of the present study could be inferred as an iteration of the conclusion made by the researchers a long back that students come to the classroom with naïve epistemologies (Grosslight et al., 1991). The novelty of the study lies in the fact that it is embedded in a new context. One of the major conclusion of the present study was that a majority of the students were in possession of naïve understanding of nature of scientific theories since they failed to comprehend the explanatory power as the criteria for success of a ST and believed that it is only emergence of new facts through technological intervention that can cause a theory to change. Further, the student failed to comprehend the constructed nature of ST and hence could not appreciate the role of scientists' creativity and imagination in development of a ST. It was also concluded that the current curriculum of science has many relevant contexts, as was evident from the frequent citation of examples from the text books that can be capitalized to improve upon the students' conception of nature of ST and for that matter of NOS.

Finally, it was concluded that it is the curricular and instructional factors that led to a lack of consistency in students' understanding of NOS thus reiterating the position that naïve understanding of NOSST is not to be attributed to the lack of student potential (Klienman, 1965). There is uncontested need of explicit guidelines on part of national curriculum frameworks, the leading curricular guideline for school science, pertaining to the specific model of NOS that is to be emphasized in our classrooms and the general guidelines for their achievement in the classroom. The students left on their own to link different science content to NOS are all prone to develop such compartmentalized understanding. Thus, the students are required to have an explicit exposure to different experiences that might help them develop a well-connected and coherent understanding of NOS.

Although the nature of the study prevents any generalization beyond the sample, nevertheless it does signify the naïve epistemological development among the learners. At the same time large scale survey is also needed to develop a rich data base pertaining to different alternative conception held by the students with respect to nature of science in India that is inevitably of great importance in guiding curricular modification to incorporate explicit instruction on different aspects of NOS.

References

American Association for the Advancement of Science (1993). *Benchmark for scientific literacy*. New York: Oxford University Press.

Abd-El-Khallick, F., Bell, R., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82,* 417-436.

Bell, R. L., Blair, L.M., Crawford, B. A., & Lederman, N.G. (2003). Just do it? Impact of a science apprenticeship program on high school students understanding of the nature of science and scientific inquiry. *Journal of Research in Science Teaching, 40*, 487-509.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). An experiment is when you try it and see if it works: A study of grade seven students` understanding of the construction of scientific knowledge. *International Journal of Science Education, 11,* 514-529.

Creswell, J. W. (2003). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Ohio: Merrill Prentice Hall.

Creswell, J.W. (2004). *Research design: Qualitative, quantitative and mixed methods approach*. Newbury Park.: Sage Publications.

Denzin, N., & Lincoln, Y. (1994). *Handbook of qualitative research.* Thousand Oaks, CA: Sage.

Denzin, N. (1970). *The research act in sociology*. Chicago: Aldine.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young pupil`s images of science.* Philadelphia: Open University Press.

Grosslight, L., Unger, C., Jay, E., & Smith, C.L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching, 28,* 799-822.

Kang, S., Scharmann, L. C., & Noh, T. (2004). Examining students' views on the nature of science: Results from Korean 6th, 8th, and 10th graders. *Science Education, 89,* 314-334.

Kleinman, G. S. (1965). Teachers' questions and students' understanding of science. *Journal of Research in Science Teaching, 3,* 307-317.

Kolsto, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socio-scientific issues. *Science Education, 89,* 291-310.

Larochelle, M., & Desautels, J. (1991). `Of course it`s just obvious`: Adolescents ideas of scientific knowledge. *International Journal of Science Education, 13,* 373-389.

Lederman, N. G., & O`Malley, M. (1990). Students` perceptions of tentativeness in science: Development, use and sources of change. *Science Education, 74,* 225-239.

Lederman, N. G., Abd-El-Khallick, F., Bell, R., & Schwartz, R. (2002). Views of nature of science questionnaire: Towards valid and meaningful assessment of learners` conceptions of nature of science. *Journal of Research in Science Teaching, 39*, 497-521.

Lincoln, Y., & Guba, E., (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

McComas, W. F. (Ed.) (1998). *The nature of science in science education. Science and Technology Education Library.* Philadelphia: Kluwer Academic Publishers.

National Curriculum Framework (2005). *Focus group position paper on science education*. New Delhi: NCERT

National Research Council (1996). *National science education standards.* Washington, DC: National Academy Press.

Norris, S. P., & Phillips, L. M. (1994). Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching, 31*(9), 947-967.

Solomon, J., Scott, L., & Duveen, J. (1996). Large scale exploration of pupils understanding of the nature of science. *Science Education, 80*(5), 493-508.

Solomon, J., Duveen, J., & Scott, L. (1994). Pupils` images of scientific epistemology. *International Journal of Science Education, 16*, 361-373.

Shoemaker, P. J. (2003). *Intercoder Reliability*. Retrieved on 23.9.08 from http://web.syr.edu/~snowshoe/content_analysis/intercoder_reliability.doc

Tsai, C. C. (1998). An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eighth graders. *Science Education, 82,* 473-489.

REFORMING BOARD EXAMS FOR LEARNING WITH UNDERSTANDING

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Board exams results in India are crucial in deciding what the students will do further in their career – whether choosing Science / Commerce / Arts (10^{th}) or the colleges that they get into (12^{th}). As a result, teachers start preparing students for such exams from lower classes, by giving them similar pattern tests, question types and make them proficient in the procedure through repetition or memorization. This paper talks about a research study project to reform 10th Gujarat board exams by using best practices from other national and international board exams. The paper talks about the steps taken to understand the school leaving exams in different countries and the type of questions that are asked. The study recommended a five year plan to reform the board exam, with an eventual goal of students learning with understanding and developing critical thinking skills rather than a drill based approach.

INTRODUCTION

The Board Exam at the end of class 10 and class 12 represents a high stakes goal for students, parents and school system. The ultimate objective of these exams at the end of secondary level may be either for obtaining a secondary school certificate, determining criteria for post secondary placements, i.e. admissions to a college or for both. In countries Like Singapore, UK, US and to some extent in India, these examinations serve as the sole purpose of getting certified as “high school graduate” whereas in countries like Finland, Russia, Brazil etc. high school exit examinations serve dual purpose of certification and admission to universities. In a few countries, students have to sit for other critical “university entrance exams” for securing admissions in specific courses. South Korean and Chinese students sit for such high stakes test. While for certification and admission to further courses, these examinations are pivotal, the whole perspective of seeing it as a constructive tool to ensure learning has to be internalized.

For this a multi-pronged approach would be required which will not only orient teachers to focus on understanding based question making, but will also modify the existing mindsets of students and families to consider education independent of the degree label.

The teaching methods in schools and coaching classes geared towards achieving success in the Board Exams are usually by way of making students practice a certain type of problem over and over– sometimes the procedure is emphasized far more than the understanding of the problem. Students are also encouraged to memorize passages or diagrams. There is a need to recognize this across the country that school-leaving exams need to become much less rote-based, thereby increasing the rigor and quality and creating a systemic change in the way concepts are taught by teachers and learned by students.

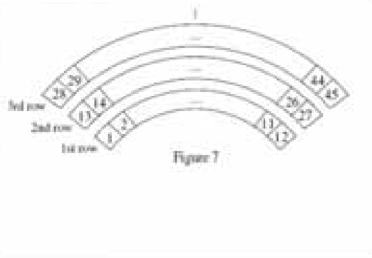
Sample Maths Questions from Gujarat	Sample Maths questions from Hong Kong (similar questions are also found in other international Boards)	
Find the nth term of an Arithmetic Progression 3, 8, 13, 18.....	*The seats in a theatre are numbered in numerical order from the first row to the last row, and from left to right as should in Figure 7. The front row has 12 seats. Each succeeding row has 3 more seats than the previous one. If the theatre cannot accommodate more than 930 seats, what is the greatest number of rows of seats in the theatre?*	
The formulae to find the total surface area of a closed cylinder are......		
Find the simple interest of Rs. 8000 at 10% for 3 years		
Fig. 1: We emphasise so much on only textbook-based and procedural questions (all the examples of the left) that our children struggle with questions that they may be in an unfamiliar form. The question on the right represents a real-life application of Arithmetic Progressions. Can we introduce many such questions in the Gujarat Board 10 paper - today there are almost none?		

Figure 1: Sample maths questions from Gujarat and Hong Kong

Educational Initiatives has been conducted assessments that have questions that focus on conceptual understanding and learning. Our experience and longitudinal data in certain impact assessments strongly suggest that asking right kind of questions can stimulate higher order thinking in students and teachers both. Questions indicating weak skills or concepts, when shared and discussed with teachers, they tend to modify their teaching methods which in turn can help students learn concepts clearly.

The National Curriculum Framework 2005 (NCERT, 2005) and the Report of the Committee on Exam Reform, Gujarat, have emphasized the need to move away from rote-based to understanding-based questions. Doing so would require changes in the pattern and types of questions asked in the Board Exam. The ultimate purpose is not simply to change the questions in our exams papers but to actually build capacity within the relevant government bodies in the State to be able to build the right type of questions.

After all a bank of questions can be obtained simply from international assessment papers However, important challenges lie elsewhere, like:

1. The Board Exams are a high-stake, multi-stakeholder process: Every student aspires to write and perform well in the Board Exam; further, for every individual the performance in the exam has important consequences for him or her and the immediate family.

The Board itself is a stakeholder as it is responsible to the government, politicians and the public and interacts with paper setters and correctors (drawn from teachers). Many of them are in turn answerable to the media and the public.

2. Board Exam paper setting and question types: Another interesting characteristic about Board Exams (and school assessments in general) is that they are extensively experienced by a large number of people. In the context of Board Exam reforms, the question paper is set for students with a varied ability to answer questions. Board exam papers are prepared in a secure environment as multiple question paper setters work on sections of the test paper. With this secure process, to get the questions rigorously set and without error is a challenge and leads to error.

3. The challenge of capacity needs to be addressed: Probably the most common response we got when we showed the question types from tests like Programme for

International Student Assessment, the International Board or the other countries was "Our children will not be able to answer these questions". Usually, this was quickly elaborated further, *"Actually our students are very capable but are not taught in this way". "Our teachers today are not able to teach in the way required for students to be able to answer such questions".*

A detailed, carefully thought through and well-planned capacity building programme would need to be designed to provide continuous and on-demand hand-holding to teachers (and answers to parents, students and others).

This capacity building is necessary not because our teachers or question setters lack any capability or are second to anyone. Rather it is needed because the expectations from their roles for decades now have been different, and to prepare children for the globalized knowledge economy that is already upon us, many existing skills would need to be polished and some new ones developed.

Educational Initiatives developed a research-based transformation of the class-10 Board Exam paper into one that has an appropriate mix of questions to test knowledge, understanding, application and higher-order thinking skills. And, since the intended change involves several stakeholders, a concrete action plan to achieve the change over 5 years was prepared. It is important to note that Andhra Pradesh SCERT (2013) has released guidelines for SSC Examination Reforms. Andhra Pradesh SCERT has also mentions reforming the pedagogy and textbooks by making new textbooks and training teachers on how to use them in the class.

This research had two major objectives:

- Recommending an alternative Board Exam pattern that is based on the same curriculum, but purports to test/ understanding and higher-order thinking skills, not just recall.
- Coming up with a concrete action plan that will address capacity building issues as well as the concerns of the various stakeholders (parents, teachers, schools, etc.) to facilitate the transition.

METHODOLOGY

The trigger of this project was a vision that the Gujarat Class 10 Board Exam question papers would be in line with those from the best school leaving exams in the world and would focus on testing students' understanding, application and other higher order skills and not merely rote or recall. To do this Boards/ countries were selected to be studied for the board exam pattern they follow.

Choosing the Countries/Boards of Study

The countries which we have studied were chosen through a scrutiny of economic and performance indicators. Two indicators which were deemed appropriate to select the countries for study are i. Gross domestic product (GDP) derived from purchasing power parity (PPP) and ii. Overall ranks of the participant countries in Programme of International Student Achievement (PISA) test in 2009 and 2009+ cycles (OECD, 2009).

PISA is an international student achievement test which assesses the students on acquisition of literacy, measures "real-life" skills pertaining to reading, mathematics and science, as well as cross disciplinary competencies (OECD 2003). More than 70 countries participated in PISA 2009 round of study.

The overall performance of some of the countries chosen for the study in PISA test and their corresponding GDP is tabulated below:

Country/Territory	PISA 2009 Rank	GDP(PPP) International Dollar
Shanghai	1	11,134
South Korea	2	31,753
Finland	3	36,723
Hong Kong	4	49,342
Singapore	5	59,936
Canada	6	40,457
New Zealand	7	27,966
US	17	48,147
UK	23	35,974
Russia	44	16,687
Brazil	54	11,845
Indonesia	58	4,668
India (HP and TN)	73	3,703
World Average		$10,700

Table 1: List of countries on two indicators

The table shows a fair degree of correlation between the rank achieved in PISA and the GDP of nations. An overview of educational performance of different countries reveals that Finland, Singapore, Canada and New Zealand are often the top performers in International achievement tests.

A comparative analysis of school leaving examinations was done for these 10 countries with the help of the following:

1. Exploring Secondary Education Systems and Assessment Practices.
2. Comparing and Contrasting Different School Leaving Examinations.
3. Understanding the Shortcomings of Gujarat Secondary Examinations Question Papers.
4. Bringing out the "Quality of Assessments" in Four Different Secondary Examinations.

In addition to this, the researchers also developed understanding of the existing Gujarat Board Examination process, meeting with different stakeholder namely students, teachers, school heads, board officials and researchers were done to understand what is now and want kind of reform they want to see in board exams in Gujarat.

DATA ANALYSIS

As part of data analysis the following were done:

1. Desk research was conducted to understand the Secondary Education Systems of Selected Countries and the key features of some the assessments at the end of the secondary school were compared and contrasted.
2. The board exam papers were collected from different countries and studied for the types of questions asked. The essence of "comparative study of the different examination boards" was
   - To identify the key qualitative issues in the question papers of Gujarat board and to bring out some qualitative features of question papers of other boards. This was done with item-wise analysis for English, Science, Social Science and Mathematics.

In order to do an Item-Wise Analysis of question papers we collected different set of question paper from different boards. The set of question papers we analyzed are tabulated below:

Board	English	Science	Social Science	Math
Gujarat Board	1-2008	1-2008	1-2008	1-2008
IB	1-HL,SL(A)	6-P,C,B (HL,SL)		4- HL ,SL
CBSE	1-2010 SA	1-Science (Theory)	1-2008, 1-2010	1-2008, 2- 2010
Hong Kong	1-Four sample papers P1,P2, P3,P4	1-Integrated Science P1,P2	History P1 History P2 Geo P1, Geo P2	Math P1,P2,E1,E2
P – Paper E- Extended Paper HL- Higher Level SL- Standard Level A- A Course SA- Summative Assessment				

Table 2: List of question papers analyzed

The question papers were looked for the type of questions, difficulty level, are the questions direct, formula based or encourage students to apply the knowledge in solving questions.

FINDINGS

The tables below describe the analysis of math and science papers across boards. The questions in Gujarat board were mostly procedural, formula based, recall of definition with lack of quality of questions and more of general knowledge. While CBSE board exam papers had some good quality questions, it also had procedural, repeats from previous years, basic questions with low level of difficulty. The Hong Kong and IB diploma papers were of higher quality in comparison to Gujarat and CBSE Board.

Gujarat Board (2008-11) Mathematics	CBSE (2008-11) Mathematics	Hong Kong (Sample Paper) Mathematics	IB diploma (2006-11) Higher Level Papers
Majority of questions are procedural. Many questions require mere substitution in a	A number of procedural questions. Year 08 question paper contains some	An assortment of different difficulty questions Encourages students to	Procedural questions Mix of application and recall of knowledge Students need to use

known formula. Few of the questions just need a recall of a formulae or definitions. Some of the questions are inappropriately framed. Lower difficulty level than it should be Lack of quality questions	good quality questions. A number of repeats from the previous years. Requires some basic knowledge Lower difficulty level questions Lack of quality questions	apply mathematics to solve scientific problems. Tests application of Mathematics to real life situations. Some of the questions are highly differentiating. Higher difficulty Level Higher order thinking	Mathematical tools Need to explain cause, effect and reason Higher difficulty level questions Avg. quality questions

Table 3: Comparison of mathematics question papers

Gujarat Board (2008-11) Science & Technology	CBSE (2008-11) Science (Theory)	Hong Kong (Sample Paper) Integrated Science	IB diploma (2006-11) Phy, Chem, Bio
Procedural questions on conventional topics Recall based questions Non-essential information Seems to test General Knowledge Lower difficulty level than it should be Lack of quality questions	Short answer and Essay type questions Simple recall of facts A number of repeats from the previous years. Requires some basic knowledge Avg. Difficulty level questions Low quality questions	Analysis and Synthesis of contemporary topics Encourage objective scientific thinking Applying Knowledge of scientific process and phenomena Tests extensive scientific aptitude Satisfactory difficulty Level Higher order thinking	Procedural questions on conventional topics Mix of application and recall of Knowledge Students need to use Mathematical tools Need to explain cause, effect and reason Avg. difficulty level questions Good quality questions

Table 4: Comparison of science question papers

Detailed Item Wise for Science and Technology Paper for Gujarat Board

1. A majority of questions **are procedural** (~60%). Require students to write about a phenomenon, a process, and state known facts, and explain functions and structures etc.
2. A second group of questions (~33%) are those which require students **to provide numerical data or define a term.**
3. A few questions (~7%) are based **on application of few basic concepts** ex. Finding numerical values by following one or two steps, or balancing a chemical equation, which may require student to think.

4. Some of the questions do **not seem to assess 'skills of science',** though important; these questions assess 'general awareness' of the students more than their understanding of science topics. For example, Q No. 15. In which country was the disease Minamata first seen? (MCQ); Q No. 16. Write full form Of G.S.L.V (1)
5. A few questions seem to check **awareness of non-essential information** e.g. the question which requires students to state the number of stars in the universe.
6. It appears that **the difficulty level of the questions** is lower than it should be. Two facts which contribute to this are: Some question loaded with hint while some others are repeats from previous year(s).
7. **Two good quality questions** we observed were: First - Which device converts solar energy directly to electrical energy? These questions certainly requires the student to think and answer, however it must be noted that if such questions are already provided in the text books, than they would no more be as effective.

Detailed Item Wise for Math Paper for Gujarat Board

1. A Majority of Questions **are procedural** (~60%). For example - Q No. 4. The roots of the equation x2-x-30 =0 are................
2. Section E with highest weightage (25%) has all the questions falling into the procedural category.
3. 20% of the questions **encourage thinking and application** of a learned concept.
4. Around 12 % of the questions **require students to 'substitute' in a known formula**. Students need not know the logic or reasoning behind the formulae. For Example, Q No. 14. The formulae to find the total surface area of a closed cylinder are......
5. Another 5 % of the questions just **need a recall of formulae or definition of term**.
6. **Few questions are ill framed**, especially the problems in trigonometry, it is assumed that all trigonometric functions are defined for all values. Q No. 11 $1/(\sin^2\theta)-1$ =........ It has been assumed that the given function is valid for all values of theta (θ), which is fundamentally an incorrect assumption

RECOMMENDATION TO GUJARAT SECONDARY AND HIGHER SECONDARY EDUCATION BOARD

To achieve this vision the following were recommended:

1. **Revamp the Board Exam Structure:** Develop an advisory council consisting of educationists from different domain. A transition cell, looking after the transition. A task force of teachers, principal and domain expert to support transition cell to communicate between schools and external stakeholders. A technical support group to provide expertise on developing and researching on assessments.
2. **Introduction of non-text bookish questions in the board exam papers:** Over a period of 5 years, such questions can be increased in a stepwise manner from 0 to 65% in the paper. The table below suggests the same. This gradual increase will help the students to change accordingly over a period of 5 years, as students now in class 5 will face the maximum number of such question and will have the maximum time to get

prepared in this process. This change will also help the way exam preparation is done in the current education system to move from rote to learning with understanding.

Year of Transition	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Percentage of 'unfamiliar' questions	0%	5%	15%	25%	45%	65%
Students are currently in class	10	9	8	7	6	5

Table 5: Proposed increase in percentage of unfamiliar questions

3. **Multipronged support to students and teachers** – Participate in international assessments like TIMSS, providing learning with understanding tests from class 3 and conduct talent search exams for promoting merit. This will motivate students and teachers to change the learning and teaching process in the classrooms.
4. **Capacity Building of Teachers** - Designing courses, creating a bank of video materials and courses in Gujarati, Creating a bank of quality material in Gujarati through an on-going translation programme, organizing regular activities including competitions and exchange programmes for teachers, rolling out the trainings – both in face to face and ICT formats.
5. **Development of advocacy plan** to create buy-in and advocacy in stakeholders.

RESULT

A detailed research report was submitted to Gujarat Board with the analysis and recommendations. Had the following 2 impacts:

1. Based on these the board chose to conduct the capacity building workshops for teachers who are responsible for setting board exam papers. The workshop covered how to create good questions, understanding concepts from understanding by design, creating question paper blueprint and sample questions. The workshops were held 12 days covering teachers mainly from math, science and social science. These workshops were held with the following objectives:
   - To improve the quality of questions in science and mathematics stream for Gujarat Board Exams
   - To develop understanding among teachers about important aspects of developing a balanced paper, development and understanding of good quality questions, and developing subject level understanding.
   - To be able to develop good quality of test papers to assess student learning with understanding.
2. Change in the types of questions asked in Board Exam Papers: As an initial step, in the year 2013 few of unfamiliar questions were asked in board exams, which were provided by Educational Initiatives from its question bank. A question used in math class 10, year 2013 is given as a sample here. More questions were used in science paper as well.

In Math class 10 in the year 2013, the following questions were asked in Gujarat Board exams. The data shown below is from ASSET, a diagnostic test developed by Educational Initiatives. This test is taken by more than 3 lac students every year.

In a Maths test taken by 35 students, the average score of 15 girls is 10 and that of 20 boys is also 10. Which of the following can be calculated based on the data we have?

A. The highest score in the class.
B. The lowest score among the boys in the class.
C. The sum of the scores of the 35 students of the whole class.
D. All of the above can be calculated

Option	Performance %
A	9.7
B	7.6
C	54.0 ✓
D	27.2

This question was designed to test if students understand the concept of average and apply it in the given context to check what can be found out and what cannot be found out. 54% of class 8 private English medium school students were able to answer it correctly. However, 27% students selected D as the answer. They have not understood that given only the average, the highest or the lowest value in the range cannot be found out.

Table 6: Unfamiliar question asked in 2013 Gujarat board exam

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References

CBSE Website (n.d). Overview of CBSE – Syllabus, format of exam, question types. Retrieved from www.cbse.nic.in

CISCE Website (n.d). Overview of ICSE –Syllabus, format of exam, question types. Retrieved from www.cisce.org

IBO Website (n.d). Overview of IB – Background, syllabus, format of exam, question types. Retrieved from www.ibo.org

NCERT. (2006). *Position paper: National focus group on examination reform.* New Delhi: NCERT

NCERT. (2005). National Curriculum Framework. New Delhi: NCERT.

OECD (2003). Retrieved from http://www.oecd.org/

OECD (2009). PISA Results 2009. Retrieved from http://www.oecd.org/pisa/46643496.pdf

Unknown (n.d). Proceeding of the Director, SCERT, A.P., Hyderabad Proc. Rc. No. 185/D1/C&T/SCERT/2013 Dated 18.03.2014. Retrieved from http://www.teachersbadi.in/2014/03/apsert-ssc-10th-class-examinations.html

Unknown (n.d). APSCERT proposed changes in the SSC 10th class exam system from 2014-15. Retrieved from http://www.teachersbadi.in/2014/03/apscert-proposed-changes-in-ssc-10th.html

World Bank Data Website: Retrieved from http://data.worldbank.org/

REFLECTIVE PRACTICES IN LESSON PLANNING: AN ENDEAVOUR FOR PRE- SERVICE TEACHERS' PROFESSIONAL DEVELOPMENT

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Lesson planning is the most important component for the pedagogical practices that helps to form a link between theory and practice. This paper reports an innovative collaborative effort of teacher educators and pre service teachers in preparing modified lesson plans. This study was encouraged by 'lesson study' approach followed by Japan teachers to improve the quality of their teaching and enriching students' learning experience. It was observed that the pre service teachers involved in the study experienced the need of collaborative reflections with research based inputs for the improvement of their teaching learning experiences. The study reveals that development and evaluation of lesson plans is a reflective, rigorous, collaborative and continuous effort to improve upon the quality of teaching learning practices.

Keywords: lesson planning, reflections, lesson study, pre-service teachers

INTRODUCTION

Lesson Planning is an integral component of pre- service professional development programme all over the world. Preparation of Lesson plans is usually an individual task with a discussion with the supervisor or observer. Lesson plan is prepared during the internship period. Before executing the lesson plan, it is expected to discuss with supervisor. A number of studies (Hart, Alston & Murata, 2011) consider lesson plans as a concrete scaffold in order to learn about specific content area. Recent researches focus on collaborative lesson planning which has further scope for improvement and implementation in in-service teachers (Fernandez, 2005; Kumar & Subramanium, 2012; Meyer & Wilkerson, 2011). These studies mainly derived from lesson study approach followed in Japan. Research studies on prospective teachers also indicate that lesson study approach appears to be effective way to connect theory and practice and develop their mathematical knowledge for teaching. In Japan, A lesson plan is a three part complex document consist of 1) Introduction to the lesson plan comprising basic description about lesson, background information about students, their current state of knowledge etc., 2) information about the unit i.e. provide information about the concept to be dealt and 3) information about the lesson i.e. together information about reaction of students' for the lesson plan executed (Fernandez & Yoshida, 2004). This preliminary lesson plan is further put the process of refinement using lesson study approach. Importance of Reflections and collaborative planning has been given important place while adopting this approach for perspective teachers. E.g. Fernandez and Zillox (2011) explored peer collaboration as most important way to develop understanding of teaching. In India, Lesson planning in B.El.Ed programme is envisioned as a reflective rigours process. Lesson planning starts from III year and continues till their internship in fourth year of the programme. These plans are usually prepared individually followed by discussion with supervisor, prior to going to the field for classroom teaching of that specific concept or content. It is followed by writing of reflections based upon their classroom experiences.

However, there is no such practice where student- teachers can incorporate their reflections for the improvement of the previous executed lessons.

THE STUDY

The present study was conducted during pre- service primary school internship of B.El.Ed. student-teachers. Writing of Reflections is a crucial exercise done by pre-service teachers in each year of the programme. In the fourth year during internship, interns are supposed to write reflections of their teaching done in the schools. These reflections obviously help the student-teachers to improve upon their teaching practices. But there is hardly any effort made to take inputs from these reflections in order to improve upon their previous lesson. In this study, Authors attempted to use collaborative reflections with research based inputs in modifying lesson plans on the topics that intern faced difficulties to teach.

Research Goals

1. Collaborative reflections and follow up discussion on the challenges faced by the interns in the execution of the lesson plans
2. Preparation of modified lesson plans based on collaborative reflections.

This paper is only focussing on the reflections and modifications suggested by two pairs of interns on the topic of multiplication.

METHODOLOGY

The study was conducted on final year (4th year) prospective teachers of Elementary education programme. During this period, interns are provided with the opportunity to put into practice and expand their understanding of what they were learning during course of study. Beside this, they are supposed to do assignment given by their teacher related to field experiences. We decided to give an assignment which was envisioned to appreciate collaborative efforts by intern for improving their teaching. We categorized the work into five phases.

Phase 1 Orientation about the Lesson Study Approach

In the first session of the lesson planning, pre-service teachers were provided with the readings related to lesson study approach taken from the book ‘Teaching Gap’. We focussed our discussion on how collaborative efforts and use of reflections help in improving quality of teaching as well as providing them a model for improving their teaching when they are in service. They were given guidelines about the upcoming assignment. Interns were teamed according to the grades and topics they were supposed to teach during internship, each group consisting of 2-3 interns.

Phase 2 Preparations of Lesson Plans

During the third year of their studies they study the Practicum titled Material Development. This practicum prepares the students for the Fourth Year Internship by involving them in following varied tasks viz. *Classroom observations* followed by reflective analysis of the observed classes on basis of the pedagogical practices implemented by the In service Teachers; *Content Analysis* i.e. analyzing the development of the content on different themes in the Primary Curriculum from books published by government agencies ;private publication and NGOS/Alternative Schools and do the comparative analysis across different publications; *Unit planning and lesson planning*- preparing unit and lesson plans in order to teach in pairs to those classes which they observed (referred as block teaching). The students acquaint themselves with an intensive in depth knowledge about the components of *unit* and *lesson* Plan. This process is followed by reflective evaluation of the planned unit and lessons. Hence in forth year, there is not much orientation required for writing of lesson plans. As preparation of lesson plans is an individual task, they are supposed to meet every week to their supervisor allotted for the discussion of the lessons they are preparing to teach.

Phase 3 Execution of the Lesson Plans designed for Mathematical Units

The interns executed the Lesson Plans designed in Phase 2 for varied Mathematics Units individually in the Primary schools in the respective grades allotted to them. One or two lessons were also observed by their partner apart from observations done by their supervisor.

Phase 4 Reflections and Discussions on Executed Units

The interns in 9 pairs, the pairs who have taught the same unit and to the same grade in different schools had in depth discussion with their supervisors (Authors) on basis of reflecting upon their classroom experiences with respect to the Lesson Plans executed. They reflected how far they have been successful in implementation of tenets of NCF 2005 and theoretical perspectives of teaching and learning mathematics. They carried the reflective analysis for the individual tasks laid in the Lesson Plans and on basis of this detailed analysis categorically laid down the problems and challenges faced in execution of the plans to facilitate the development of the concepts with respect to varied pedagogical considerations.

Phase 5 Preparation of Modified Lesson Plans

The interns on basis of reflective analysis prepared modified unit plan and corresponding Lesson Plans.

RESULT AND DISCUSSION

Lesson plans prepared by interns were basically dealing with revisiting place value, introducing multiplication as repeated addition, multiplication in different contexts, connecting place value with multiplication algorithm by introducing lattice method.The interns did reflective analysis of all the executed tasks on basis of execution of task by them; learner's involvement and learners' responses to assess if the learning objectives of the designed tasks are fulfilled else the need of modifications to be explored. Description of the tasks in which interns faced challenges is given below:

Task: Sankhaya Banao (Make Number)

On account of revisiting the concept of place value prior teaching Lattice Method the interns executed task "Sankhya banao". The task required learners to make number corresponding to the bundles of sticks and loose sticks given and vice versa provide the requisite number of bundles and loose sticks for a number cited. The responses revealed that learners are not able to recapitulate the representations via use of concrete material (sticks) and relations as many learners visualized the bundle of tens also as a 1 (ones)…when asked to give 52 sticks most of grade 4 learners were not able to give five bundles of ten sticks each with two loose sticks…..

During discussion, it was realized that the modification in form of the need of context alongside use of concrete material is required to enable learners revisit the concept of Place value. The context can be provided in form of story as of "*Lakad wala*" and use of sticks to represent the logs of wood he has piled.

Task: Ganit me Jaadu

This task was prepared to introduce multiplication as repeated addition and similar task was also done in order to appreciate commutative property in multiplication. In this task, students were divided in group of 5 and an egg tray was given in each group. Each group was asked to put pebbles like 8 pebbles, 2 in each row; 9 pebbles 3 in each row followed by probing questions like how many marbles are there in 5 rows, if 3 marbles are put in each row.

Reflections reveal that this activity was not successfully executed.

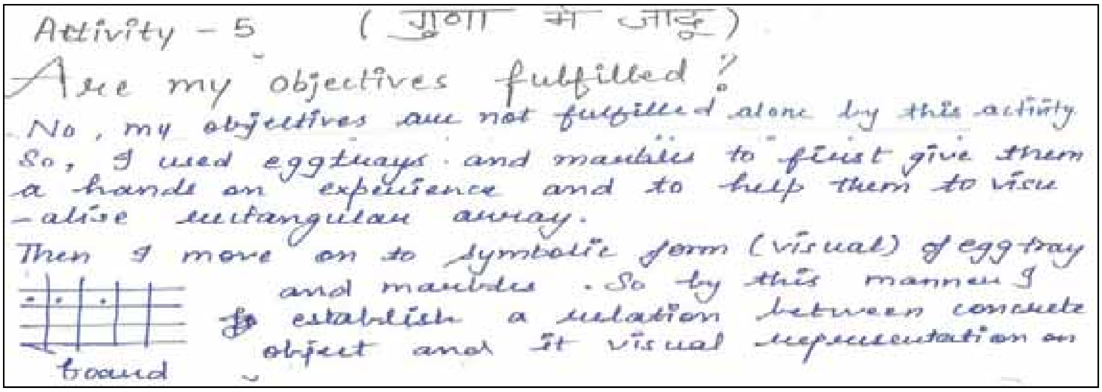


Figure 1: Reflections on the activity

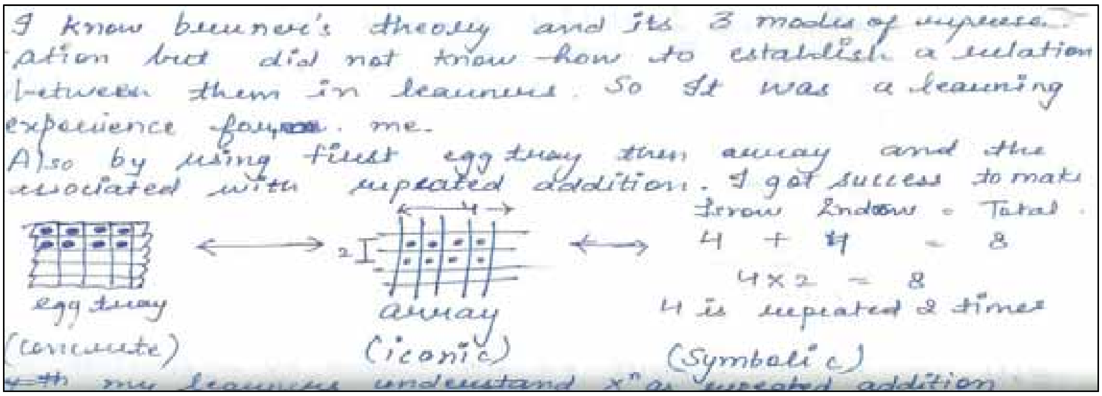


Figure 2: Reflections on the activity

Task: Make situations

The learners were given the worksheet required to write word stories for the given multiplication facts after they have been taught regarding the varied contextual situations related with multiplication namely rate; multiplying factor and Cartesian product. This was to assess if learners are capable of appreciating the meaning of multiplication. The observed responses revealed that most of the learners are not able to create the situations and so need of an intervening task was reflected upon.

The learners analyzed that if visuals can be provided; say; five baskets each with four apples and learners asked to write multiplication fact for the visuals as

4+4+4+4+4   5 times 4   5*4

prior giving the facts ; the learners may make an effort to visualize and create their own stories.

There was **another task** ‘The Junk seller’ to introduce lattice method with a context was not successful. Reflections of the task revealed that prior knowledge of the procedure of the standard algorithm restrict their thinking. During discussion, it came out that using money in context may help children to realize place value in lattice method. This was tried out and intern observed that it was working.

Problems and Challenges Faced with Respect to Following Aspects Related with Pedagogy and Classroom Experiences

I) Problems due to learner’s previous knowledge: Interns asserted that they encountered two types of problems:

Problems due to Pre conceived Knowledge: “The learners of our class knew formal algorithm of multiplication and memorized the multiplication tables as learnt in grade 3. it led to problems to encourage learners to construct the meaning of multiplication”

For example: In the words of intern “*When I gave them the problem: There are 40 students in each class of a school .How many students are there in 8 classes?” It was observed that most of them employed the formal algorithm for multiplication but when asked:*

a) *Why have you employed multiplication?*
b) *Can we employ any other mathematical operation? ...*

The learners were not able to respond.

Problems due to lack of Pre requisite Knowledge: In words of interns *“I also faced problems due to lack of pre requisite knowledge of Place Value Learners of my class did not possess the conceptual knowledge of place value due to which I faced problems in teaching them the Lattice Method. For example while finding 36 * 5 by Lattice method when learners were asked to express 36 in expanded form with respect to place value, they were not able to do so...”*

II) Problems due to different cognitive level of learners in same grade

The interns observed the need of plans catering to needs of individual learners as one plan for the entire class was not suitable for class with learners at varied cognitive levels. For example they observed whilst teaching multiplication to grade 4 learners:

In a class there are students:

- who are skilled in informal strategies to find the sum of two or three addends;
- who know counting but do not appreciate the number sense;
- who do not know the concept of place value;

They reflected that owing to multi grade classrooms it is not feasible to teach employing a single lesson plan.

III) Problems due to previous pedagogy employed in classroom

Interns observed the classes being taken by the regular school mathematics teacher prior to their Internship emphasize more on formal algorithm of varied operations as compared to construction of meaning in varied contexts related with the operations;

For example as asserted by interns:

a) "*In our classes when we asked learners to create their own stories corresponding to given multiplication facts say 15*5;most of them initially responded 75 instead of creating situations….learners are in habituated to have mechanical questions and find answers to these mechanical questions….*"

b) Interns also observed that the learners are used to problems as:

2*5=……; 3*7=…….; but not appreciated solving and creating meaning for the problems of the type:
……*5=20;
……*……=45

IV) Problems with respect to Pedagogical considerations implemented by interns:
The interns further have classified the problems and challenges associated with above as:

Establishing the relationship between different modes of representation namely concrete; visual and written symbolic form. The interns asserted that they observed if the use of concrete material/manipulative for the development of the concept is not translated with appropriate visual and symbolic forms the learners are not able to appreciate the mathematical concept and make appropriate linkages.

For example whilst doing Lattice Method with help of match sticks; they were able to revisit the concept of place value and find the product by representing numbers in tens and ones using the bundle of matchsticks and individual sticks; however when the same multiplication is posed with only numbers and to be represented as say for 25*5 in the following array:

25	20	5
5	20*5=100	5*5=25
	100+25=125	

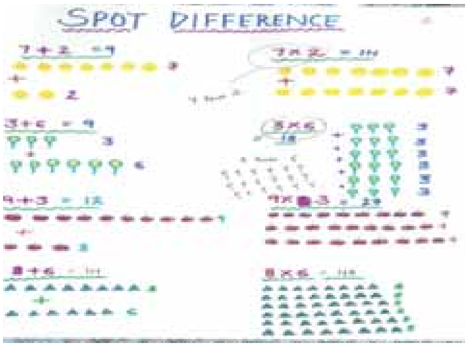
Table 1: Array

It was observed that learners were not able to appreciate the written form unless and until they are not scaffold for the linkages in these representations alongside the use of concrete manipulative. The interns reflected upon the emphasis on the interlink ages between different modes of representation to develop the concept.

Besides these, interns also faced problems related to time management for a particular activity, their lesson plans not promoting maths talk lively and assessment tasks designed by them was merely assessing the final response of the learners and not determine the thinking and associated strategy employed by them.

REVISED TASKS

This task was designed to spot difference between addition and multiplication sign significantly followed by discussion questions.



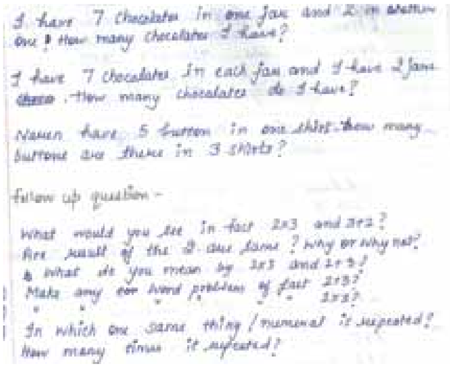


Figure 3: Spot differences in'+' &'×'   Figure 4: Contextual problems to spot differences

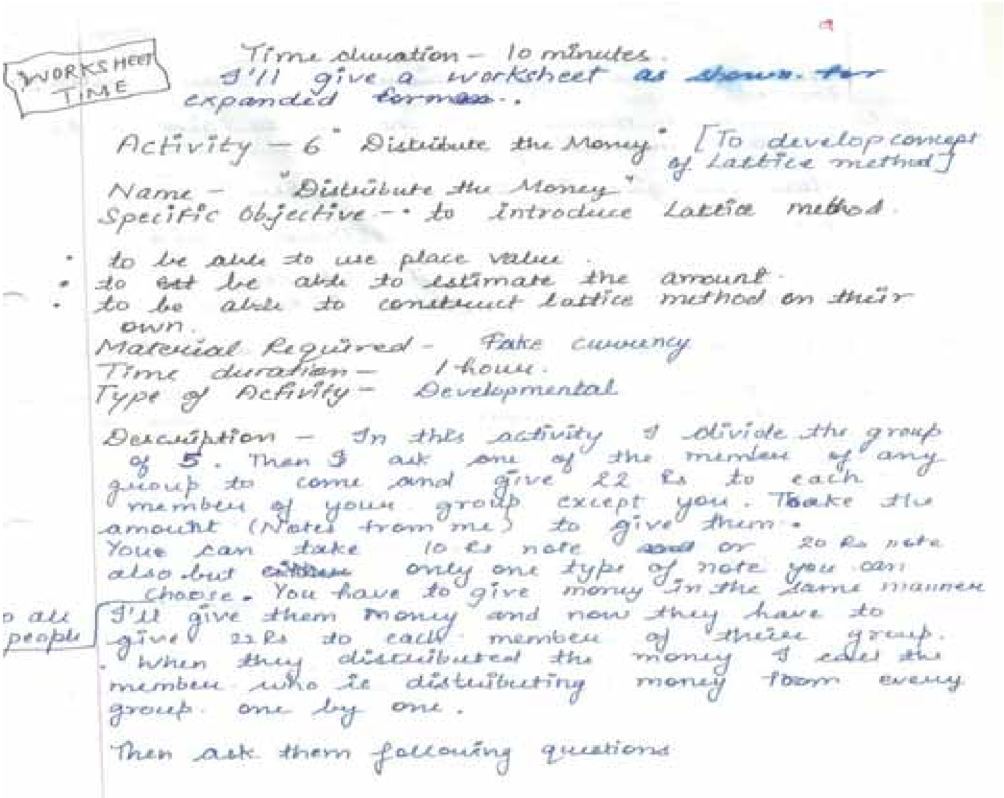


Figure 5: Task to introduce lattice method by using context of money

CONCLUSION

The Assignment led to

- Involvement of fellow pre service interns in a constructive reflective discussion emphasizing upon varied dimensions of teaching and learning mathematics and empowering them for critical discourse during In-service Teaching;

- Broaden their understanding of theoretical pedagogical considerations for teaching and learning mathematics and the development of the mathematical concepts through their implementation via lesson planning;
- An opportunity for participatory involvement of pair/group of teachers reflecting upon their teaching practices on basis of detailed discussions, reflections of the tasks planned and executed and make participatory efforts to prepare model lesson plans always with a scope of further reflection and improvization;
- Pre Service teachers professionally being prepared to form community of learners based on their field experiences motivating them for efforts to continue with these practices as In-service teachers;
- Development of an attitude of rigour and research amongst the Pre Service Teachers.

Acknowledgements

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References

Fernandez, C., & Yoshida, M. (2004). *Lesson study: A Japanese approach to improving mathematics teaching and learning.* USA: Lawrence Erlbaum

Fernandez, M. L., & Zilliox, J. (2011). Investigating approaches to lesson study in prospective mathematics teacher education. In L.C. Hart, A. Alston & A. Murata (Eds.), *Lesson study research and practice in mathematics education: Learning together.* New York, NY: Springer.

Fernandez, C. (2005). Lesson study: A means for elementary teachers to develop the knowledge of mathematics needed for reform minded teaching? *Mathematical Thinking and Learning, 7*(4), 265-289.

Hart, L. C., Alston, A., & Murata, A. (Eds.). (2011). *Lesson study research and practice in mathematics education: Learning together.* NY: Springer.

Kumar, R. S., & Subramaniam, K. (2012). Understanding teachers' concerns and negotiating goals for teaching: insights from collaborative lesson planning. In *Proceedings of 12th International Congress of Mathematical Education* (pp.5157-5166). Seoul, Korea: ICME.

Meyer, R. D., & Wilkerson, T. L. (2011). Lesson Study: The impact on teachers' knowledge for teaching mathematics. In L. C. Hart, A. Alston & A. Murata (Eds.), *Lesson study research and practice in mathematics education: Learning together.* NY: Springer.

NCERT (2006). *National focus group on teaching of mathematics report*. New Delhi: NCERT.

NCERT (2005). *National Curriculum Framework*. New Delhi: NCERT.

USING PROGRAMMING WITH RURAL CHILDREN FOR LEARNING TO THINK MATHEMATICALLY

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Is it possible to use computer labs in a rural setting that encourages reasoning, visualization, abstraction in children (as envisioned in NCF 2005) while at the same time addressing curricular needs? This paper addresses the question through the use of programming in two rural schools including integration of curricular areas for fractions, cube roots, algebra, compound interest, data handling, geometry, etc. We explore three styles of instruction - projects for children to demonstrate their understanding, challenges to visualize abstract concepts, and games created by children themselves for mastery.

CONTEXT

We are presenting the work in two outreach schools of Auroville – Isai Ambalam School and Udavi School- that cater to the villages of Annainagar, Edyanchavadi, Irumbai, Pooturai, Pattannur, etc. We used **existing** computer facilities of the school, working with children on Mathematics through programming.

These are rural schools and have demographics similar to government and NGO run schools throughout the country. The schools believe in the holistic development of the child and school managements are progressive and encourage experimentation and research. From middle school onward much of the time is spent on academic subjects, in line with the expectation of parents. Both the schools have computer facilities. In this sense too they are typical, as over 75% of the secondary and higher secondary schools have computer facilities (DISE, 2014).

Aura Auro Design is a team of four engineers who volunteer 3 hours a day at the schools. We work with around 50 children from 6-8 grades along with their teachers. Classes range from 8 to 16 children. We are presenting the use of programming in this paper, however, we complement programming with puzzles, and strategy games, building physical models and TLM to create an environment of joyful mental exploration in the schools (Ranganathan, 2014).

Philosophies in Learning

Constructivist Education Theory (Bruner, 1960) indicates that knowledge is not delivered into the learner (whether child or adult) but recreated by the learner on his or her own. Children actively construct their knowledge by connecting new knowledge to what they already know. Constructivist education encourages discovery learning and learning by doing. It encourages activities that challenge a child's worldview since conceptual change and deeper conceptual learning come from experiential and interactive activities. Bruner further suggests “spiral learning”, claiming that any subject could be introduced to any child at any age if it is in some form that is honest.

In India, Sri Aurobindo (Aurobindo, 1910) indicates that nothing can be taught, but the teacher can support and encourage a child in the process of learning, thus guiding them towards perfection. More recently, Mukunda (2009) describes the three aspects of learning that are relevant to schools - conceptual knowledge, procedural knowledge and higher order reasoning. Conceptual knowledge (and change), she states, greatly benefit from constructivist approaches. In this paper we look at all three aspects of learning.

The Constructionism theory (Papert & Hare, 1991), adds to the constructivist theory the belief that children construct their own knowledge best by creating something outside their minds that is often sharable. In this research project, we explore creation in the virtual media through computer programming.

The National Curricular Framework 2005 (Pal et al., 2005) states that the 'useful' capabilities relating to numeracy, number operations, measurements, decimals and percentages are only a narrow goal of Mathematics education. Most middle schools across the country focus on these narrow goals for better marks in examinations. Examinations presently test children primarily on procedural learning: drill and rote learning become the primary tools for education. The NCF 2005 points out that across the country children do not enjoy Mathematics and are poor at applying these concepts or handling complexity.

The higher purpose of Mathematics, it says, is Mathematization: the understanding and application of mathematics in different situations with a focus on abstraction, patient problem solving and logical thinking. Meeting this goal requires a fundamental change in the approach used in schools. It requires classrooms to move away from simplistic 'sums' to more complex problem solving and contexts. It requires a shift in conversations in the classroom from the 'right answer' to considering and discovering approaches to problem solving. Our team thinks of Mathematics **in its wholeness,** achieving higher goals while also meeting the narrow goals. We also provide alternative ways for children to demonstrate their mastery of a subject beyond examinations.

We believe that the teacher is not an instructor or taskmaster, but a helper and a guide (Aurobindo, 1910). We believe that as teachers we should be aware of the situations when we need to step in (technical difficulties – mouth down frustration) and when we need to step back (struggle necessary for learning – mouth up frustration) (Martinez & Stager, 2013).

Programming and Children Learning

Use of programming to teach children Mathematics (Papert, 1986) happened before personal computing had reached its peak. A programming language LOGO was created to help children communicate with the computer and instruct a robotic "turtle" that could move and draw on paper. The positive effects of programming on children's cognitive learning were also examined (Pea & Kurland, 1984). A variety of hardware was made accessible to children to program including cars and robots (Lego Mindstorms) and resulted in the Maker movement.

The Maker movement focuses on learning through inventing: making, tinkering and engineering (Martinez & Stager, 2013). **Making** taps into the innate nature of human beings to create and its active role in learning requires visualization of a 'product'. **Tinkering** is a mindset – a playful approach to solving problems through experience, experimentation and discovery. **Engineering** is the process of extracting the principles from experience and organizing it to bridge intuition to formal learning, enabling better understanding and prediction of results. We find all three aspects necessary in our research for a more meaningful way of utilizing computers in school.

Programming Language and Setup

Scratch 2 (Resnick et al., 2009) is an advanced visual programming language built beyond the capabilities of LOGO. It has a low floor (easy to learn: you can stitch code together), high ceiling (includes variables, functions and event driven simulation) and broad walls (allows for users with different interests from drawing, music, animation, and computation). The availability of such a program at no cost enabled us to use it with rural children who have limited English skills to take up programming.

We used the Scratch 2 off-line editor to enable work without the internet. We installed public domain OS Ubuntu 14.04. The OS and software(s) are available free of cost and offline and the setup can be replicated in any computer center rural or urban across the country. We also set up a local LAN to allow centralized storage of files. This allowed children to save and continue their work from any machine. The complexity of the children's programs significantly increased when they were assured that their work was saved and available.

Educational Computation and Children Programming in India

In urban India there is a significant movement for children to learn programming beyond school. Among younger children Scratch is a popular program. Computing availability in rural India is limited and when computer facilities exist, they are rarely used beyond an hour or two in a day in a school.

Progressive schools do introduce children to Scratch, sometimes as a creative medium for animation and to develop higher level thinking. In Udavi School Scratch was already used by children. With minimal guidance they had played and tinkered with example games.

USING PROGRAMMING WITH MATHEMATICAL CONCEPTS

We present these case studies of different aspects of children's learning through programming.

Cubes and Cube Roots

Pooja (8th grade) encounters cubes and cube roots; she often mistakes x^3 (*x* multiplied by itself three times) with *3x* (*x* multiplied by three). For perfect cubes (e.g. **830**58<u>4</u>) one can guess their two-digit cube roots (e.g. **9**<u>4</u>) by estimating how big a number is (how many 1000s) and looking at its unit digit. I hoped this would help her get a sense of numbers. She was unable to follow the procedure and had difficulty with the sense of numbers. (She is not alone).

She starts to program to find the cube roots of numbers. Her initial goal is to print the first 10 cubes. Power is not an available expression and she needs to construct the expression for a *number* (variable). In time she creates *result*=*number*×*number*×*number*. She increments the *number* each time and puts it in a loop. To view the results, I ask her to add a delay of 1 second after each operation. I ask her to notice the numbers, but she doesn't find a pattern. She then changes the loop condition to keep running till the *result* becomes a large cube given in her book. Now, she is interested in where the program stops and intently looks at the results. She soon figures out when she is too far and needs to wait for the result and asks to reduce the time between calculations. I tell her she could change the program for fewer calculations, but retain the time after a calculation to see the result.

She decides to skip numbers in her program. I connect it to the original process and ask her to change in steps of 10 (10, 20, 30, etc) till the *result* is too large, go to the previous step and then go in steps of 1. She implements this as two loops: first loop in steps of 10 and second loop in steps of 1. It takes her time and she makes errors, but she understands what she is trying to do and debugs it with known cube numbers and their cube roots.

To use the program she generates a random two-digit number (feature available in Scratch) and uses its cube as the *target* (variable). This time when she looks at the steps of 10 she notices the last three digits are 000s. She then notices that the non-zero digits have the same pattern as cubes of single-digit numbers. When the second loop starts the numbers are much more complicated. I ask her to focus on the units place. Now, she notices a pattern e.g. 1 in the units gives 1 in the units of the cube ($\mathbf{2}\underline{1}^3 = \mathbf{9}26\underline{1}$). Similarly, 4 gives 4, 5 gives 5, 6 gives 6, 9 gives 9. The others were flips 3 with 7 ($\mathbf{4}\underline{3}^3 = \mathbf{79}50\underline{7}$ and $\mathbf{5}\underline{7}^3=\mathbf{185}19\underline{3}$) and 2 with 8.

She starts working this out systematically as the computer does and now she gets it. In time she skips the 'unnecessary' steps and gets straight to the cube of the 10s before and (to check the 10s after) and then writes the number including the units. She makes the program a game that accepts inputs to check her answer. The program still works through all the steps for her to cross check her thinking and then announces if the result is accurate. In the next class she works out 50 cube roots in an hour in her notebook and checks with the computer. She gets one wrong and understands why that one confused her.

She now revisits squares wanting to do something similar there. Though the numbers are smaller the process is more involved as it has the mapping in the units place and is not one-to-one (e.g. units place 4 and 6 result in a square with units place 6) and you need to estimate which square it is closer to. However, she masters it by following a similar process.

In this example we see that it is possible to learn a higher order skill – sense of numbers, logically thinking with learning a procedural skill and developing an understanding of the concept. We also notice that in the process of creation the learning becomes her own.

Multiplication and Corresponding Division Stories

Much of science that children encounter in school is one quantity (distance) as a product of the two others (speed and time). Other examples are density, mass, volume; mass, force, acceleration; changing units. The simplest form of these boil down to:

Multiplication story: 1 box has 6 apples, how many apples are there in 4 boxes.

Division story 1: There are 24 apples in 4 boxes, how many apples are there in one box.
Division story 2: There are 6 apples in 1 box, how many such boxes are needed for 24 apples.

Rahul (6^{th} grade) seemed to get the concept, but was unable to retain it. He started to create a program to animate his story. Scratch provides a stage and you need to bring in characters that do their part. He needed to think of a concrete example and stay with the example while he programmed the appropriate apples and boxes to appear and disappear based on his story. He needed to synchronize the timing of his voice and the corresponding display. The rigor of staying with a problem helped him to retain this concrete story. Knowing one concrete example well helped him abstract other stories. The process of personalization of learning through the process is so strong that at the end of the year when we displayed the work of children, not just Rahul, but every child could recognize their work by just the initial stage even before we started playing their demonstrations.

Circles

We planned to use the process of personalizing the projects for adding fractions as well. In visualizing fractions the children decided to use a circle to represent the whole (as it's obvious when something is missing). We added a constraint: children would need to instruct (program) the computer to draw rather than draw themselves by hand.

Scratch has bare bones pen commands allowing you to draw from point-to-point (lines with coordinates) or lines of arbitrary length at arbitrary angles from a point. How then do you get a circle (more accurately a good approximation of a circle) with lines?

With *making* of the fractions project in mind, the children started to *tinker* with various shapes with lines that would resemble a circle. This led to interesting conversations about what fundamentally a circle is, something that is constantly changing its angle. They then broke the full angle (360) into angle chunks, moving a constant distance and rotating by that angle chunk (*engineering*). Depending on the size of the chunk they got various regular polygons. Starting from equilateral triangles to squares to pentagons and so on finally settling at a shape with large enough sides to look like a circle. Eventually, a simple program *repeat 360 {move 1 step; rotate 1 degree}* gave them a very good approximation of a circle.

Fractions

Given that we had spent quite some time on this wonderful deviation we decided to experiment with a higher level thought process for playing with functions and created a base function for drawing a fraction with various inputs. The idea of controlling where the fraction should be drawn, and how big it should be was a significant exercise in their understanding of coordinate geometry. The last screen of such an animation by Ahalya (7th Grade is shown below).

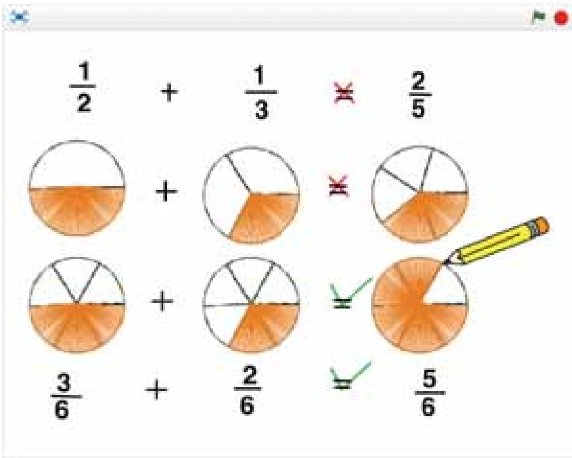

Figure 1: Final image of one animation project on fraction additions

Children who participated in that session were required to think in a different way about circles and were asked to examine fractions in detail. A few months after making their animations the children were tested on adding fractions. All of them knew that you couldn't just add the numerators and denominators, most were able to create equivalent fractions to add fractions, and, on being prompted half were also able to resort to LCM to add fractions which is the expected procedure.

Percentages, Algebra, Compound Interest

The conceptual understanding of abstract concepts were better understood by children when they were asked to demonstrate their understanding visually. For percentages they created programs to make pie charts of the time spent on activities in a day. For this they took the hours and framed fractions of the day, scaled angles with different colors of the pie and also represented percentages. This helped them link multiple independently dealt with concepts at the same time. The process of debugging (fixing errors) helped them face the assumptions and misconceptions they had e.g. Jaya had assumed that now that she was working with percentages fractions needed to be scaled by 100 for everything including angles. Only part of her circle appears densely colored. She debugs her program and realizes that even though they are dealing with percentages it does not scale angles automatically from 360 degrees. This helped Jaya realize that what she knew before had not suddenly become irrelevant now.

Data Handling

The fundamental art in having to explain something to a computer is that children need to be clear about the procedure and break it down into simple steps they can code. Equally importantly, they need to create test cases that they are absolutely confident of. The meta-cognition of average children in middle school is low and being able to say they are absolutely sure of something, especially a new concept, gets them to stretch beyond their comfort zone. They start trying to understand the concept to come up with a simple test case e.g. one group of children were trying to get an average in their book exactly right, in another group a child started a discussion on what would happen if all the data was the same since this was easy to generate on the computer, indeed this resulted in a much more trivial test case, but more involved understanding of the concept. As before, plotting the results helped them estimate averages even before calculating them. Further, Scratch's ability to create large random data helped them notice the law of large numbers by themselves i.e. average of randomly distributed data between two numbers tends to be the average of the two numbers.

Observations

As children explain a procedure step-by-step through programming it helps clarify these procedures in their minds. Further, it fundamentally changes their relationship with computers. In the year-end surveys one of the children remarked that only now she understood how much effort and intelligence it goes into making the computer *look* smart. Other than the appreciation of what it takes to do something in real life, the import was that she no longer considered the computer smart *in itself*. Computer usage in schools is generally an extension of an authority figure which is always correct e.g. softwares that explain something to children or test them (openly or through 'games'). In these cases, the computer is all knowing and always right and children have nothing to offer to it but 'right' answers. It provides no scope for invention, questioning or possibility of higher order learning.

MAKING, TINKERING, ENGINEERING

Conversations which lead to learning in deeper mathematics can come up in many making situations. As part of the study on the moon the children in 7th grade decided to make a time-scaled animation of the earth spinning on its axis, going around the sun with the moon rotating around the earth. They also decided that they wanted earth to travel in an ellipse rather than a circle. This started an exploration of how to get an ellipse rather than a circle.

One solution took them through attempting to extract this information by solving the equation that Geogebra gave. The idea that a two dimensional expression e.g. $1.37x^2+2.25y^2-61798.1$ that they did not know how to process could be solved by the computer by selecting a value of y and sweeping x till the expression became zero was fascinating for them. Since they were drawing pixels they only needed the integer part of the solutions, but a curve does not only have integer solutions. They needed to use the fact that expressions change sign when it steps over the solution (expression changes sign as it crosses zero). They developed a healthy respect for integer multiplication when they realized that this could use the product of two successive results to locate a solution (*engineering*).

The children *tinkered* around with the limits of using these sweeps and realized that in closed curves there are no solutions beyond a y value point for any value of x. The earth was now rotating around the Sun. For a sum that is generally simple getting an answer is enough, however, in making you can gauge the quality of work and there is always room for progress.

The children noticed that the earth seemed to be speeding up the upper extremes (y was being stepped linearly and the slope was close to zero). They further tinkered and made multiple ranges putting points closer together as they came to the extreme to compensate for change of slope.

Another group of children simply tinkered around longer to come up with a different solution by visualizing the circle as getting stretched in the center to create an ellipse. They divided the angles between a smaller and bigger circle to achieve the same result. The code went something like this *repeat 45 {move 1, rotate 1}, repeat 90 {move 2, rotate 1}, repeat 45 {move 1, rotate 1},* and so on for the other half of the ellipse.

DIFFICULTIES AND ASSESSMENTS

Most children we worked with had already been using the computer to play (educational) games, watch videos or work with Paint. Their initial excitement for using the computer had died out and there was resistance to intellectual work using the computer. What helped us was that children still enjoyed making and tinkering (as suggested by their surveys). The drift to engineering depends on the ability of the instructors to create a situation where children want to create a project and struggle to find a solution with tinkering and want more predictability in their work e.g. making a circle can be accomplished through tinkering, but making a set of specific circles needs understanding about perimeter and radius of circles.

Initially, the time projects took concerned us. We gave it time since the children were engaged and challenged. Teachers spend a lot of time repeating concepts that the children apparently learnt and have 'forgotten', when in fact, the children had not really learnt it (Brooks & Brooks, 1993). We found that children retained concepts they learnt over time.

The biggest difficulty is actually that we, as teachers, want to teach (and instruct) but that often steals the most important learning from the child. In time we learnt to notice when we were too keen to teach and learnt to step back to allow the children to struggle and learn on their own.

One group of girls had created a wind chime, calculated 22.5% lengths of the pipes, hacksawed the steel pipes, used a power drill to drill holes and complete their product. When we did surveys with the children at the end of the year we had expected this to be the top of their list of accomplishments. It was hence a surprise when Ahalya indicated that the fractions program (Fig. 1) was her finest work. I reminded her of the wind chime, she smiled and said that it was a great experience, but the fractions were her best work. It helped me realize that in this increasingly technological world children see the virtual world as something tangible and real.

CONCLUSIONS

Programming allows an important interaction between a child and a computer altering fundamentally the equation for being a user to being a programmer, from being a receiver to being a creator. Programming is significantly different from using passive media that converts the computer to a personalized television, or enables children to play games on the computer as users only. This fosters the assumption that the computer is always right and we/they are always playing catch-up. We must let children program the computer instead of attempting to program the children through computers (Papert, 1993).

Making projects (through programming) can be a way for children to demonstrate their learning and offer alternatives to examinations as the only form of assessment. This also offers an opportunity for self-evaluation and constant progress.

Programming a computer helps children learn conceptual ideas because they need to break it down into small bites for a computer to follow. It also helps them visualize abstract concepts. They can also create their own games to develop rigor.

Rural children are growing up with an increasing access to technology and programming can be meaningfully used with them to support their higher order learning and mathematical thinking while addressing curricular aspects in a more meaningful way. This paper is a case study intended to show that the 330,000 schools across the country that have computer resources could use this resource in a creative way to develop higher order reasoning skills through discovery and invention while addressing useful academic skills.

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References

Aurobindo, S. (1910). *The human mind*. India: Karmayogin.

Brooks, J. G., & Brooks, M. G. (1993) *The case for constructivist classrooms*. Alexandria, Virginia: Association for supervision of curriculum development.

Bruner, J. S. (1960). *The process of education*. Cambridge: Harvard University Press.

District Information System for Education (DISE). (2014). Elementary education in India: Where are we?. Retrieved from http://dise.in/Downloads/Elementary-STRC-2013-14/All-India.pdf

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom.* CA: Constructing Modern Knowledge Press.

Mukunda, K. V. (2009) *What did you ask at school today?* New Delhi: Harper Collins.

Pal, Y., et al. (2005). *National Curricular Framework.* New Delhi: National Council of Educational Research and Training. Retrieved from http://www.ncert.nic.in/rightside/links/nc_framework.html

Papert, S. (1986). *Constructionism: A new opportunity for elementary science education.* Cambridge, MA: M.I.T Media Laboratory, Epistemology and Learning Group (NSF Grant Proposal).

Papert, S. (1993). *Mindstorms: Children, computers and powerful ideas.* NY: Basic Books.

Papert, S., & Harel, I. (1991). *Constructionism.* NJ: Ablex Publishing Corporation.

Pea, R., & Kurland, D. M. (1984). On the cognitive effects of learning computer programming. *New Ideas in Psychology*, *2*, 137-168.

Resnick, M. et al. (2009). Scratch: Programming for all. *Communications of the ACM, 51*(11), 60-67.

Ranganathan, S. (2014) *Program to encourage critical thinking in children – 2013-2014*. Grant report by Udavi School to SAIIER.

ROLE OF INTERACTIVE SIMULATION IN UNDERSTANDING THE ELECTRIC FIELD

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The subject of Physics mostly deals with abstract and non-intuitive concepts. To ameliorate functional understanding of such concepts and physical processes, learners need an effective medium. Simulation being one such tool can render an opportunity through varied experiences and hence can facilitate conceptual understanding. Electric field is one such abstract concept which entails tangible experience. The present study investigates how simulation influences in elucidating the electric field concept. The first stage of the study explores the initial understanding of the field concept, followed by the use of simulation activity and validation test. Results indicate improved performance in the perception of the electric field concept, though procedural difficulties in vector representation are not completely eliminated and suggest explicit instruction implication.

INTRODUCTION

Understanding learning has been the quest of cognitive scientists, neurobiological scientists, psychologists and many others, and more recently of physicists so as to make learning more effective (Larkin, 1981; Van Heuvelen, 1991; Hake, 1998). The new area of research on how people learn Physics has instructional implication, as well as application for understanding how specific learning in the domain under consideration occurs (Bao & Redish, 2006; Hake, 1998; Heckler & Sayre, 2010). This new domain based education research has opened up many avenues for research in understanding aspects of effective learning of Physics. Physics has often been perceived as a surly subject thus causing many students to move away from it. Even among those who choose to pursue Physics, learning is tenuous. Extensive research initiatives have probed in to the various aspects of Physics learning. Often, the readiness with which a new idea or concept gets accepted is strongly influenced by the learner's perception of the relevance of the concept. This often does not happen in many domains of learning, also in Physics. Many Physics concepts, like electric field, do not possess associated physicality which makes comprehending experiences with the concept tedious. In addition to the complex concepts, Physics learning brings in use of novel representational formats - like graphical, vectorial, mathematical, etc which deter effective learning (Tornkvist, Pettersson & Transtromer, 1993; Beichner, 1994; Sherin, 2001; Torigoe & Gladding, 2011; Pepper, Chasteen, Pollock & Perkins, 2012).

In addition, the teaching-learning processes strongly influence the manner in which the understanding of a particular concept develops. Learning, more often than not, is influenced by the learners previously held ideas and beliefs. Pedagogical studies have been carried out in several domains of Physics learning - many in the domain of mechanics and relatively few in the domain of Electricity and Magnetism (E&M) (Viennot & Rainson, 1992; Tornkvist, Pettersson & Transtromer, 1993; Galili, 1995; Maloney, O'Kuma, Hieggelke & Heuvelen, 2001; Singh, 2006; Pepper et al., 2012; Gire & Price, 2014; Karam, 2014).

Concepts involved in the discipline of E&M are predominantly abstract and non intuitive more so while learning advanced Physics. Forming a mental model as a consequence of this becomes a serious impediment while learning the concepts for which the analogous mental picture is not feasible. In addition, physical experiences cannot be tangibly associated with the concept. However, what can positively influence understanding is the experience with features of the concept that can be illustrated (Shubha & Meera, 2015a). Along with the introduction of concept, comes in the requirement to adopt novel representations, for example vector representation for the electric field concept. Research has shown difficulties learners possess in using vector representations in the context of Physics (Knight, 1995; Nguyen & Meltzer, 2003; Flores, Kanim & Kautz, 2004; Van Deventer & Wittmann, 2007; Van Deventer, 2008; Barniol & Zavala, 2014; Gire & Price, 2014, Shubha & Meera, 2015b). Results indicate a lack of procedural knowledge. Interactive simulation tool with its visual attribute has the potential to generate experiences and hence can supplement traditional teaching/learning. It can also be an effective medium to reinforce the procedural understanding (Shubha & Meera, 2015b).

Studies have indicated that learning with virtual labs or computer simulations can have a positive effect on the acquisition of conceptual knowledge (Lindstrom, Marton, Ottosson & Laurillard, 1993; Jaakkola, Nurmi & Veermans, 2011; Sarabando, Cravino & Soares, 2014; Shubha & Meera, 2015a). Simulation is one of the effective learning tool that renders an opportunity to visualize varied experiences with the concepts and helps to build a mental model. The use of simulations in learning ameliorates conceptual understanding by use of visual representations (Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky & Reid, 2005; Van der Meij & de Jong, 2006; Adams, Paulson & Wieman, 2008; Podolefsky, Perkins & Adams, 2010; Zacharia & Olympiou, 2011; Chini, Madsen, Gire, Rebello & Puntambekar, 2012; Shubha & Meera, 2015b). We have chosen the simulation from the available repertoire of simulations, not really designed them for this study.

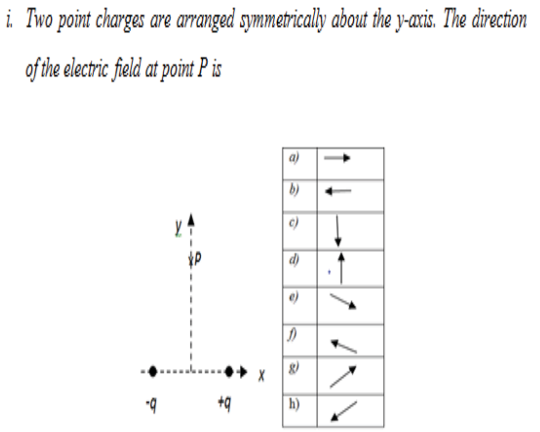
METHOD OF INVESTIGATION

This study intends to probe the model of students' understanding of the electric field concept and to obtain an insight on the role of the effect of interactive engagement activities using simulation. Student interviewees are volunteers from first year Masters Physics Course, Department of Physics, Bangalore University. The activities were conducted in three stages. In the first stage of study, seventy students were presented with ten questions in Multiple Choice Questionnaire (MCQ) form, related to elementary concepts (such as force, field & flux) of E&M. In this study, the responses to questions related to the concept of electric field are analyzed. Responses to the MCQ enable us to tailor and design the activities that explicitly deal with the relevant aspects. Based on the conceptual and procedural difficulties identified in the first stage of the study, after thorough review of available simulations pertaining to the electric field concept, we selected the Electric Field in One-Dimension Easy Java Simulation. In this stage, students' exploration of the simulation is accompanied by a set of questions framed on specific aspects pertinent to those aspects that were uncovered in the first stage of the study and that is in tandem with the features of the simulation. In the final stage, a validation test interview was conducted to evaluate the influence of interactive simulation on conceptual and procedural understanding of electric field representation.

PRE-INVESTIGATION STUDIES

The first stage of this study involved eliciting student responses to questions that probe their understanding of questions related to electric field concept.

Pre-test Questions and Responses



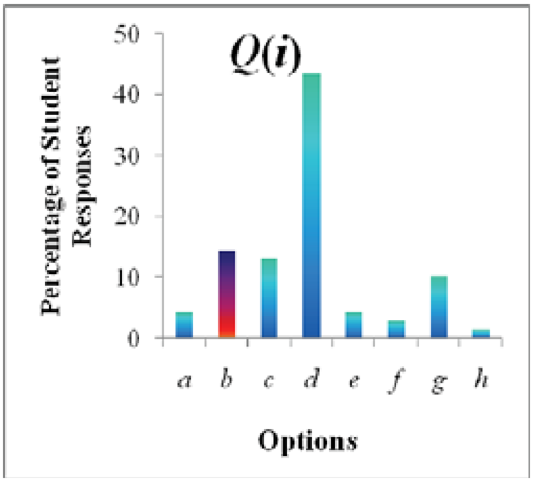
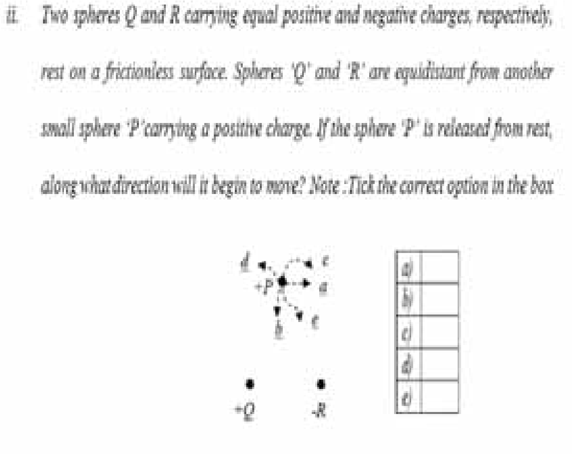


Figure 1: Question *Q(i)* and responses of students to *Q(i).*

Answering question Q(i) requires students to use their conceptual and procedural understanding to draw field vectors and to obtain resultant field vector. Considering that students have had a rigorous course on vectors and have had the experience of drawing the vectors and their resultant in the context of mechanics, the answers for these questions were surprising. Fig. 1 shows the responses of students. About 15% have selected the correct option (b) whereas about 44% have selected the (incorrect) option (d). Though responses for Q(i) show faulty understanding, they do not depict underlying thought process. We reiterate here again that the MCQ questions are meant to provide us with a pointer for framing our simulation activity.



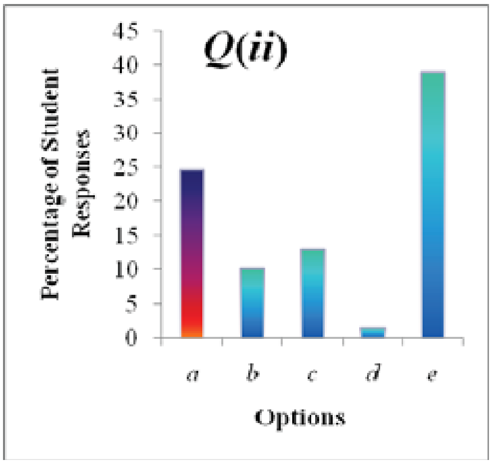


Figure 2: Question *Q(ii)* and responses of students to *Q(ii).*

This question *Q*(*ii*) evidently is *Q*(*i*) but *Q*(*i*) is a Physics problem and *Q*(*ii*) is a physical problem. The response to the question *Q(ii)* is expected to mimic the responses of *Q*(*i*). 24.64% have selected the correct direction (*a*). Fig. 2 shows the responses of students. Nearly 39% have selected the incorrect direction (*e*).

RESULTS OF PRE - INVESTIGATION STUDIES

Responses to questions in the pre-investigation study shows that the student difficulties observed in the MCQ test may be, to begin with, due to the lack of procedural understanding in the geometric representation of individual vector and finding resultant field vector for point charges. Research studies on usage of interactive simulation in teaching/learning process in different domains of Physics have established that a simulation enriches students' knowledge through experiences in conceptual understanding by visualization and interaction. To set up an intuitive understanding with varied experiences, this study is extended with interactive simulation as a learning tool.

SIMULATION – BASED LEARNING ENVIRONMENT

This research work uses Electric Field in One-Dimension interactive simulation as shown in Fig. 3 by using a software tool Easy Java Simulation (EJS).

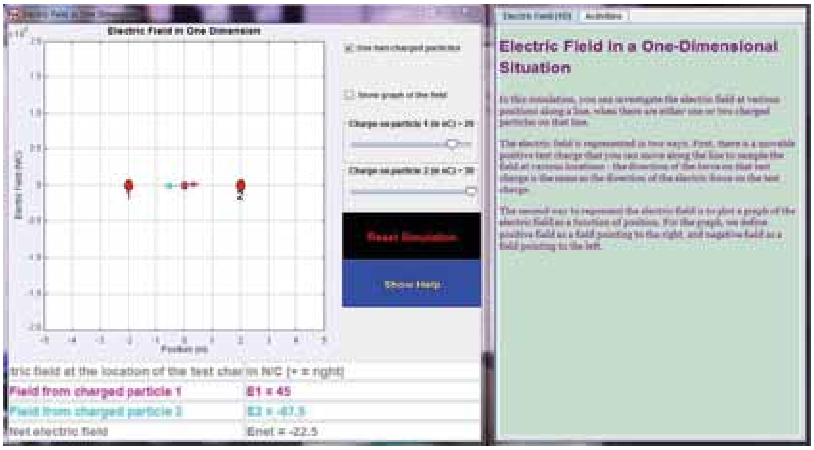


Figure 3: An illustrative screen shot of electric field in 1-D simulation.

Eleven students were provided with the simulation activity. The students were provided with an electronic writing pad by which answers to the questions posed has been recorded and interactions with simulation controls are recorded using CamStudio software. This provides us responses to the questions in real time.

SIMULATION ACTIVITIES

Five questions/activities were framed to bring to focus the functional understanding of vector arrow representation of physical quantities in concept learning by using simulation. The activities explore students understanding of the vector representation of electric field for the case of single charge and two charge situations as charge and distance parameters are varied.

ANALYSIS OF RESULTS OF ACTIVITIES

Activity 1 and 2 reinforces student understanding of the electric field vector with varying charge and distance. It is observed that all students interacted with charge control slider (to change charge quantity) and the click and drag tool (to change distance). In activity 1, six students did identify the proportional relation of the electric field vector (E_1) with charge (q_1). Of the remaining responses, one student who depicted the field vector in pictorial form had not drawn the longer arrow (with increase in charge). In activity 2, nine students did identify the inverse relation of vector arrow length (magnitude) with varying (increase or decrease) distance.

Activity 3 tests often explored conceptual inference of the effect of electric field E_2 (due to charge q_2) on E_1 and E_{net}. The simulation window presents the numerical values of individual electric fields and net electric field and also the question did bring in the attention to this aspect. Out of eleven students, ten students clicked on the checkbox (use two charge particles) to select second charge particle on the simulation window screen. Among the ten, majority students namely nine noted the numerical values of E_1, E_2 and E_{net}. Of these, three of them pointed that the length of the vector (magnitude) of E_1 remains same when q_2 is on. Two students recognized that net electric field (E_{net}) as the algebraic sum of constituent electric fields (i.e., $E_1 + E_2$). The betterment in answer is made by one student who translated the observation pictorially and depicted the distinct field (E_1, E_2 & E_{net}) vectors on the positive test charge.

Activity 4 was framed with an objective to know whether the student can recognize the change in the length of field vector E_2 (by decreasing charge q_2) and its effect on E_1. It is noted that six students identified and inferred the answer correctly. Of the remaining five, three students could not identify the decrease in the arrow length of the field vector (E_2) but however they could enumerate that there is no change in the magnitude of E_1. In contrast, the remaining two students who identified the decrease in arrow length of field vector E_2 but not its effect on E_1.

Activity 5 was framed to consolidate the nested ideas of activities from 1 to 4 and transfer it to graphical illustration of electric field as a function of distance. Ten have executed the understanding of E vs d in the graphical form. Among them, six interpreted the same even in verbal form as an increase in arrow length with a decrease in the distance and two of them has corroborated it as parabolic curve.

VALIDATION TEST

In order to validate learning gain, we presented students with two problems. Five students were presented with these problems after they participated in the simulation activities (immediate response group) and four were given these after a gap of six months since they had used simulation (delayed response group).

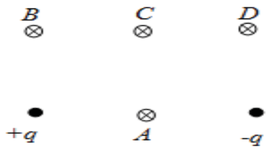
Validation questions

A. *Sketch the electric field lines for the point charges.*

a) $+q$

b) $-2q$

B. *The two point charges +q and –q which are separated by a distance 'L'. In the diagram, draw the net electric field vector due to the charges +q and -q at the locations A, B, C and D respectively.*



Responses to Validation Questions

For *Q*(*A*), five students sketched the field lines on a positive charge (+*q*) and indicated the direction outwardly and for charge (-*2q*) have indicated the direction inwardly. Among them, four students are from the immediate response group and one student is from the delayed response group. Two students from the immediate response group, did not give attention to the proportional variation of line density with the increase in charge (-2*q*) shown in the Fig. 4.

Figure 4: Sample representation of incorrect proportional line density.

Of the remaining students, two have drawn the field line representation erroneously and in contrast two have depicted field lines as a field vector. Fig. 5 shows the representations.

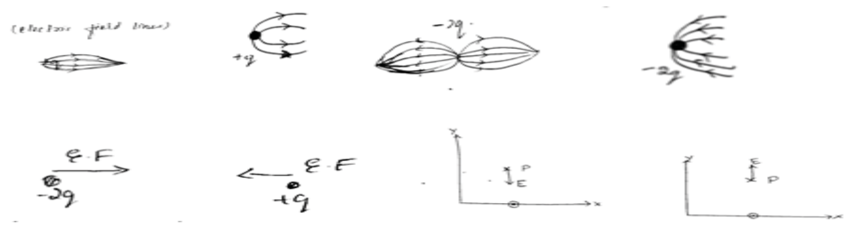


Figure 5: Incorrect representations made by students for charges +q and -2q.

For *Q*(*B*), two students have represented the resultant vector at all points (*A, B, C & D*) correctly. Among them, one student is from the immediate response group and another one is from the delayed response group. And a student from the delayed response group has joined the vector arrows at sampling points in space as a connected field line representation. Of the remaining seven students, three of them have decomposed the vectors "component wise" and drawn constituent field vectors due to (+*q and –q*) but not the resultant field vector at locations (*A, B, C & D*). And four of them have given the representation in fuzzy manner.

DISCUSSION

The present study was carried out to obtain an insight on the nature of concept student possess and role of use of simulation activities on developing conceptual understanding of the electric field. It also looks at how simulation influences understanding the vector arrow representation in visualizing the electric field at different points in space which inherently helps in acquiring procedural and conceptual knowledge for the same. Since the questions are presented in MCQ form and the question requires identifying the correct option and not really drawing the resultant vector, functional analysis carried out by students to find the solution is hidden.

As discussed earlier, simulation can be useful in developing experiences that promote intuitive conceptual understanding. The learning flaws observed in pre-investigation studies provide an insight in framing simulation activities. These activities cue directions while exploring the simulation. The validation test intends to assess the functional use and creation of vector representation that follows the simulation activities in altered situations. Results do indicate weak intermediate stages in learning even in post simulation experience which present instructional implications. Learning and general cognition can be influenced in a positive way by using visual inputs as it reinforces pattern formation. However in domains with strong abstractness, this may generate faulty patterns and in such situations simulation should only bring out features associated with the concept. Notwithstanding the proven effectiveness of the use of visual inputs, careful considerations in certain domains are essential.

References

Adams, W. K., Paulson, A., & Wieman, C. E. (2008). What levels of guidance elicit engaged exploration with interactive simulations? *Proceedings of American Institute of Physics Conference, 1064,* 59-62.

Bao, L., & Redish, E. F. (2006). Model analysis: Representing and assessing the dynamics of student learning. *Physical Review Special Topics - Physics Education Research*, *2,* 010103, 1-16.

Barniol, P., & Zavala, G. (2014). Force, velocity, and work: The effects of different contexts on students' understanding of vector concepts using isomorphic problems. *Physical Review Special Topics-Physics Education Research*, *10*, 020115, 1-15.

Beichner, R. (1994).Testing student interpretation of kinematics graphs. *American Journal of Physics*, *62*(8), 750-762.

Chini, J. J., Madsen, A., Gire, E., Rebello, N. S., & Puntambekar, S. (2012). Exploration of factors that affect the comparative effectiveness of physical and virtual manipulatives in an undergraduate laboratory. *Physical Review Special Topics - Physics Education Research, 8,* 010113, 1-12.

Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P. B., Perkins, K. K. Podolefsky, N. S., & Reid, S. (2005). When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment. *Physical Review Special Topics- Physics Education Research*, *1,* 010103, 1-8.

Flores, S. Kanim, S. E., & Kautz, C. H. (2004). Student use of vectors in introductory mechanics, *American Journal of Physics*, *72,* 460-468.

Galili, I. (1995). Mechanics background influences students' conceptions in electromagnetism. *International Journal of Science Education, 17,* 371-387.

Gire, E., & Price, E. (2014). Arrows as anchors: An analysis of the material features of electric field vector arrows. *Physical Review Special Topics - Physics Education Research*, *10,* 020112, 1-11.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66,* 64-74.

Heckler, A. F., & Sayre, E. C. (2010). What happens between pre- and post-tests: Multiple measurements of student understanding during an introductory physics course. *American Journal of Physics*, *78,* 768-776.

Jaakkola, T., Nurmi, S., & Veermans, K. (2011). A comparison of students' conceptual understanding of electric circuits in simulation only and simulation-laboratory contexts. *Journal of Research in Science Teaching*, *48,* 71-93.

Karam, R. (2014). Framing the structural role of mathematics in physics lectures: A case study on electromagnetism. *Physical Review Special Topics - Physics Education Research, 10,* 010119, 1-23.

Knight, R. D. (1995). The vector knowledge of beginning physics students. *The Physics Teacher*, *33,* 74-78.

Larkin, J. (1981). Cognition of learning physics. *American Journal of Physics, 49,* 534 - 541.

Lindstrom, B., Marton, F., Ottosson, T., & Laurillard, D. (1993). Computer simulation as a tool for developing intuitive and conceptual understanding in mechanics. *Computers in Human Behaviour, 9,* 263-281.

Maloney, D. P., O'Kuma, T. L., Hieggelke, C. J., & Heuvelen, A. V. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics*, *69*, S, 12-23.

Nguyen, N., & Meltzer, D. E. (2003). Initial understanding of vectors concepts among students in introductory physics courses. *American Journal of Physics*, *71,* 630-638.

Pepper, R. E., Chasteen, S. V., Pollock, S. J., & Perkins, K. K. (2012). Observations on student difficulties with mathematics in upper-division electricity and magnetism. *Physical Review Special Topics - Physics Education Research, 8*, 010111, 1-15.

Podolefsky, N. S., Perkins, K. K., & Adams, W. K. (2010). Factors promoting engaged exploration with computer simulations. *Physical Review Special Topics - Physics Education Research*, *6,* 020117, 1-11.

Sarabando, C., Cravino, J. P., & Soares, A. A. (2014).Contribution of a computer simulation to students' learning of the physics concepts of weight and mass. *Research conference on virtual worlds - Learning with simulations, Procedia Technology, SLACTIONS 2013, 13*, 112-121.

Singh, C. (2006). Student understanding of symmetry and Gauss's law of electricity. *American Journal of Physics*, *74,* 923-936.

Sherin, B. L. (2001). How students understand physics equations. *Cognition Instruction*, *19*, 479-541.

Shubha, S., & Meera, B.N. (2015a). Impact of visual representation on the conceptual understanding of abstract Physics concept - electric flux. *American Scientific Publishers, Advanced Science, Engineering and Medicine, 7,* 533-537.

Shubha, S., & Meera, B.N. (2015b). Students' perception of vector representation in the context of electric force and the role of simulation in developing an understanding. *World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic and Management Engineering, 9*(2), 501-509.

Torigoe, E. T., & Gladding, G. E. (2011). Connecting symbolic difficulties with failure in physics. *American Journal of Physics*, *79*, 133-140.

Tornkvist, S., Pettersson, K. A., & Transtromer, G. (1993). Confusion by representation: On students' comprehension of the electric field concept. *American Journal of Physics*, *61*, 335-338.

Van der Meij, J., & de Jong, T. (2006).Supporting students' learning with multiple representations in a dynamic simulation-based learning environment. *Learning and Instruction*, *16*, 199-212.

Van Deventer, J., & Wittmann, M. C. (2007). Comparing student use of mathematical and physical vector representations. *Proceedings of American Institute of Physics Conference*, *951*, 208-211.

Van Deventer, J. (2008). Comparing student performance on isomorphic math and physics vector representations. Master's thesis, The University of Maine. Retrieved from http://umaine.edu/center/files/2009/12/Vandeventer_Thesis.pdf

Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based strategies. *American Journal of Physics*, *59*, 891-897.

Viennot, L., & Rainson, S. (1992). Students reasoning about the superposition of electric fields. *International Journal of Science Education*, *14*, 475-487.

Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in Physics learning. *Learning and Instruction*, *21*, 317-331.

RETHINKING GESTURE WITH NEW MULTITOUCH DIGITAL TECHNOLOGY

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This paper is about re-thinking gesture in order to reckon with its material and haptic nature, especially in the current multitouch technology environment. This re-thinking of gesture returns to the principle of indexicality found in Peirce's material semiotics, and develops this principle through the work of Gilles Deleuze around hand-eye relationships. Drawing on the work of Jürgen Streek, we propose and discuss the notion of the tangible gesture, in the context of mathematical explorations of young children with a multitouch iPad environment designed to promote counting on and with the fingers.

INTRODUCTION

In the context of education research, vast amounts of video studies focus on student and teacher use of gesture in classrooms, but this work tends to code and sort gestures insofar as they are *representations* of thinking. These studies tend to divorce the motoric hand from the feeling swipes and swishes of fingers. Material semiotic approaches to the study of interaction, on the other hand, consider gesture less as representations and more in terms of the material effects they achieve (Roth, 2001). Our goal in this paper is to take up this approach to study the gestures used in new digital media, and to unpack the implications for understanding mathematics learning in relation to new media. We begin by locating our work in relation to current semiotic ways of conceiving of gestures, as used in the field of gesture studies and adopted in mathematics education research. We then point to different ways of conceiving the role of gestures that have emerged principally from the work of the philosophers Gilles Deleuze, pointing to new forms of tangible gesturing that may operate in fundamentally new ways. Thus we aim to expand the definition of gesture formulated by Kendon (2004) so as to address the changing ways in which hand and media interact.

We argue that new media offers—and will always offer—new ways to rethink the relationship between body and gesture. By focusing on a burgeoning new technology, we can show how our understanding of gesture depends on our bodily configurations and, as Rotman (2008) and others have suggested, on our current technological prosthetic extensions. If inventive gestures are always at the threshold, then taxonomies of gestures are limited by their assumptions about where the body ends. What we find in the literature on mathematics and gesture is a concerted effort to code these gestures without adequate attention to how new gesturing habits emerge *as the body itself is reconfigured*. In other words, we cannot take for granted what a body can do. As new media emerge, so do new gestures, and these together actualize the contours of a newly assembled body and a newly assembled set of concepts. Thus we examine the ways in which new media gestures demand a reconsideration of how the capacities of sense organs—eyes, hands, ears—are coordinated *provisionally* and in response to material interfaces. In order to illustrate how these new media gestures operate, we draw on research involving the use of a multitouch application *TouchCounts*.

THE INDEXICAL GESTURE AND INSCRIPTION

Researchers such as McNeill (1992) have identified different categories of gestures (icon, metaphoric, deictic and beat) so as to distinguish different relationships between gesture and speech. McNeill has drawn on Peirce's semiotics in which signs (icons, indices and symbols) differ in terms of the nature of the relationships between the signifying sign and the signified. According to Peirce, icons operate according to likeness or resemblance between the signifier and the signified, like the image of a man or woman on a bathroom door. Iconic *gestures* are also described in terms of their *resemblance* with events or objects. If iconic signs become conventional codes within particular cultures, they may become *symbols*, which have an arbitrary relationship with that to which they refer. The third category, indices, emphasizes the material link between signifier and signified. Unlike icons and symbols, indexical signs are bound to the context in important ways—they "show something about things, on account of their being physically connected with them" (Peirce, 1894/1998, p. 5). As in the case of smoke billowing from a chimney indicating that the fireplace is in use, the smoke *indexes* the fire. In other words, smoke is *produced by and contiguous with* the fire.

What is distinctive about the index is that it is a sign that is materially linked or coupled to "its object". According to Peirce (1932), an index "refers to its object not so much because of any similarity or analogy with it, (…) as because it is in dynamical (including spatial) connection both with the individual object, on the one hand, and with the senses or memory of the person for whom it serves as a sign, on the other" (2.305). For Peirce, the pointing aspect of indexical signs was only a consequence of their essential material link or connection to their object. Visual indexical signs, for instance, like the smoke example above, capture this far better, as they entail a visual trace or mark that evokes or refers to that which formed the trace or mark. This latter indexical dimension is usually not emphasized in the semiotic study of mathematical activity, since we tend to focus on the completed trace and dislocate it from the labour that produced it. Such habits of focus have resulted in our neglect of how the activity of the body and various other material encounters factor in mathematical activity.

Pierce's diagrammatic approach to signs—and his focus on the visual—has been superseded in the research literature by an emphasis on gesture as part of "the human capacity for language" and the study of gesture as "language in action" (Rossini, 2012). However, research that codes gesture only in terms of linguistic potential tends to overlook the physicality of the hand movement of gesture, except insofar as such movement contributes to or obscures linguistic meaning. As Streeck (2009) indicates, "it is common to treat gesture as a medium of expression, which meets both informational and pragmatic or social-interactional needs, but whose "manuality" is accidental and irrelevant" (p. 39). He defines gesture:

> … not as a code or symbolic system or (part of) language, but as a constantly evolving set of largely improvised, heterogeneous, partly conventional, partly idiosyncratic, and partly culture-specific, partly universal practices of using the hands to produce situated understandings. (p.5)

Thus he studies gesture for how it is "communicative action of the hands" with emphasis on the term *action* (p.4). This focus on action allows Streeck to study gesture for how it couples with and intervenes in the material world in non-representational ways. Researchers often distinguish between hand movements *in the air* and hand movements *that make graphic marks*, where the former is deemed a gesture and the latter an act of inscription. However, such distinctions become fuzzy when we follow Streeck and study the movement of the hand across and through media, where 'media' can be more or less receptive of trace or mark. In other words, all hand movements traverse and incorporate media. We see a trace in certain media, and not in others, but since the logic of new media is to break with current conventions of perception, this distinction is provisional. As gesture recognition technology evolves, hand movements in the air become productive of various kinds of traces.

In the case study we discuss below, the hand actually operates very close to the surface of a screen: pointing to objects on the screen by tapping them; sliding objects along on the screen so as to leave visual and aural traces of the finger's path; pinching objects together in order to make new ones. These gestures of pinching and flicking and pointing both communicate meaning and inscribe marks. In this paper, we discuss an application in which the gesture plays an even more central role in the mathematical activity. Briefly, there are two worlds: enumerating and operating. The former features an ordinal model of numbers and the latter a cardinal model of numbers. In the Enumerating World, each finger tap produces a yellow disc. Tapping the screen four times consecutively will produce three discs, each numbered 1, 2, 3, 4, respectively, and three sounds "one", "two", "three", "four". The discs fall off the bottom of the screen unless gravity is turned off, in which case they remain on the screen, or unless the finger tap is made above the horizontal line, which acts as a 'shelf' on which the discs rest (figure 1b) (video: http://tinyurl.com/q8lpzrc). In the Operating World, tapping the screen with four fingers simultaneously produces a 'herd' with the numeral 4 on it, as well as four smaller discs (see figure 1c). Multiple herds can be combined by using a pinching gesture (4 and 1 are being combined in figure 1c). The resulting herd will be labelled with the sum, and this sum is said aloud. A herd can be partitioned into two herds by using a splitting gesture (video: http://tinyurl.com/omancvf).

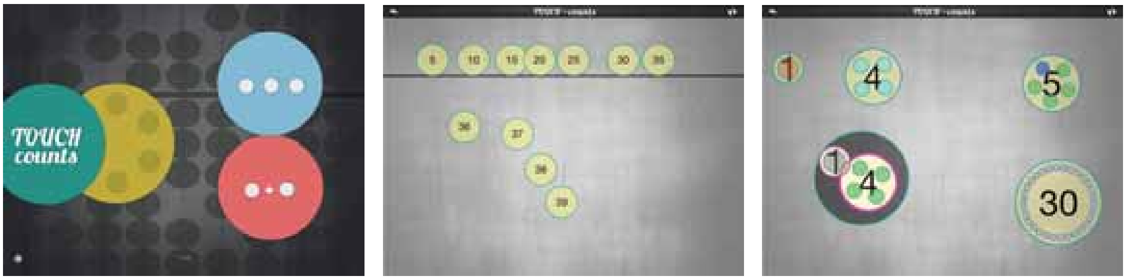

Figure 1a: The enumerating world (•••) and the operating world (•+•); (b) Ordinal numbers falling off the shelf; (c) Herds of different cardinalities.

Rather than study gestures as iconic or symbolic representations of some concept, we examine gestures for how they function as indexical, material actions. By focusing on the indexical, we can study gestures as materially coupled, generative devices, rather than only as forms of representation.

RETHINKING THE RELATIONSHIP BETWEEN HAND AND EYE

The philosopher Gilles Deleuze (2003) points to the complex and changing relationship between hand and eye, directing our attention to how particular senses outrank others in particular situations. He examines how the eye and the hand compete for control of meaning, where confusion or even contradiction is resolved when one sense dominates the other. He identifies four *relationships* between hand and eye, and he names them: the digital, manual, tactile and haptic. The first term designates situations where the eye dominates the hand, while the next two terms track an increasingly more dominant hand in relation to the eye, and the last term a more ‘equal’ contribution of the two.

The tapping of the finger on a surface or screen corresponds to the *digital* aspect because the eye is dominant as it determines where and when the tapping should occur. The hand is subordinated to the eye: “the hand is reduced to the finger, that is, it intervenes only in order to choose the units that correspond to pure visual forms” (p. 124). But screen gestures also include various dynamic gestures, such as sweeping. Through these, the hand becomes *tactile*. The space is not entirely depleted of dynamic potential, and it is these potential dynamic dimensions that are enlisted. The flicking gesture might provide a good example here of the tactile category in that there is a virtual referent of speed involved because flicking must begin by touching an object and then quickly swooshing it higher or lower, where the quickness of the swoosh determines the speed at which the object changes.

Deleuze suggests that the hand can revolt against this optic regime in acts of creative art. He refers to *manual* relationships as ones in which the hand takes charge, where there is “movement without rest, which the eye can barely follow and which dismantles the optical” (p. 124). In the manual relationship, the eye may not be able to direct the hand, being somehow refused access to what the hand now controls. Maybe the eyes are closed, or maybe the action performed by the hand takes precedent over the visual aspects of the objects on which it is performed. The eye and hand are still somewhat individuated as organs. It is in the *haptic* relationship that it becomes difficult to distinguish the eye from the hand: “there is no longer a strict subordination in either direction, but when sight discovers in itself a specific function of touch that is uniquely its own, distinct from its optical function” (p. 125). In a haptic relationship, the eye begins to see with its hand.

TWO CASE STUDIES

In the next section, we discuss a case study of children working with *TouchCounts*. We examine two excerpts, each focusing on an encounter between a child, a teacher and an iPad.

Indexical Gestures and Rhythm

In this example, a five-year-old girl named Katy is interacting with *TouchCounts* for the first time. Without prompting, Katy’s hand approaches the screen, and her finger touches the top of it and slides down to the bottom. A yellow disc appears under her finger with the numeral ‘1’ on it and the sound ‘one’ is made. The index finger moves back to the top of the screen, slowly swimming downwards. A chorus of ‘two’ comes both from her mouth and the iPad. This happens repeatedly, although sometimes only the iPad can be heard announcing the new numbered disc while Katy’s lips move in synchrony (Figure 2a). The appearance of ‘10’ on the tenth yellow disc attracts attention, perhaps because of its double digits, and Katy bends over to look closely. Now only the iPad counts the numbers (Figure 2b).

Figure 2(a) Katy swiping; (b) Following the yellow disc; (c) Tapping while looking up.

After ‘seventeen’, several fingers fall on the screen at once, and then ‘twenty-one’ is heard. This produces a pause, and Katy’s lips spread into a smile. All but the index finger are tucked away, as the rhythmic tapping continues along with the chorus of named numbers. At ‘twenty-seven’ Katy looks up, no longer watching the screen (see Figure 2c), and continues swiping and saying numbers. This continues until a finger accidentally lands on Reset.

Grasping with Multiple Fingers and Subitising

As seen above when multiple fingers alighting on the screen resulted in the jump from “seventeen” to “twenty-one”, there can be a significant difference between one-finger and multi-finger interactions. Indeed, in *TouchCounts*, there is a possibility of asking children to produce a given number “all-at-once”, which involves them placing a required number of fingers on the screen simultaneously, rather than sequentially tapping a finger.

Figure 3: (a) Using fingers to counting up to seven; (b) Making seven on the fingers.

In this example, Cameron (four years old) was asked to make seven all-at-once. We want to draw attention to how the hand and eye, as well as the ear, work together in what happens. He first takes his hand out, unfurls his fingers one by one as he counts them softly to himself (see Figure 3a). Then he looks at what his fingers have formed, palms up, and then turns his hands over to place the outstretched fingers on the screen. But he accidentally touches the screen in more then seven spots so that *TouchCounts* says “eight”. When asked if he wants to do it again, he nods and his hands immediately take on the same seven-finger gesture he had made before (without first having to count out the fingers nor look at them to validate), and he carefully places his fingers on the screen (Figure 3b), thus producing “seven”.

DISCUSSION

Fingers can serve as both a physical extension of what Rotman (1987) calls the ‘one-who-counts’ (p. 27) as well as the thing-to-be-counted: fingers are thus simultaneously subject and object, both of the person and of the world (Alibali & diRosso, 1999). This is what makes the finger actions of Katy and Cameron so interesting; the act of counting with *TouchCounts* fuses this duality and in so doing changes the relationship between hand and eye (and ear).

Katy’s hand actions change over the course of the episode, not only in the particular muscular form they take, first sliding down the screen as if lingering on the yellow discs to produce or partake in their falling off the screen, and then tapping impetuously so that each new touching of the screen follows the end of the sounds of the voiced numerical. The swiping gesture seems more exploratory while the tapping gesture seems to concatenate into a unit the touch-see-hear bundle of sensations involved in making a new disc-numeral-name. As Streeck writes, tapping is also "characteristic of ritualized behavior" (p. 76), which suggests that Katy has moved from exploration to practice. In both the swiping and the tapping, the finger can be seen as making an indexical gesture, with the trace being both visible and audible, not to mention tangible for Katy. Although the initial movement and touch of her finger is what produces the disc, it is the disc that determines the swiping movement of her finger. Indeed, both her finger and her eyes *follow* the yellow disc as it heads down the screen. In shepherding the numbered disc off the screen, Katy is able to see when it's time to lift her finger and start making a new disc. But with the tapping, the eyes attend to the numerical sign on the disc—indeed, when "10" appears, Katy notices the change from the previous one-digit numerals. In this sense, the eye and the finger do very similar things when swiping; the visible trace is followed closely by Katy's eyes as the swiping takes place, so that the hand is subordinated to the watchful eye in Deleuze's *digital* sense. With the tapping, the hand seems less subordinated, as the eye is only interested when a novel situation comes up, like a double digit. When Katy looks up, the hand is no longer subordinate at all and the relationship is a *manual* one. Her fingers do the seeing and touching as they are repetitively summoned on the screen.

But of course, there is more than the eye and hand involved in this situation. The ear and voice feature importantly as well. Indeed, while the voice is subordinate to the touch (it only speaks while Katy taps), Katy's hand is also subordinate to the ear in that the ear judges the moment of the next tap. And the ear is disrupted by the hand, when several fingers touch the screen at once, causing the voice to jump from "seventeen" to "twenty-one." The eye, which was about to drift off, must return to survey the situation; the hand returns to its single digit tapping. The importance of the aural and the vocal is interesting in terms of the counting activity at play. Indeed, the ritual origins of counting are oral in nature, and counting with young children is often undertaken as the learning of a song that one memorizes and chants. The involvement of the hand in this otherwise oral event provides a visual and tangible trace of the count, while also associating each counted number with a single swipe or tap.

One might question whether Katy's actions on the screen, which we might think of as touch-pointing, can really be thought of as gestures. In discussing the importance of the pointing gesture in enabling people "to make discriminations, and highlight, emphasize, and interpret the present world and orient each other to it" (p. 59), Streeck argues that such gestures (and indeed all gestures) emerge from the touching and handling of things—the tracing (or other "data-gathering devices" such as caressing, probing, cupping) of objects that allows one to discover its texture and temperature. When the hand has done its exploring, which fulfills an epistemic function in gathering information, it may then be lifted off the object and inclined to repeat the same movements 'in the air': "the hands' data-gathering methods are used as the basis for gestural communication" (p. 69). Streeck identifies such gestures as being communicative. In this sense, Katy's touch-pointing becomes a gesture once she lifts her hand from the screen to do her tapping.

Distinguishing hand movements that explore from ones that communicate is problematic though. As Streeck writes, exploratory actions can become communicative when they are made visible to others, who may join in the action or infer tactile properties. If we look at Katy's swiping and tapping gestures, we might say that they are both exploratory, with the swiping gestures involving prolonged tactile contact that enables her to discover what would happen when her finger touches the glass—that a yellow disc would appear, with a numeral on it; that the disc would move down the screen; that the iPad would speak the number's name aloud, and that this could all be repeated as often as she wished. But Katy's swiping and, later, her tapping, are also communicative inasmuch as they tell *TouchCounts* what to do and say. The same might be said for clicks of the mouse or key presses of the keyboard, with the difference that the touchscreen is acted upon by direct hand motions. Instead of disentangling the tracing from the pointing (the exploration from the communication), we suggest that re-assembling them into an indexical enables us to see how Katy's hand movements can tap into the potentiality of the body by reconfiguring the relationships between sensations of touch, sight and sound that are at play. This potentiality mobilizes new mathematical meanings as Katy uses her fingers to count on, to count with and to count out one by one and indefinitely. Streeck recognizes that hand-gestures "enable translations between the senses" (p. 70) as tactile discoveries provide visual information for interlocutors. With Katy though, the tactile discoveries provide visual and auditory information to herself. She is her own interlocutor.

In the case of Cameron, multiple fingers engage with the screen. Whereas the first gesture in Figure 3a is *digital* because the hand is subordinated to the eye, which carefully tracks the number of fingers being raised, the final gesture in 3b has become *haptic* in the sense that neither the eye nor the hand is subordinate—the eye is seeing the "seven-ness" in its multiplicity, which the simultaneous touch has actualized. While the eye had condoned the initial gesture, the ear announced that its trace on the screen was unexpected. It was not the right sound, but it was just one word, rather than a succession of one, two, three, four, five, six, seven, eight. The eye accepted the gesture and the ear prompted Cameron to revise the precision of his hand's action so that in the next attempt the hand is placed more carefully on the screen to prevent any other parts of the hand from touching—or being touched by—it. Here it seems to be the hand's responsibility to mould itself in a particular shape so that only fingertips touch. The eye watches but the hand is in charge. Throughout, the relevant trace is the aural one, as Cameron does not stop to count the number of discs on the screen.

The gesture of seven-fingers-lifted that Cameron makes immediately becomes a communicative version of an exploratory act: first it successfully tells *TouchCounts* how to say "seven" without saying the preceding numbers—the gesture annotates the act of having lifted seven fingers up one by one; it also enables Cameron to see/produce the cardinal seven so that seven becomes a reified version of the sequential counting out of the fingers. As with Katy, Cameron becomes his own interlocutor and his hands, eyes and ears are reassembled into a new configuration through which counting becomes count—that is, through which the slow, ordered sequence of finger lifting becomes a sudden flash of the hand. Finally, Cameron's gesture communicates to the children around him, who now only need to mimic his flash of the hand in order to make their own sevens—and, later, their own sixes and eights and most happily, tens. For them, the gestures may initially act as signs, but once they place their fingers on the screen, those gestures become indexical in simultaneously pointing and tracing. Again, as with Katy, we cannot say that the epistemic hand-action has merely culminated in a communicative gesture, in part because the hands have been coupled with a certain spatial arrangement of yellow discs as well as a singular announcing of the count.

CONCLUSION

In tracing the evolution of the hand and its role in human development, Streeck shows how the hand's actions in the world, which enable fundamental actions such as eating and making, become communicative. He argues that hand-gestures cannot be taken only as components of a language system, which are cast apart from the material world, and used only to communicate about the world. Rather, they are *of* the world, and part of how we *feel* the world around us. This perspective requires us to see the moving hand as "environmentally coupled" (Goodwin, 2007), that is, as inextricable from the things it touches and engages with. But while Streeck implies a vector from the exploratory hand action to the communicative hand-gesture, our case studies reveal how the exploratory hand frees itself from the optic regime and invents meaning as much as it communicates it. This new kind of gesture is possible in large part because of the feedback mechanism of digital technologies, which can talk, push and show back. With the touchscreen interface, and particularly the multitouch actions, the hand is involved in a process of communicating that is also a process of inventing and interacting.

In both of the examples we presented, we have tried to show that the gestures made by the children in *TouchCounts* had a significant indexical nature in part because they not only involved some kind of pointing (with one finger or more) but they left a trace that is both visible and audible. The trace is important in drawing attention to the material engagement of the children's gestures. They obviously arise out of movements of the hand, but they also result in material reconfigurations that can *give rise to* new movements of the hand. In discussing the effect of new digital technologies in disciplines such as mathematics, Rotman has written about the future cultural neoteny in which speech would "become reconfigured (as it was once before when transformed by alphabetic writing), re-mediated and transfigured into a more mobile, expressive, and affective apparatus by nascent gesturo-haptic recourses emerging from the technologies of motion capture" (2008, p. 49). In other words, the word and perhaps even the strictly communicative gesture cedes the way to the gesture-haptic so that even pre-school children can count 'on their hands' to 100.

References

Alibali, M., & diRusso, A. (1999) The function of gesture in learning to count: More than keeping track. *Cognitive Development, 14*, 37-56.

Deleuze, G. (2003). *Francis bacon: The logic of sensation*. (Translated from the French by Daniel W. Smith). London, UK: Continuum.

Goodwin, C. (2007). Environmentally coupled gestures. In Duncan, Susan D., Justine Cassell and Elena T. Levy (Eds.), *Gesture and the dynamic dimension of language: Essays in honor of David McNeill* (pp. 195–212). Amsterdam, Philadelphia: John Benjamins Publishing Company.

Kendon, A. (2004). *Gesture: Visible action as utterance.* Cambridge, UK: Cambridge University Press.

McNeill, D. (1992), *Hand and mind: What gestures reveal about thought,* Chicago: University of Chicago Press.

Peirce, C. S. (1894/1998). What is a sign? In Peirce edition Project (Eds.), *The essential Peirce. Volume 2.* Bloomington, IN: Indiana University Press.

Peirce, C. S. (1932). Elements of logic. In C. Hartshorne and P. Weiss (Eds.), *collected papers of Charles Sanders Peirce, Volume 2.* Cambridge: Harvard University Press.

Rossini, N. (2012). *Reinterpreting gesture as language: Language in action*. US: IOS Press.

Roth, W.-M. (2001). Gestures: Their role in teaching and learning. *Review of educational research, 71*(3), 365-392.

Rotman, B. (1987). *Signifying nothing: The semiotics of zero.* London, UK: MacMillan.

Rotman, B. (2008). *Becoming beside ourselves: The alphabet, ghosts, and distributed human beings*. Durham: Duke University Press.

Sinclair, N., & Jackiw, N. (2014). *Touchcounts* [Software application for the iPad]. Burnaby, BC: Tangible Learning Project.

Streeck, J. (2009). *Gesturecraft: The manu-facture of meaning*. Amsterdam, NL: John Benjamins Publishing Company.

DOES IT WORK?
USING COMPUTER GAME AS A TOOL FOR LEARNING – TEACHING EARLY ALGEBRA

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The question in this paper is if the suitably designed computer game may foster 12 years old children to enter the world of algebra. Particularly - the game concerns solving linear equations with one unknown (Dragon Box). What algebraic obstacles do students jump over using the game? How do they accustom to symbols? How can they transfer rules of the game to paper- and-pencil work? If we compare students who used game with others - do they make less mistakes? The results of using special digital tool by a group of students suggest that well-built computer game is obviously relevant didactic medium but cannot replace other tools. It seems to be a powerful supplement to other forms of teaching. For the process of learning the most important moment is the transfer from playing to paper-and- pencil-work that is why the part of a teacher is invaluable.

INTRODUCTION

What do we think about students at present? Are they really different than one day, some years ago? I think they are the same in a way. They need a goal and some kind of activity that would help them to reach it. They are different because they live in different world, they have different experiences; something else is interesting for them and something else is important. And this is the reason why our “old fashion” teaching doesn’t fit to student’s new possibilities.

Computer Games in Education

Digital games, an interactive technology within the multimedia learning environment, can effectively and interestingly foster learning processes, particularly among young learners. Well-designed educational video games offer meaningful learning experiences based on principles of situated learning, exploration, immediate feedback, and collaboration. The power of experiential learning in engaging contexts that have meaning for learners has been demonstrated in several studies (Shute, Ventura & Ke, 2015). Games are also thought to be effective tools for teaching complex ideas because they (a) use action instead of explanation, (b) create personal motivation and satisfaction, (c) accommodate various learning styles and skills, (d) reinforce mastery, and (e) provide interactive, decision - making context (McAlister & Charles, 2004; Squire, 2002). Moreover video games may create a new learning culture that better corresponds with the habits and interests of today’s children and young adults (Prensky, 2001).

In math teaching, it is found that computer game utilizations foster the success level and creative ability of students in education and help to peer teaching and interaction that in turn creates a positive effect (Ozusaglam, 2007). Abrams (2008) mentions that computer games are strong motivation tools for math lessons. Analysis showed that using computer games in mathematics education improves students' self-efficacy for learning and improves their interest in mathematical activities. In Keith Devlin's opinion modern devices allow us to greatly expand on the symbolic interface, which for many people is a known barrier to mathematics learning (Devlin, 2011). Though regulated by rules, computer games allow manipulation of objects, supporting development towards levels of proficiency (Fabricatore, 2000).They are said to be particularly effective when 'designed to address a specific problem or to teach a certain skill' (Griffiths, 2002), for example in encouraging learning in curriculum areas such as maths.

Potential benefits of using games during educational process are persuasive. But there is one more thing that I'm interested in - games are mainly used to facilitate tasks appropriate to learners' level of maturity in the skill, but players must possess such skills to some degree earlier. For me the most interesting would be the game that teaches completely new mathematics concepts and my research concern such a game.

Hypothesis

I designed special kind of learning. A group of 12 years old children were playing DragonBoxAlgebra5+ (http://dragonboxapp.com/) before they got to know anything about solving equations. Students have already looked for solutions of x+ b = c or ax = c, but only by guessing or finding inverse operation. Starting the game they didn't know what it was about and that it was somehow connected with mathematics.

My hypothesis was: there is relationship between using the game for learning and reasonably manipulation of algebraic symbols in solving equations.

Rules of the Game

The game (DragonBoxAlgebra5+) starts from presentation of the table, divided into two parts and different cards. There is one particular card between them – a blinking box. The main principle says: "In order to win you must isolate the box on one side". Students follow the rules that say what move is needed to get rid of the useless cards: what to do if the cards are scattered, if they are stuck together, or if one is below another. One of the first rules says: "You can add the card from the deck". From now on the student always gets this information with a leaping picture on the deck of the board. He cannot make the next move until he places the same card on the other side.

Figure 1: The game

Next principles come in slowly and they are used in several examples before anything new is introduced. Having solved an equation the student gets feedback. It covers three points and gives three stars as an award: the first one - for leaving the box alone, the second one - for the right number of moves, and the third one - for the right number of cards used. You can always move back. You can also solve your task again from the beginning. There is no timing in the game. Students have as much time as they need to finish.

The game starts from replacing colour icons but slowly the pictures are replaced by cards with numbers and letters. Soon “blinking box” is transformed to the card with “x”. On one of the last levels the signs of arithmetic rules appear and the line dividing the board is replaced by the equal sign. The change from various cards to letters and initiation of using mathematics signs are barely noticeable. It’s only new kind of pictures on which students already made moves according to well-known rules. However, manipulation on symbols starts to look like solving equations.

Learning Arrangement, Discovering

I carried out the plan of special learning arrangement in the group of 12 years old children. There were 20 students in the class. At first pupils were playing at school, using the interactive white board, but very soon most of them bought the game and got it on their own tablets or smart phones. During the first three lessons they had opportunity to play, discuss every example and look for the best strategy. They often moved back the steps, solving the task from the beginning several times. Some students cooperated, others worked without any help. Everybody wanted to take part in it and were really involved in the game. I acted rather like an observer – sometimes I helped students to understand English commands. I didn’t interrupt, didn’t make suggestions.

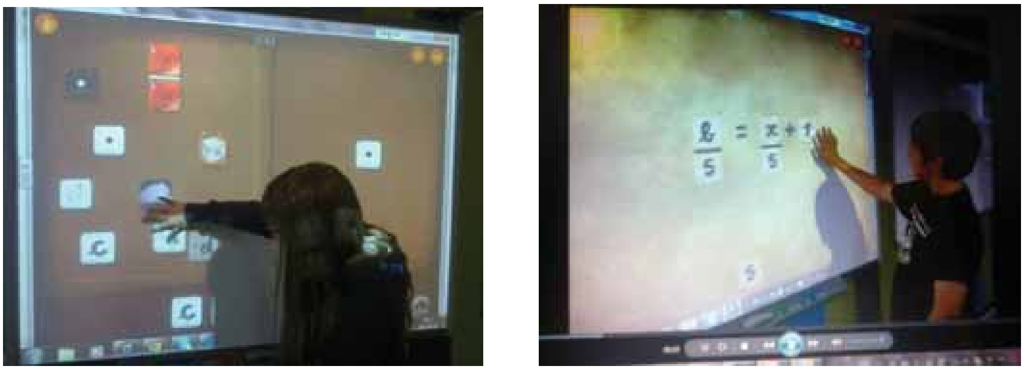

Figure 2: Students playing the game

I listened to my students and watched what they discovered. How did they join the pictures with numbers and the moves with arithmetic rules? How did they notice that bright and dark icons were like opposite numbers and what meant their disappearing after being moved one upon the other? If the same pictures were situated one below another you could get rid of them by dragging one to its twin. It looked for children like reducing a fraction. Some cards were stuck. It was sufficient to put one of such a card below that pair to make a fraction. Then you could use a preceding rule and divide the numbers. Students were not surprised when the pictures started to gather in groups joined with the sign of addition and in the place of line dividing the board the sign of equation appeared. Before this change there wasn’t anything meaningful that the right side is equal the left one. Students only linked it with necessity of adding everything to both sides of the board. This rule is stressed all the time – you can do nothing if the move isn’t repeated.

In more difficult examples students thought about the order of the moves. What was more effective – to start from putting a card below another one? - then you had to do the same to all groups of cards; or maybe it's better to get rid of useless cards from the side where the "x" card was blinking? Sometimes they took away the pictures from the side without the box, but then opposite cards appeared on the other side. They noticed that it's very important to see where the box is at the beginning to decide about the order of moves.

Students made a lot of mistakes and moved back many times. I can say – they learned by their mistakes. Sometimes they solved the problems together or they worked in pairs so there was opportunity to dispute a lot. I didn't chip in. After getting the feedback about the stars they knew what was wrong – if it was correct, if the order was the best and if there were no useless cards. Students didn't want me to help – they preferred to look for their mistakes by themselves.

The game gave children much pleasure. They enjoyed mathematics lessons. They also played after the lessons, during the breaks. They discussed, compared their achievements.

Learning Arrangement, Paper-and-Pencil Work

After such amusing introduction by playing, I said that it was time for transferring the same to paper-and-pencil work. We started from the easiest equations. I encouraged students to transfer the rules of the game to code all needed operations in such a way, that it would be legible and understood. Students created notation for: adding cards from the deck, moving one on the other, dragging cards. Ideas were very rich. We chose the best solutions.

The first problem was how to write down the addition of cards to both sides. There was no possibility to drag a picture with a finger. Students added the numbers writing them on border sides of the equation. They drew the arrows to code the addition and they wrote the results below them. Putting number below another one they added the fraction line. Or they stuck on the number to the number to get rid of a fraction. Sometimes it was clear in the writing that a student only placed numbers next to each other – like in the game — and after a while he put the multiplication sign. Every new operation they wrote down using different colour to mark it off. They used game language - "I drag on top, I place below..."

First examples were very simple. They consisted of one operation only. Students have already solved such equations, but only by guessing or finding inverse operation. I encouraged them to compare what they did before with the rules of Dragon Box. I often asked a question: Which way is easier for you in definite task – doing operations on both sides or rather finding an inverse operation? Students decided what to do differently in different situations. I think they often tend to forget methods that they learned earlier – trying to do everything in one way, without a reflection that it's possible to do it differently.

During such a transfer from the game to paper-and-pencil work it's very important to pay attention to the meaning of the expression "solution of the equation" and to verify its correctness. Students don't get the feedback yet. The only way to check the solution is to substitute and calculate.

The next problem was how to remember about repeating every operation on both sides. The game reminds about it from the first to the last level. The added card is leaping on the deck as long as the move is repeated on the other side to every group of cards. Now there is no reminder. Children agreed that using colour pencils helps them to remember about both sides. They often checked their solutions and compared them. I posted up incorrect answers and they were looking for the mistakes. Very soon students expected some kinds of errors so they were looking for special ones. Some students started to abandon writing single operation but more often it led to the wrong solution. Taking the notes of every transition gave them more chances that they would succeed.

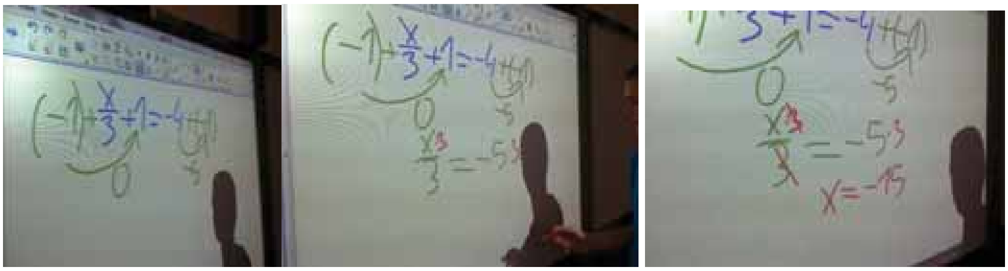

Figure 3: Students and their calculations

Very slowly students started to use the specific algebraic language in the place of language of the game. But they always could adduce to Dragon Box. Particularly in more difficult, doubtful situations – coming back to the game helped them to take the proper decision.

Learning arrangement, New types of equations

The first part of DragonBox5+ is just an introduction to solving linear equations with one unknown. There are only equations with an unknown on one side of the equality sign. But it can give opportunity to make a new research, encourage students to transfer the rules to new equations, for example: **2x +5 = x + 6** . 12 years old students have already known how to add expressions like **2x + 3x**. In the game they got used to see (-x) like a dark version of x, so it was nothing new to add (-x) if it was necessary. The game also makes children familiar to leave x on any side – it doesn't matter which one .The aim was the same: to isolate x. Children asked their own questions too, for example: which side would be better? Very soon they decided that it was more safe to add (-x) to both sides than to add (-2x) because of positive result on the left side.

It appeared that the new type of equation wasn't so hard, students just applied earlier experiences and it was like creating the next levels of the game.

The Results of Comparison

A year later I tested a group of pupils from the point of view of solving linear equations with one unknown. It was a group of 100 students from five different classes, taught by three different teachers. There were 20 pupils among them that had played DragonBoxAlgebra5+ and then continued with DragonBoxAlgebra12+. The others were taught in the traditional way – using the balance metaphor.

Group E – (experimental group - students using the game)

Group T – (traditional group - students who didn't play the game)

	Some kinds of mistakes	Group E	Group T
1	Students forget about operations on both sides	8%	19%
2	Mistakes like: 4x – x = 4	0%	5%

3	Incomprehension of the algebraic structure	0%	6%
4	Students didn't start on a task	2%	7%
5	Troubles with the sign of equation	0%	4%
6	Creating "quasi methods"	2%	5%

Table 1: Results of comparison

Students had to solve a few equations - with the unknown on one side only, or with unknown on both sides. There were also different coefficients – integer and fractional. Some of the equations needed only single operation to do and in others students had to transform the expressions.

Testing the students had two main goals – the first one was to answer the question: "What kind of mistakes did students make?" The second one was to compare students using the game with others. Did they make less mistakes? Which mistakes were less frequent?

There are some general conclusions: the experimental students less frequently forgot about both sides of equation. They didn't mistake unknown with numbers. The misconception of the algebraic structure was also less frequent. Group T didn't start on the task more often and had more troubles with the use of the equation sign. They also created their own - wrong - "quasi-methods" more often.

How Could Playing the Game Influence the Results?

In my opinion playing such a game can foster children to solve equations because:

From the beginning students get used to distinguish between "blinking box" and the other cards, so then they don't mistake the unknown with numbers.

It's impossible to make any move if you don't repeat the operation on both sides of the board – the main rule in balance metaphor is also the main one in the game.

Children solve the same problem many times, looking for the best solutions, so they get to know algebraic structure of expressions, considering the order of moves.

The box can be situated on each side – it doesn't matter which one.

They discover the rules and create the notation by themselves so they remember it all better.

Students are not afraid of symbols and operations, they use them, try them. They are not afraid of the failure so they want to start on every task.

When students solve equations, they can call the rules of the game in every moment to remember which move was necessary in such a situation.

Conclusions, Plans for Future Research

Well-built computer game used as a tool for discovering of mathematics is obviously a relevant didactic medium. It encourages learning. It is also very close to students' interests; most of them spend many hours playing different games. I think it's worth taking advantage of this situation. Firstly – the game shows something new, secondly - the game provides incentive for the player to keep practice. Solving equations seems to be boring and sometimes never-ending for many pupils but as we know - it is essential to be able to use algebra in the future.

I also agree with Keith Devlin who said that games cannot be the only way that students should learn math. They can be a powerful supplement to other forms of teaching, because they are ideally suited for learning basic math. But they cannot replace good textbook, cannot replace the teacher first of all (Devlin, 2011). There are other good sources of mediums that I use to teach algebra – for example: special kinds of blocks or well prepared computer applications. If children have more different models to learn it's easier for them to cross the following algebraic thresholds.

The results of testing showed me some problems with the understanding of the concepts "solution" or "set of solutions". Sometimes students have no idea how to finish solving the equation 2x = 5x or 0 = 3x or 2x = 2x + 1. They have problems with answering the question: what numbers are the solutions? And their answers suggest a lot of misconception. I am looking for the reason of such troubles. I think it's a good idea to use special blocks for it. I mean Lab Gear - special manipulative designed to model algebra concepts (http://www.mathedpage.org/manipulatives/alhs/alhs-0.pdf). In the future I'm also going to investigate its use for solving more equations with two variables, for example, and for inequalities.

References

Abrams, L. (2008). *The Effect of computer mathematics games on elementary and middle school students' mathematics motivation and achievement.* Unpublished Doctoral dissertation, Capella University.

Devlin, K. (2011). *Mathematics education for a new era: Video games as a medium of learning*. Natick MA: AK Peters.

Fabricatore, C. (2000). Learning and videogames: An unexploited synergy. Retrieved from www.learndev.org/ dl/FabricatoreAECT2000.pdf

Griffiths, M. D. (2002). The educational benefits of videogames. *Education and Health, 20*, 47-51.

McAlister, M., Charles, D. (2004). Building digital learning environment. *Journal of Advanced Technology,* September 2004.

Ozusağlam, E. (2007). Web-based mathematics education and courses example of presentation. *Pamukkale University Faculty of Education Journal, Vol.21,* 33-43.

Prensky, M. (2001). *Digital game - based learning.* New York: McGraw -Hill.

Shute, V. J., & Ventura, M., Ke, F. (2015). The power of play: The effects of Portal 2 and lumosity on cognitive and no cognitive skills. *Computers and Education 80*, 58-67.

Squire, K. (2002). Cultural framing of computer/video game. *The International Journal of Computer Game Research*, *2*.

FULLY ONLINE METHODS COURSES? RECONCEPTUALIZING STEM TEACHER PREPARATION THROUGH "SPACES OF LEARNING"

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Rather than viewing eLearning as being best suited for courses fitting a particular type, we suggest a paradigm shift, involving a reconceiving of the nature of instructional experiences within a course. We share how we have reconceptualized mathematics and science (STEM) teacher preparation at the University of Colorado Denver (CU Denver) through designing and implementing fully online methods courses for our prospective STEM teachers (pSTEMs). Our fully online methods courses incorporate Spaces of Learning (SOL)—multidimensional instructional experiences that provide opportunities for pSTEMs to engage in a variety of activities designed to promote and scaffold their investigation of, reflection on, and response to STEM teaching practices. By reconceptualizing what it means to engage in STEM teacher preparation, we are expanding possibilities for our pSTEMs through their participation in SOL.

Although online courses have been available for years, certain types of courses may be seen as challenging or even undesirable to deliver through eLearning. Methods courses in teacher education programs —in which prospective teachers develop knowledge, pedagogy, and strategies for teaching—represent courses of this type. Rather than viewing eLearning as being best suited for courses fitting a particular type, we suggest a paradigm shift, involving a reconceiving of the nature of instructional experiences within a course. We share how we have reconceptualized mathematics and science (STEM[1]) teacher preparation at the University of Colorado Denver (CU Denver) through designing and implementing fully online methods courses for our prospective STEM teachers (pSTEMs).

As part of their teacher preparation program at CU Denver, pSTEMs take two methods courses in either mathematics or science education. The methods courses occur in the last two semesters of the program, in conjunction with field experiences at local middle and high schools. Currently, we offer one methods course in science education and one in mathematics education in a fully online format. We have designed the program experience such that pSTEMs can enrol in the two methods courses in any order, rather than requiring that one methods course precede the next. In making these design decisions; we are working to create greater access for pSTEMs in urban, rural, and remote locations.

1 Throughout the paper, we refer to the combination of mathematics and science as "STEM." We use the acronym STEM—standing for science, technology, engineering, and mathematics—to be more succinct in our writing. We do not mean to suggest we consider STEM to include only mathematics and science.

THREE REASONS WHY ONLINE METHODS COURSES ARE APPEALING

One of the reasons why online versions of teacher preparation courses—including STEM methods courses—are so appealing is the varied background and current life circumstances of the prospective teachers enrolled in the program. Prospective teachers selecting CU Denver have a range of life experiences. Some are undergraduate students, attending CU Denver just after finishing high school. Others are working adults, participating in a graduate teacher preparation program while balancing demands of work, home, and family. STEM methods courses at CU Denver are intended to meet the needs of a range of pSTEMs, whose concurrent field experiences span middle and high school grade bands and encompass a wide variety of STEM content. We see the diversity of our pSTEMs' experience as a strength of our program. By differentiating our STEM methods courses to meet the needs of our diverse pSTEMs, we work to maximize affordances and minimize limitations related to accessibility by making the program—including methods courses—available online.

Another reason why online versions of STEM methods courses are instructionally appealing is the challenge of engagement in face-to-face courses. In our face-to-face courses, we have noticed that there are students who are physically present but not intellectually engaged with the work of the course. One of the advantages of a fully online course is that it allows space and time for all students to engage with and make contributions to all of the course materials and activities.

Finally, we were keen to develop and deliver online versions of our STEM methods courses because of our pSTEMs' busy schedules. pSTEMs at CU Denver have classroom field experiences during the day. If the STEM methods courses are not online, the pSTEMs have to come to campus for classes in the evening after a full day in their field-experience classrooms. Releasing temporal bounds supports our work with our pSTEMs in part by removing challenges of a traffic laden commute to an urban campus and a balancing act between family and school responsibilities. By allowing our pSTEMs to engage with the STEM methods course content when they can be most present, we can support their learning.

Through fully online methods courses—one in both mathematics and science education—we can design powerful experiences that robustly address the needs of our population and prepare pSTEMs for the high-touch, high-interaction endeavour of teaching middle and high school students.

PRESENCE+EXPERIENCE

To guide our[2] design of fully online STEM methods courses, we created the Presence+Experience (P+E) framework (Dunlap, Verma & Johnson, in press), which integrates the Community of Inquiry (CoI) model (Garrison, Anderson & Archer, 2000; Garrison & Arbaugh, 2007) with Kolb's experiential learning cycle (Kolb, 1984; Kolb, Boyatzis & Mainemelis, 2000) (see Figure 1). An established model in the online-education realm, the CoI model serves to explain the relevance and criticality of attending to three key presences in online learning environments: teaching, social, and cognitive presence. Teaching presence refers to the decisions and actions of the instructor in a learning environment, such as the decisions related to the organization and structure of a learning experience, the design

2 In sections of this article in which course planning and design decisions are described, "our" and "we" refers to the two authors who developed the courses described in this article.

of instructional materials and activities, the facilitation of instructional activities, and the assessment of student learning. Social presence involves the connections students and faculty establish in a learning environment; social presence is influenced by the quality and quantity of student-to-student and student-to-instructor interaction, helping all involved to feel more involved, engaged, and real in an online space. Finally, cognitive presence refers to the interactions students have with course content; supported by teaching and social presence, students' cognitive presence is engaged through relevant cognitive-processing activities and assessments that lead to enhanced conceptual understanding.

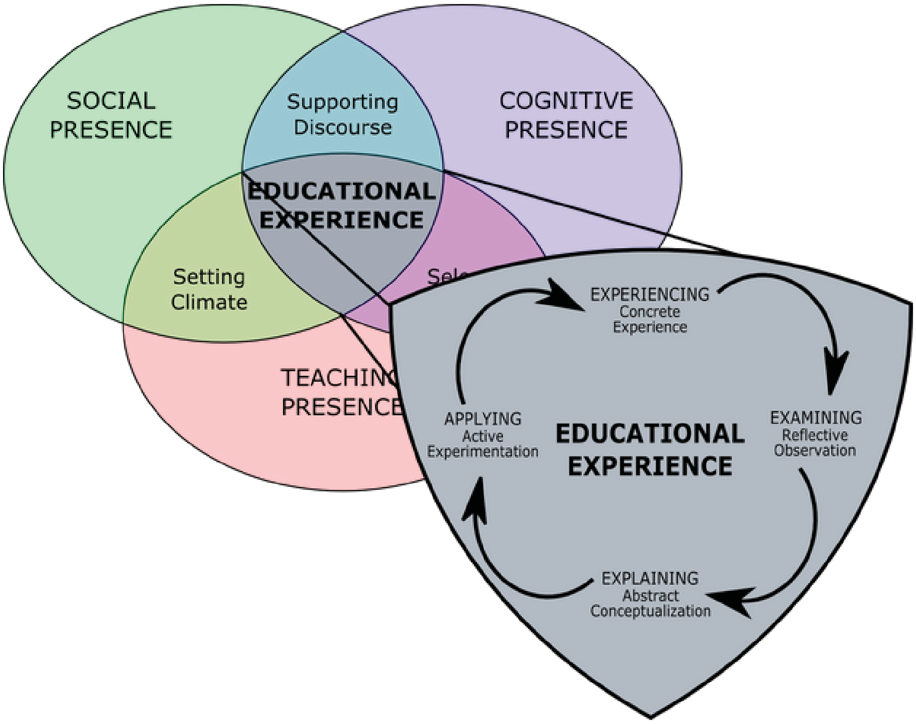


Figure 1: The presence+experience (P+E) framework

Defining learning as the transformation of experience, Kolb's experiential learning cycle involves four key components: Experiencing (Concrete Experience), Examining (Reflective Observation), Explaining (Abstract Conceptualization), and Applying (Active Experimentation) (Kolb, 1984; Kolb, Boyatzis & Mainemelis, 2000). Kolb's cycle recommends starting with a concrete experience, in which students engage in a specific experience. Then, students reflect on the experience, considering various aspects of their observed experience and drawing meaning from the experience. At this point, students are primed to handle the abstract conceptualization of what they have been studying, drawing logical conclusions based on their reflections and in light of theoretical constructs that explain aspects of the experience. Finally, students apply their new learning and understanding through active experimentation (e.g., completing a project, simulation, case study, fieldwork).

Because the CoI model is more descriptive than prescriptive, the P+E framework simply overlays Kolb's cycle on the CoI model to provide specific online-course design and facilitation guidance. Using the P+E framework, online course designers and educators can leverage Kolb's experiential learning cycle to systematically address the teaching, social, and cognitive presences of the CoI model.

THE PRESENCE+EXPERIENCE (P+E) FRAMEWORK IN ACTION: "SPACES OF LEARNING (SOL)"

When developing fully online STEM methods courses, we drew on resources (e.g., readings, classroom videos, and interactive web-based tools such as simulations) similar to those we would use in a face-to-face STEM methods course. Using the P+E framework, we designed Spaces of Learning (SOL) (see Figure 2)—multidimensional instructional experiences that provide opportunities for pSTEMs to engage in a variety of activities designed to promote and scaffold their investigation of, reflection on, and response to STEM teaching practices. Figure 2 shows overlap between the investigation, reflection, and response dimensions because the dimensions do not live in isolation. For example, a pSTEM's reflection may stimulate further investigation, and her subsequent response may stimulate yet more investigation and reflection.

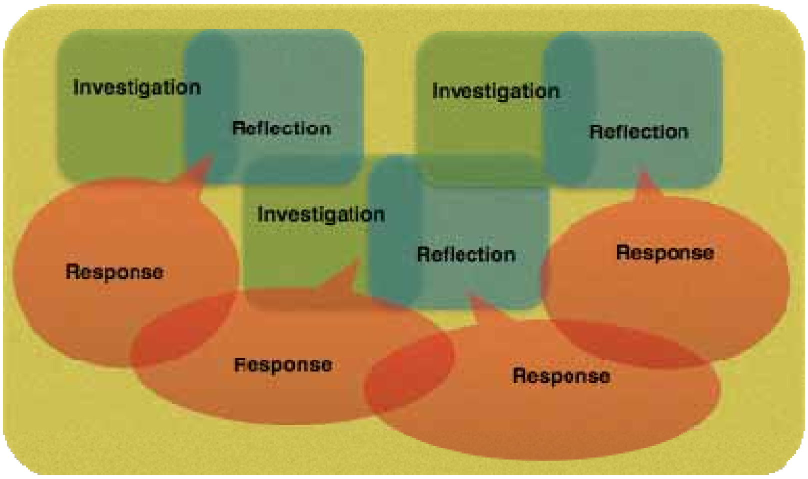


Figure 2: Investigation, reflection, and response dimensions of the spaces of learning (SOL)

In the investigation, reflection, and response dimensions of the SOL, pSTEMs engage in each of the four components of Kolb's (1984) experiential learning cycle. Furthermore, each dimension addresses the teaching, social, and cognitive presences of the CoI model. In particular, we design and facilitate the SOL (teaching presence) to engage pSTEMs in critical thinking related to the work of teaching (cognitive presence) in ways that support their interaction with other pSTEMs and their instructor (social presence).

A key feature of our SOL involves our strategic use of vetted classroom video to support our pSTEMs' development of teacher noticing, which refers to teachers' interpretation of a teaching situation for a particular purpose (e.g., Sherin & Han, 2004; van Es & Sherin, 2002). Through the investigation-reflection-response dimensions of our SOL we provide opportunities for our pSTEMs to engage in teacher noticing to foster their development of high leverage teaching practices (Ball & Forzani, 2009). By high leverage practices, we mean those "tasks and activities that are essential for skilful beginning teachers to understand, take responsibility for, and be prepared to carry out in order to enact their core instructional responsibilities" (p. 504).

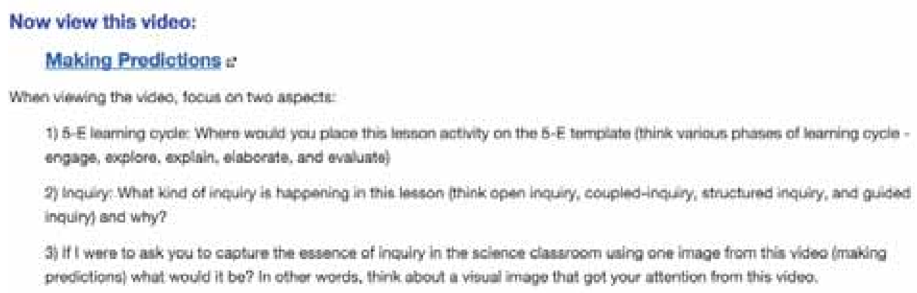
Investigation: In the investigation dimension, pSTEMs observe videos of STEM teaching practice and explore interactive web-based tools, addressing the Experiencing (Concrete Experience) component of Kolb's (1984) experiential learning cycle. We drew on reputable web resources with freely available video and interactive web-based tools, including but not limited to the Teaching Channel (https://www.teachingchannel.org/), Annenberg Learner (http://www.learner.org/), PBS Learning Media (http://www.pbslearningmedia.org/), the National Council of Teachers of Mathematics' (NCTM's) Illuminations (http://illuminations.nctm.org/), and the National Science Teachers Association's (NSTA's) Learning Center (http://learningcenter.nsta.org/).

For example, in the mathematics education course, pSTEMs could explore an interactive web-based tool that could be used to foster their students' learning of key STEM content, such as NCTM Illuminations' "Cost per Minute": http://illuminations.nctm.org/Activity.aspx?id=6380, which dynamically links graphs representing different linear relationships. In a related investigation, pSTEMs could observe a classroom video for the purpose of noticing how a teacher's STEM teaching practices provide students opportunities to draw on multiple resources to support students' developing proficiency in graphing linear equations, such as the Teaching Channel's "Graphing Linear Equations: Full Body Style" Lesson: https://www.teachingchannel.org/videos/graphing-linear-equations-lesson. In another investigation, pSTEMs could observe a different classroom video using a different full-body approach to graphing linear equations, such as the Teaching Channel's "Linear Graphs: Life-Size Coordinate Pairs" lesson: https://www.teachingchannel.org/videos/linear-graph-lesson-plan.

In the science methods course, students watch multiple video to investigate how reform guided teaching looks in an actual classroom. As an example, students watched a video called making predictions to investigate ways in which a teacher promotes inquiry in his classroom, how the teacher helps his students make predictions throughout the lesson, and understanding collaborative meaning making.

Reflection: In the reflection dimension, pSTEMs determine salient aspects of interactive web-based tools and identify key teaching moves represented in the videos, addressing the Examining (Reflective Observation) component of Kolb's (1984) experiential learning cycle. As an example, in the mathematics education course, exploring the "Cost per Minute" interactive web-based tool, pSTEMs could develop conjectures about how changes in one graph could result in changes in a linked graph. In related reflections, pSTEMs could identify specific practices in each classroom video that fostered students' drawing on multiple resources to develop proficiency in graphing linear equations, making explicit connections to the different lessons.

In the science methods course, students reflected on various prompts posed by the instructor that tied the class readings to the investigation activity. See a screen shot of this investigation activity below:



Now view this video:

Making Predictions

When viewing the video, focus on two aspects:

1) 5-E learning cycle: Where would you place this lesson activity on the 5-E template (think various phases of learning cycle - engage, explore, explain, elaborate, and evaluate)

2) Inquiry: What kind of inquiry is happening in this lesson (think open inquiry, coupled-inquiry, structured inquiry, and guided inquiry) and why?

3) If I were to ask you to capture the essence of inquiry in the science classroom using one image from this video (making predictions) what would it be? In other words, think about a visual image that got your attention from this video.

Screenshot 1: Investigation and reflection dimensions of the spaces of learning (SOL)

Response: In the response dimension, pSTEMs demonstrate their developing competency and emerging STEM teaching practice, addressing both the Explaining (Abstract Conceptualization) and Applying (Active Experimentation) components of Kolb's (1984) experiential learning cycle. pSTEMs have the opportunity to respond to instructor prompts designed to focus their attention on salient aspects of STEM teaching practice represented in the videos and to foster their strategic use of web-based tools with which they interacted.

In mathematics education course, pSTEMs could explain how they might facilitate their students' use of the "Cost per Minute" interactive web-based tool to develop conjectures about how changes in one graph could result in changes in a linked graph. In a related response, pSTEMs could use images, videos, and/or text to communicate aspects of the STEM teaching practices they were noticing in one or both of the lessons that they viewed. In another response, pSTEMs could compare and contrast the tasks used in the different lessons, explaining how those tasks might be used to support students' developing proficiency in graphing linear equations. In conjunction, pSTEMs could address how they are working to enact compatible high-leverage STEM teaching practices around the same or related content in their concurrent field experiences.

In science education course, pSTEMs could also use multiple modalities (e.g. images, videos, text) to share their understandings about successful aspects of the investigation activity. In addition, they were able to demonstrate their competencies as they start to enact these practices in their own teaching. The screenshot shared below captures the essence of the response dimension of *Spaces of Learning*:

Posting to the Discussion Board - No Group Work for this discussion board

this is a media comment

1) Based on watching the video (making predictions), take a screenshot of a particular instance in the lesson that captures the essence of inquiry for you. Post it here (don't attach) - rather embed the image for everyone to see on the discussion board (do this individually):

- Provide a short title for the screenshot (**6 words or less**)
- In **50-100 words**, explain how the instance in the lesson that you captured fits in the inquiry conversations (did you find the lesson to be structured, guided, coupled, or open inquiry). Where do you fitting this prediction activity in the 5-E learning cycle template?

2) Please share your initial ideas about your 5-E unit plan. We will be using this template t o write our unit plans. Become VERY familiar with this template. Read the prompts and guidelines I have provide in the explore and engage section of the template. Now, post a response to the following prompts using bullet points (please don't write it out as a paragraph) - **do this individually:**

- Topic for your unit plan (At least 1-2 sentences)
- Initial Engage Ideas for your unit plan (let's start with one lesson) - At least one paragraph
- Initial Explore Ideas for your unit plan (let's start with one lesson) - At least one paragraph
- Classroom management challenges you anticipate in implementing this unit plan - identify 2-3 challenges
- Inquiry Continuum categorization - As of now, where do you see you engage and explore activities on inquiry continuum (structured, guided, coupled, or open inquiry)? At least one paragraph

I've included a my picture and caption to get things started.

Screenshot 2: Response dimensions of the spaces of learning (SOL)

CONCLUDING REMARKS

Rather than engendering pSTEMs' progression through a lock-step sequence of instructional experiences, such that particular competencies must be demonstrated prior to moving forward, we leverage Spaces of Learning (SOL) to enculturate pSTEMs into STEM teaching practices. In particular, SOL provide safe spaces in which pSTEMs can engage in teacher noticing and develop high leverage STEM teaching practices through rich, multidimensional experiences.

Multidimensional SOL provide an example of a way in which online course designers can use the Presence+Experience (P+E) framework to design learning experiences for courses that may be seen as challenging or even undesirable to deliver through eLearning. Although we designed SOL for our online STEM methods courses, we believe that SOL could be useful for other types of online methods courses.

Not only is it possible for STEM methods courses be delivered through eLearning, we argue there are a greater range of possibilities available by leveraging the affordances of eLearning. SOL allows us to tap into those affordances. Important, we are not "converting" face-to-face STEM methods courses to fully online methods courses. Rather, we are expanding possibilities for our pSTEMs by reconceptualizing what it means to engage in STEM teacher preparation.

References

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education, 60*(5), 497-511.

Dunlap, J., Verma, G., & Johnson, H. (in press). *Presence + Experience: A framework for the purposeful design of presence in online course.* Tech Trends.

Garrison, D. R., Anderson, T., & Archer, W. (2000) Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education, 2*(2-3), 87-105.

Garrison, D. R., & Arbaugh, J. B. (2007). Researching the community of inquiry framework: Review, issues, and future directions. *The Internet and Higher Education, 10*(3), 157-172.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs: Prentice-Hall.

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2000). Experiential learning theory: Previous research and new directions. In R. J. Sternberg and L. F. Zhang (Eds.), *Perspectives on cognitive, learning, and thinking styles* (pp. 227-247). New York: Lawrence Erlbaum.

Sherin, M. G., & Han, S. Y. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education, 20*, 163-183.

van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education, 10*(4), 571-596.

DESIGNING A TECHNOLOGY ENHANCED LEARNING ENVIRONMENT FOR HYPOTHETICO-DEDUCTIVE REASONING IN GENETICS

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Hypothetico-deductive reasoning is an important skill for pursuing science. Students face difficulties in developing hypothetico-deductive reasoning. In this paper, we propose the design of a technology-enhanced learning environment, Geneticus Investigatio, which aims to develop hypothetico-deductive reasoning in the domain of genetics education for undergraduates. In this system, the student has to choose different hypotheses for a given problem, design experiments based on the hypothesis, predict the outcome of experiment, run simulations to test the prediction of the experiment, compare predicted and observed outcomes and accept or reject the hypothesis. The system requires that student reason at each and every step. Students are provided with scaffolds in designing of experiment and prediction based on designed experiment. This system utilizes the affordances of technology enhanced learning environment like variable manipulation in simulation, immediate and customized feedback and self-paced learning.

INTRODUCTION

Any concept in science requires scientific reasoning for its understanding. "Scientific reasoning can be conceptualized as using a set of mental rules, plans, or strategies to devise causal inferences for a phenomenon that is beyond direct observation."(Lawson 2004).According to this definition five subset of skills are crucial components which are hypothetico-deductive reasoning, control of variables, proportional reasoning, co-relation reasoning and probabilistic reasoning (Koslowski, 1996; Zimmerman, 2000; Lawson, 2004). This is indeed a problem because mostly causal inference behind any observation is difficult to comprehend. This comprehension is necessary for understanding of various scientific processes. For example, in a real situation, it is difficult to infer the blood group of the parents given the blood group of the child. That is, it is possible for parents with blood group A and B to have a child with blood group O. In order to find out the blood group and genotype (genetic composition) of parents (both father and mother) students have to form hypothesis and design experiment to check hypothesis. They have to form hypothesis in such a way to check what are the different genotypes of parents can lead to child blood group as O. Once they form hypothesis they have to design experiments based on antigen-antibody reactions and confirm the genotypes.

The development of scientific reasoning skill has been the focus of a lot of research in science education research and it goes under different terms like inquiry learning, inquiry-based learning, scientific reasoning, mechanistic reasoning, science skill etc. Different teaching strategies like individual or collaborative learning are used in both face to face and online learning environment to develop scientific reasoning skill among students. Recent science education research has focused on the affordances provided by Technology Enhanced Learning (TEL) environments which help in facilitating collaborative learning, variable manipulation during experimentation, and immediate feedback to student responses.

In all such research, a key reasoning pattern that frequently occurs is hypothetico-deductive reasoning (Lawson, 2000) which includes formation of hypothesis to explain a phenomenon, checking of individual hypothesis by experimentation, designing of experiment, predicting the outcome based on experiment, collecting the observed outcome and matching predicted and observed outcome. Hypothetico-deductive reasoning is important in the understanding of many topics and domains in science. In the context of genetics, different causal explanations are possible for any observation which may be at different level of biological hierarchy. In order to identify the correct hypothesis this reasoning is required. This TEL environment is focussed on checking of individual hypothesis by designing experiment based on hypothesis chosen rather than generation of hypotheses. These hypotheses are generated on observed pattern given in the experimental observations. Students are able to accept or reject hypothesis based on whether predicted and observed result matches or not. In order to do that, they have to reason explicitly behind accepting or rejecting individual hypothesis.

The goal of this paper is to propose the design of a TEL environment, Geneticus Investigatio for hypothetico-deductive reasoning in the context of genetics education for undergraduates. While researchers have worked on the teaching-learning of hypothetico-deductive reasoning in biology (WISE, GO-LABS), most of these efforts are at the school level. Fewer efforts have been made at college level biology to address this reasoning skill especially in the context of genetics education. Secondly, this paper takes the approach of using the affordances of TEL environments to focus on students' ability to design experiments to test hypotheses. We have not encountered a TEL system that explicitly focuses on hypothetico-deductive reasoning for college level genetics so far.

What is Hypothetico-Deductive Reasoning (HDR)?

Hypothetico-deductive reasoning is a series of reasoning steps followed in order to explain any phenomena (Lawson, 2000). These steps are formation of hypothesis, checking of individual hypothesis by experimentation, designing of experiment, predicting the outcome based on experiment, collecting the observed outcome and matching predicted and observed outcome. Lawson (2000) proposed a sequence of steps (Figure 1) to implement the hypothetico-deductive reasoning process.

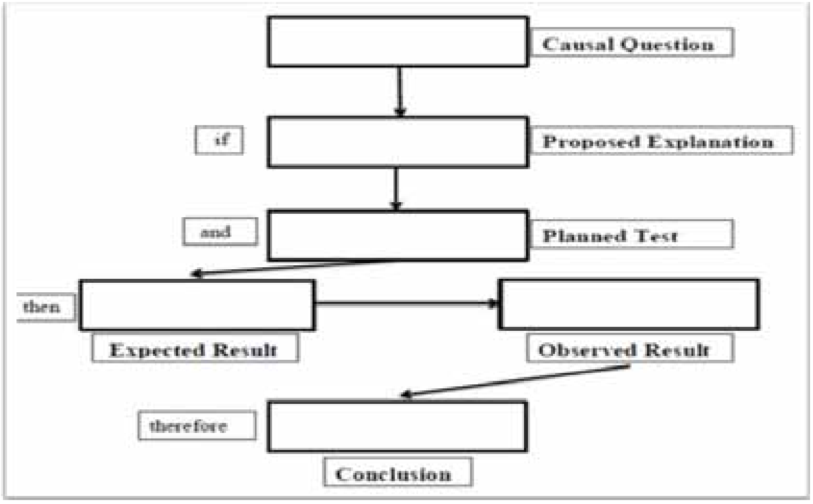


Figure 1: Sequence of steps as proposed by Lawson

Different steps of Lawson's flowchart actively engage students in the reasoning process. The first step of formation of hypothesis requires student to consider the context, For example, the scientific phenomenon to be explained. Students are first supposed to understand and describe context in their own words. In order to explain this context he/she forms different hypotheses. The generated hypotheses should be testable through experimentation i.e. students have to design an experiment to test considered hypothesis in the next step. Designing an experiment requires student to consider all dependent and independent variable (control of variables).This step requires synthesis of previous knowledge. Actual conduction of experiment requires sub-skills like proportional reasoning, co-relational reasoning and probabilistic reasoning. In this step student should be able to identify which independent variable to vary and what dependent characteristics to observe. Once the experiment is designed and results are collected, it has to be compared with the predicted outcome. If it is not supported then subsequent hypothesis is to be tested. This reasoning skill is related to Predict, Observe and Explain (POE) cycle (White & Gunstone 1992) but differs in the order in which some steps are carried out.

As an example consider the case of blood type alternate hypotheses for genotype of father and mother respectively are: (1) I^A I^A and I^B I^B, (2) I^A I^A and I^B i (3) I^A i and I^B I^B and (4) I^A i and I^B i

HDR is made explicit in the form of "If . . . and . . . then . . . And/But . . . Therefore . . . arguments."(Fig 1) An example to explain the hypothesis using these reasoning steps

If . . . I^A i and I^B i (chosen hypothesis)

and . . . the experiment is conducted as planned (planned test)

then . . . then one of the child can have O blood group (ii) (prediction)

and . . . one child have O blood group (ii) (result)

therefore . . . I^A i and I^B i hypothesis is supported (conclusion).

Hypothetico-deductive reasoning in genetics

Genetics is a branch of biology which connects different levels of biological hierarchy from molecular to sub-cellular to organismic level. In order to understand this connection scientific reasoning is important. Since different topics in genetics as given in "An introduction to genetic analysis" by Griffiths (2005) like pattern of inheritance, gene mapping have many competitive underlying reasons. In order to pin-point to the correct reason hypothetico-deductive reasoning process is required. An example from pattern of inheritance is in order to identify traits related to Mendel's pea plant which focuses on di-hybrid cross one has to perform cross breeding experiment with parent or offspring. It is done by matching experimental observations already known with actual observations through experimentation which is to be performed. Also in order to identify the correct locus and distance between genes in the genome in the process of gene mapping, this reasoning is required.

Hypothetico-deductive reasoning is fundamental to genetics and it is required in different context and for different target audience. For a researcher who is designing new experiment this reasoning skill is important otherwise he/she won't be able to do research independently, he/she will just do procedural activities. For a teacher who is teaching genetics to students it is important for them because he/she aims to develop this reasoning skill among student. Learning this skill in the context of genetics is also important because students of different biology domains like microbiology, botany, zoology, environmental biology etc. have to learn genetics as a part of compulsory course in curriculum.

Since hypothetico-deductive reasoning is important for developing scientific reasoning and for different target audience, our TEL system, Geneticus Investigatio will help them to improve this reasoning skill in its various steps through-out the system. Since Geneticus Investigatio makes each and every step of this reasoning skill explicit, allows for reflection and practice, provides opportunity for experimentation it will help these target audience as a supplement of traditional learning.

Literature Review

Science aims at understanding natural phenomena in as much detail and depth as possible. In order to do this scientific reasoning is important. This reasoning skill is made explicit in the form of hypothetico deductive reasoning, probabilistic reasoning, co-relational reasoning, and proportional reasoning (Koslowski, 1996; Zimmerman, 2000; Lawson, 2004). Students have difficulty in this reasoning and the difficulties are in the formation of hypothesis, designing of experiment, predicting the outcome of experiment (de Jong & van Joolingen, 1998). In order to address these difficulties, the teaching-learning of any concepts focus on inquiry-based learning. Inquiry-based learning is a student centred active learning approach focussed on critical thinking, questioning, and problem solving. Inquiry based environment can be guided or non-guided. In guided learning students are provided with immediate feedback which is considered more productive than non-guided learning (Alfieri et al., 2011). Mostly such feedback is in the form of scaffolds of different types: structural, reflective and subject matter (Fund, 2007). Scaffolds are also required in designing and actual conduction of the experiment. During designing of experiment student should be able to do variable manipulation through simulation (Blake & Scanlon, 2007) and observe result.

In the past two decades, technology enhanced learning environments have been used to provide the necessary instructional support, such as, guided prompts, self-paced learning, variable manipulation during experimentation and so on. Examples of such TEL environments to develop scientific reasoning include Go-Labs (Learning by Experience), Geniverse (Concord Consortium, 2010), Model-It (Jackson et al., 1996), AppleTree (Chen, et al., 2013) and WISE (Slotta, 2002). These environments are to be used either online or can be downloaded. Most of them focus upon junior and high school education. For example Go-Labs which is an online learning environment focusing upon guided experimentation. It has repository of 158 remote and virtual labs, 152 inquiry spaces and 34 apps for different subjects like physics, astronomy, chemistry, biology, geography, and math. Apple Tree focuses upon dual representational and interactional spaces, automated assessment for learning and staged-based collaboration scripts (Chen et al., 2013). In case of biology most of these learning environment focuses on concepts of ecology and evolution.

Design of Geneticus Investigatio

Learning objective

Hypothetico-deductive reasoning is defined as ability of formation of hypotheses, testing of hypothesis through experimentation, comparing predicted and observed result and revising hypothesis. By using Geneticus Investigatio students should be able to show Hypothetico-deductive reasoning. This reasoning is made explicit in different steps of Geneticus Investigatio. After interacting with Geneticus Investigatio , students should be able to:

- identify hypothesis which is to be tested through experimentation.

- design an experiment to test the hypothesis.
- write predicted outcome based on the designed experiment.
- run the experiment and collect result in terms of observed or measurable outcome.
- compare predicted and observed outcome and decide whether it matches or not.

Theoretical basis

Geneticus Investigatio is based on sequence of different steps followed during hypothetico-deductive reasoning as proposed by Lawson (2000). So, the system should allow students to make this reasoning explicit in the form of typed statements. It should also allow students to go back and forth between steps. Also, design of experiments requires different independent variables to be manipulated and dependent variable to be observed. These requirements suggests for TEL environment which can make these reasoning steps explicit. TEL environment makes students actively engaged in the learning activity. Designing of experiment is made explicit in simulation where student choose which independent value(s) to vary and what dependent characteristics to observe (Lee et al., 2002). It also provides students with immediate feedback based on their responses (Nicol & Macfarlane-Dick, 2006).This system allows student for self-paced learning.

Overall learning path

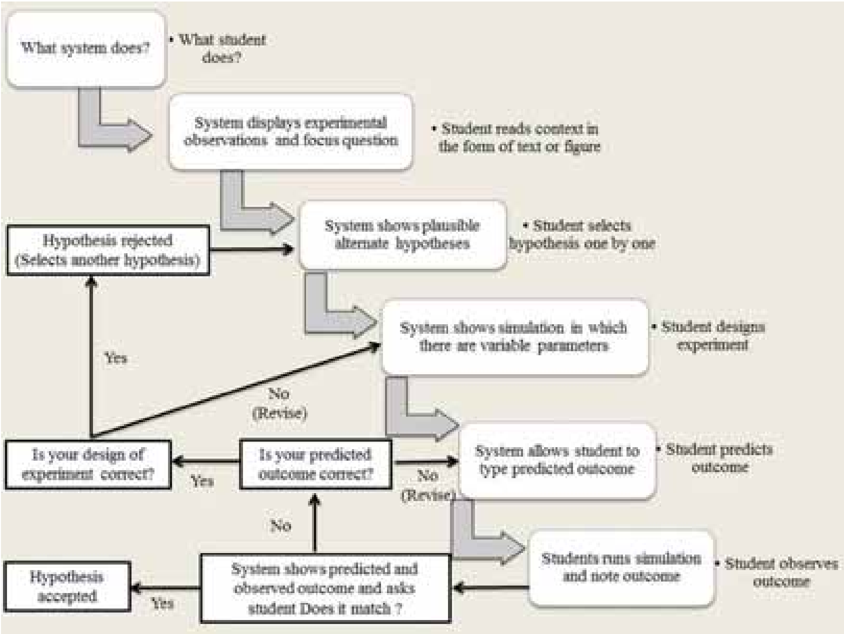


Figure 2: Overall learning path of Geneticus Investigatio

Design Elements

1. *Get familiar with the experimental observations:* Students are provided with experimental observations of phenomenon in the first interface. Students read the context and experimental observation. Separate experimental observations are included in different boxes (Fig 3).

2. *Choose hypothesis to be tested:* Students are shown different hypothesis which are to be tested. They have to select one hypothesis at a time which is to be tested in next stage of design of experiment (Fig 4).
3. *Design of experiment:* Student have to propose the design of their experiment in the given text box. At this point they will be able to see the simulation interface where they can perform the experiment. They can see which variables can be manipulated and based on that they have to design their experiment (Fig 5). At this point they won't be able to run experiment. If they want hint they can click the tab and ask for hint which will help them to identify the dependent and independent variable. In the next tab students are asked to write the predicted outcome based on the designed experiment (Fig 6).They have to type their response within the box. Once they click submit button then run button appears on the same interface where they can perform the experiment based on the designed experiment (Fig 7).
4. *Comparison of predicted and observed result:* They see the hypothesis which was chosen, design of the experiment, predicted outcome and type the observed result. While writing observed result student will be able to draw diagram and do calculations. Then they are asked whether predicted and observed outcome matches or not (Fig 8). If they say yes then hypothesis considered is accepted.
5. *Feedback and scaffolds:* Feedback and scaffolds are provided at different steps in the system. Once during the design of the system where they have to choose dependent and independent variable another after comparison of predicted and observed result. The system asks students is predicted outcome correct and if incorrect revise the predicted outcome? If predicted outcome is correct system asks student to reconsider the design of the experiment. If the design of the experiment is incorrect then student have to revise design of experiment. If it is correct then hypothesis is rejected and another hypothesis is considered for testing.

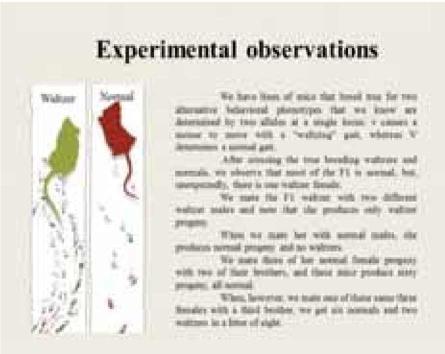


Figure 3: Know the experimental observation

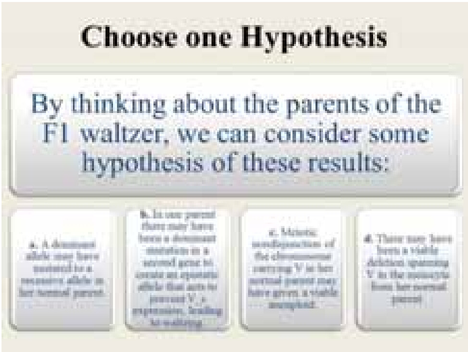


Figure 4: Choose hypothesis for testing

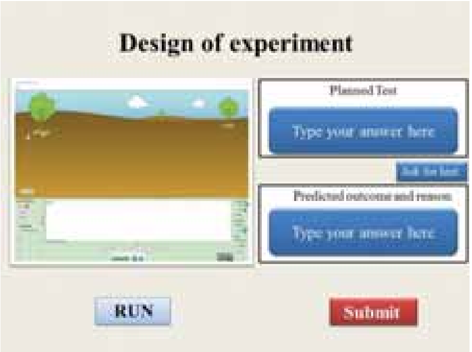


Figure 5: Write planned test

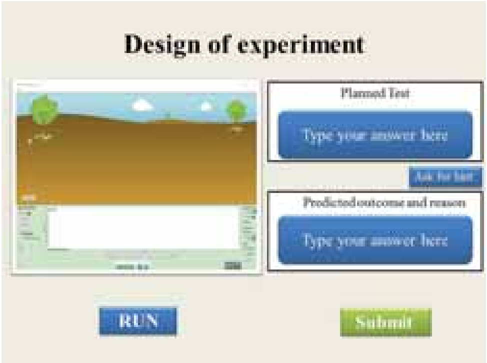
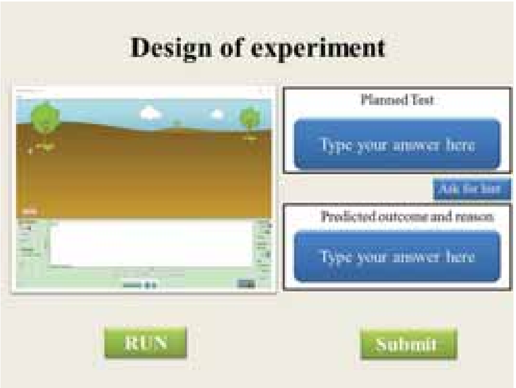


Figure 6: Write predicted outcome



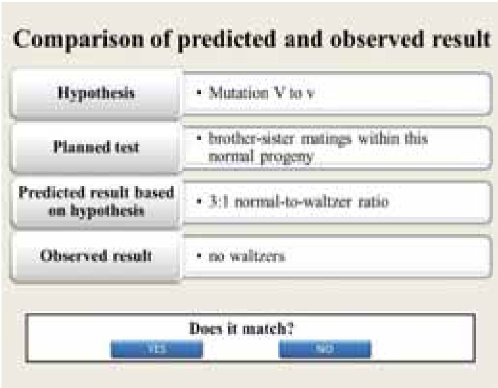


Figure 7: Design of experiment Figure 8: Comparison of predicted & observed result

Proposed Method

Design Based Research (DBR) focus on creation and analysis new solution of identified problem. As proposed by Reeves in 2006 (Fig 9) it includes four different steps and iterations between these steps.

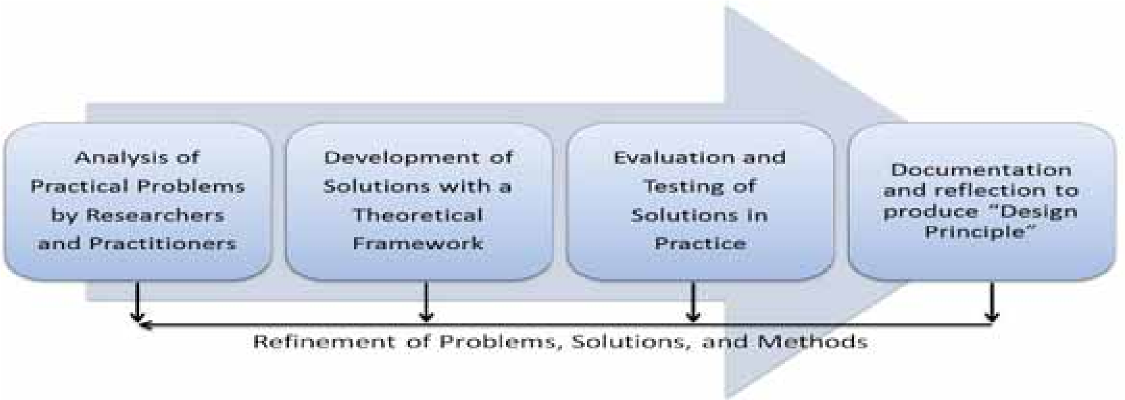


Figure 9: Steps of design based research approach (Reeves, 2006)

In the first step of identification of practical problem by researchers and practitioners problem in hypothetico-deductive reasoning was identified which was also supported through literature. It includes problems faced by students in different steps of hypothetico-deductive reasoning. In order to solve this problem Geneticus Investigatio is designed in which different steps were proposed which has theoretical basis like explicit writing of predicted and observed outcome, immediate feedback, self-paced learning and revision based on reflection.

In the next step of evaluation and testing of solution Geneticus Investigatio will be implemented with first year undergraduate biology student. Implementation will include measurement of learning outcome (pre-post difference) study with Geneticus Investigatio as intervention. Questions in tests will focus on assessment of scientific reasoning. Students will be asked to participate in system usability survey and interview will be taken about feedback on interaction with Geneticus Investigatio. Based on feedback user interface changes will be incorporated in the next cycle of DBR. Also it would be interesting to do a co-relational study with number of iteration of reasoning activities and its effect on students' development of HDR skill.

SUMMARY

Geneticus Investigatio is a technology enhanced learning environment that aims to develop HDR skill in undergraduate students. This paper describes the importance of this skill and problem faced by students in the context of genetics education. Different steps of this environment is based on affordances provided by TEL environment like variable manipulation in simulation, self-paced learning, immediate feedback, reflection and revision and an opportunity for experimentation. Future work aims at next step of DBR cycle in which Geneticus Investigatio is to be implemented with undergraduate students and study on learning and perception of student is to be done.

References

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Educational Psychology Review*, *103*(1), 1–18.

Blake, C., & Scanlon, E. (2007). Reconsidering simulations in science education at a distance: features of effective use. *Journal of Computer Assisted Learning*, *23*(6), 491-502.

Chen, W., Looi, C., Xie, W., & Wen, Y. (2013). Empowering argumentation in the science classroom with a complex CSCL environment. In S. C., Tan et al. (Eds.), *Proceedings of the 21st International Conference on Computers in Education.* Indonesia: Asia-Pacific Society for Computers in Education.

Concord Consortium. (2010). Geniverse (Accessed: 13 Oct. 2015). *Geniverse* [Online]. Available: https://concord.org/projects/geniverse

De Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, *68*(2), 179-201.

Fund, Z. (2007). The effects of scaffolded computerized science problem-solving on achievement outcomes: a comparative study of support programs. *Journal of Computer Assisted Learning, 23*(5), 410–424.

Griffiths, A. J. (2005). *An introduction to genetic analysis*. Macmillan.

Jackson, S. L., Stratford, S. J., Krajcik, J. S., & Soloway, E. (1996). *Model-It: A case study of learner-centered software design for supporting model building.* Arlington, VA: National Science Foundation.

Koslowski, B. (1996). *Theory and evidence: The development of scientific reasoning.* MA: Mit Press.

Lawson, A. E. (2000). The generality of hypothetico-deductive reasoning: Making scientific thinking explicit. *The American Biology Teacher*, *62*(7), 482-495.

Lawson, A. E. (2004). The nature and development of scientific reasoning: A synthetic view. *International Journal of Science and Mathematics Education*, *2*(3), 307-338.

Lee, A. T., Hairston, R. V., Thames, R., Lawrence, T., & Herron, S. S. (2002). Using a computer simulation to teach science process skills to college biology and elementary education majors. *Computer Simulations Bioscene*, *28*(4), 35-42.

Learning by Experience G0-LAB (Accessed: 13 Oct. 2015). GO-LAB [Online] Available: http://www.go-lab-project.eu/

Nicol, D. J., & Macfarlane Dick, D. (2006). Formative assessment and self regulated learning: a model and seven principles of good feedback practice. *Studies in Higher Education, 31*(2), 199-218.

Reeves, T. C. (2006). Design research from a technology perspective. *Educational Design Research*, *1*(3), 52-66.

Slotta, J. (2002). Designing the "Web-based inquiry science environment (WISE)." *Educational Technology*, *42*(5), 15-20.

White, R., & Gunstone, R. (1992). *Probing understanding.* London and New York: The Falmer Press.

Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review*, *20*(1), 99-149.

SYNERGISM THROUGH GOOGLE CLASSROOM, A BLENDED LEARNING PLATFORM: EFFECTIVENESS, OPERABILITY AND CHALLENGES

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This study entails upon to find out effectiveness of Apps in education. Google classroom was employed for this study. By appropriately interweaving it with face to face teaching-learning, the researcher attempts to judge its effectiveness in terms of achievement, the researcher attempts to document the experiences of the users of Google classroom so as to suggest ways by which it could be made more user friendly. B Ed as well as M Ed students were considered for the study. Moreover feedback from course teachers was taken. Results indicated an existence of synergism while blending Google classroom with conventional class. A positive vibe existed as far as achievement is concerned while comparing it with traditional teaching-learning. Moving ahead it also enlists the problems and challenges faced by the students while using Google Classroom.

Keywords: synergism, effectiveness, operability, google classroom, blended learning

INTRODUCTION

The Indian government is planning huge expansion at all levels of education. While there is no doubt that this will be the decade of change at a transformational scale and pace, India's rise faces daunting challenges. The education system as a whole is beset with issues of quality, access and equity, and change is happening much faster in some states than others. There are not enough places in schools, colleges or universities to cope with the enormous and increasing demand. Traditional approaches to meet this demand will not be sufficient in the time-scale needed (AISHE 2011-12, Provisional).

The three interrelated areas (Equity, Excellence and Expansion) are not new: all have been addressed in various forms in previous five-year plans dating back to 1980. The main difference in the 12th plan is its holistic nature, with a clear focus on quality, or 'excellence', as an overarching guiding principle for expansion and equity. To counter this significant investment in ICT in terms of infrastructure and content development is being carried out. This is where Google cloud and Google apps could play a role on intensifying upon the utilization of ICT aspect in teaching learning (British Council India, 2014). Google classroom could be the prospective towards intensification on this ICT aspect of teaching learning.

Google classroom is available to anyone with Google Apps for Education, a free suite of productivity tools including Gmail, Docs, and Drive. Google Classroom is a blended learning platform for schools that aims to simplify creating, distributing and grading assignments in a paperless way. It was introduced as a feature of Google Apps for Education following its public release on August 12, 2014. It is beyond merely a data storage device and creates online environment for teaching learning. Its aim is to be a paperless educational system. With respect to learning purpose Classroom is designed to help teachers create and collect assignments paperlessly, including time-saving features like the ability to automatically make a copy of a Google document for each student. It also creates Drive folders for each assignment and for each student to help keep everyone organized. Students can keep track of what's due on the Assignments page and begin working with just a click. Teachers can quickly see who has or hasn't completed the work, and provide direct, real-time feedback and grades right in Classroom (About Classroom, 2014).

REVIEW OF LITERATURE

Studies have produced evidence of differences in online and traditional testing results, typically favoring courses offering a traditional setting to some degree. Waschull (2001) found a trend toward a higher final exam score in traditional versus online students. Ashby, Sadera and McNary (2011) found the highest exam scores in the traditional class, followed by online, then hybrid. Terry (2007) reported that both traditional and hybrid exams were higher than online and Fillion, Limayem, Laferriere and Mantha (2009) likewise reported that hybrid students outperformed online ones. In contrast, Lim, Kim, Chen and Ryder (2008) reported higher exam scores in both online and hybrid courses, compared to traditional. Taking the findings on exam scores as a whole, the picture becomes very muddied, with research demonstrating every possible combination of findings (McDonough, Roberts & Hummel, 2014).

Research on online course outcomes, which has focused primarily on exam scores and final grades, has produced conflicting results. It suggests that outcomes and satisfaction are equivalent in online, hybrid, and traditional courses, and that a student's own diligence and drive might better predict success in online learning. Comparing online to traditional (in class, face-to-face) courses, equivalent exam performance has been reported by many researchers (e.g., Elvers, Polzella & Graetz, 2003; Hemmati & Omrani, 2013; Hollister & Berenson, 2009; Jensen, 2011; McGready & Brookmeyer, 2013; Stowell & Bennett, 2010; Summers, Eaigandt & Whittaker, 2005; McDonough et al., 2014).

Edmonds (2006) found that traditional students received higher exam scores than online students, after controlling for SATs and High School GPA, but the other demographic variables have been largely unstudied. Within individual studies some researchers have reported no significant differences in their online vs. traditional samples (e.g., Waschull, 2001), but this may be attributed to a small sample size. More research on the interplay of demographics is needed. Second, and of great concern to educators and colleges, is the possibility of cheating online. Hollister and Berenson (2009) conducted a thorough analysis to ascertain whether online students' test scores could be attributed to cheating, but found no evidence of cheating online. Further, the studies reviewed in Dr. Colleen's paper (McDonough et al., 2014) do not show that online students overwhelmingly outperform traditional students on exams; on the contrary, most of the research finds that exam scores are either equivalent, or traditional students do better. These results imply that educators need not be too concerned about cheating online, but it is still an issue of concern, particularly among online- learning critics. Third, the format of an online course typically requires the student to be disciplined and self-motivated. Failure to access the online course regularly, coupled with procrastination, can easily result in poor outcomes. Elvers, Pozella and Graetz (2003) found that in an online course (but not a traditional one), procrastination led to lower exam scores.

Another important outcome to consider is the students' level of satisfaction with the course. Some aspects of online learning may be perceived as extremely advantageous to students. For example, students who are afraid to raise their hands in front of a room full of their peers may be much more comfortable voicing their opinions on a web-based discussion board. In contrast, online lectures often fail to maintain student attention the same way that classroom-based lectures do, and some students are partial to the personal interaction afforded by traditional classes. The importance of student satisfaction is not to be underestimated. In a climate of extreme market competition, colleges and universities need to be on top of student attrition, and faculty members are similarly concerned with their course evaluations for the purposes of promotion and tenure (McDonough et al., 2014).

As with the academic course outcomes, satisfaction outcomes have produced very conflicting results. While some studies have reported increased satisfaction in hybrid and online courses (Hemmati & Omrani, 2013; Lim et al., 2008), others have demonstrated the opposite pattern (Summers, Waigandt & Whittaker, 2005; Terry, 2007). Gecer and Dag (2012), and Kirtman (2009), along with Yudko, Hirokawa and Chi (2008) found that online and hybrid courses received positive ratings overall, and Beqiri, Chase and Bishka (2010) found that online courses were most preferred by males, graduate students, married students, and commuters. However, Waschull (2001) found no difference in satisfaction between traditional and online courses. The satisfaction findings, unclear as they are, may also be attributed to extraneous factors. For example, Arbaugh (2010) reported that instructor teaching presence and response time significantly improved student satisfaction in an online course (McDonough et al., 2014).

Targeted research on underprepared students is generally lacking. Jaggers (2011) reported that underprepared students typically do poorly in online coursework for four reasons: 1) the technical difficulties associated with navigating the online content, 2) social distance from classmates and instructor, 3) lack of student supports online, and 4) the lack of structure in online platforms. However, Kim and Lee (2011) suggest that the self-paced nature of the online environment may be beneficial to these same students (McDonough et al., 2014).

Reviews suggest studies on pros and cons for online media, however there is no work on Google classroom regarding its acceptability, effectiveness and problems encountered. Hence the researcher decided to explore possibility of using Google classroom in teaching –learning. Also the researcher decided to gauge the level of achievement through a combination of Google classroom and conventional teaching learning so as to establish a synergistic co-existence. Synergism is interaction of discrete agencies or conditions such that the total effect is greater than the sum of the individual effects (Webster Dictionary). For this study, synergism is operationalized as output w.r.t achievement for those using a combination of conventional class room and Google class room upon those taught through conventional classroom alone or through Google classroom alone.

OBJECTIVES OF THE STUDY

- To develop resources for Google classroom for content from B Ed. Course of Mumbai University.
- To study the effectiveness of learning in terms of achievement through Google classroom by comparing it with traditional face to face learning and understand the impact of the technological solution.
- To study the effectiveness of learning in terms of achievement through Google classroom blending with conventional classroom by comparing it with traditional face to face learning and understand the impact of the technological solution.

- To understand the usefulness of Google classroom in teaching-learning from operational point of view and to enlist out the challenges encountered while experiencing using Google classroom.
- To suggest ways and means to improve upon so as to make Google classroom user friendly.

HYPOTHESES

- There is no significant effect of the treatment on achievement scores when the difference in the pre-test scores of the two groups (i.e. control group and those using Google classroom only) has been controlled (Ho1).
- There is no significant effect of the treatment on achievement scores when the difference in the pre-test scores of the two groups (i.e. control group and those using Google classroom blended with conventional teaching) has been controlled (Ho2).

RESEARCH QUESTIONS

- Is there an existence of synergism in achievement of students while learning through Google classroom blended with conventional classroom as compared to traditional face to face learning and learning through Google classroom individually?
- What were the perceptible challenges faced while using Google classroom from operational point of view?
- What are probable ways and means to improve upon so as to make this app more users friendly?

METHODOLOGY AND DESIGN OF THE STUDY

- For the present study the researcher has selected the Experimental Method by keeping in mind the objectives of the study and the problem. The researcher has used Quasi experimental research design involving Pretest-Posttest Equivalent Groups Design. The pre-tests was administered before the application of the experimental and control treatments and post-tests at the end of the treatment period. Gain scores were compared and subjected to test of significance of the difference between means. Pre-test scores were used in analysis of covariance to statistically control for any differences between the groups at the beginning of the study.
- Survey technique was also employed to understand the problems encountered while operating Google classroom. A questionnaire comprising of few open ended questions was prepared for this purpose.
- The video recordings of students and teacher educators tapping the views about Google classroom were transcribed verbatim. All the answers and the transcribed recordings were read several times to take out the key ideas and phrases from each answer, percentages were calculated based on the number of times the key ideas and phrases appearing in the answers.

SAMPLE OF THE STUDY

Sample for the present study included B Ed and M Ed students and teacher educators of Mumbai University. For the experimental study, 150 students of B Ed level from Mumbai University of which 50 students formed the control group and 100 students were taken as experimental group students. The 100 students of experimental group were divided into two groups of 50 students each. One group was taught through Google classroom only while the other group was through Google classroom blended with conventional classroom teaching. The survey involved 110 respondents comprising of students of B Ed and M Ed level as well as teacher educators.

INTERVENTION GIVEN

The Course content involved pre-reading materials, videos, power point presentations, assignments catering to all domains mainly knowledge and application, analyzing cases, making projects like creation of self learning material and programmed learning material, problem solving. In Google classroom, submissions were done individually as well as collaboratively by the students.

Testing of Hypotheses

Incidental sampling technique was used to select the samples for both experimental and control group. Achievement test was implemented for pre and post testing the students of both the experimental and control group. Thus the technique used to test the above mentioned hypothesis is ANCOVA.

For Students Using Google Classroom Only

In this the experimental group students were taught through Google classroom only whereas the control group students were taught through the conventional method of teaching learning. Means of Pre-test and Post-test scores of Experimental group are 6.4 and 11.8 respectively and for control group are 6.3 and 11.3 respectively.

Source of	df	SSX	SSY	MSX(VX)	MSY(VY)
Among Means	1	2.743902	1127.024	2.743902	
Within Groups	50	4148.537	4780.732	51.85671	59.75915
Total	51	4151.28	5907.756		

Table 1: Summary of ANCOVA of pre-test and post-test scores

The results of ANCOVA of Pre-test and Post-test Scores indicates F_X=0.052. From table F df 1/50, F at 0.05 level =4.00, F at 0.01 level= 7.08. Neither F is significant which shows that the experimenter was quite successful in getting equivalent groups. In the next step M_{yx} was calculated.

Source of	df	SSX	SSY	S_{xy}	$SS_{Y.X}$	$MS_{Y.X}(V_{Y.X})$	$M_{Y.X}$
Among Means	1	2.743	1127.024	-55.6098	1204.08	1204.08	
Within Groups	49	4148.53	4780.732	2855.439	2815.332	35.63712	2.1443
Total	50	4151.28	5907.756	2799.829	4019.412		

Table 2: Calculation of Myx

Now, testing the difference for df = 49, $t_{0.05}$=1.99; $t_{0.01}$= 2.44 which shows F is not significant. Thus, Ho1 is accepted. Thus there is no significant elevation in the achievement for experimental group students using online material through Google classroom.

For Students Using Combination of Conventional Classroom and Google Classroom

In this the experimental group students were taught using combination of conventional classroom and Google classroom whereas the control group students were taught through the conventional method of teaching learning. Means of Pre-test and Post-test scores of Experimental group are 6.5 and 14.1 respectively and for control group are 6.3 and 11.3 respectively.

Source of Variance	df	SSX	SSY	MSX(VX)	MSY(VY)
Among Means	1	3.75	1540.2	3.75	
Within Groups	50	755.23	5675.3	13.032	182.88
Total	51	758.98	7215.5		

Table 3: Summary of ANCOVA of pre-test and post-test scores

The results of ANCOVA of Pre-test and Post-test Scores indicates F_X=0.28. From table F df 1/50, F at 0.05 level =4.00, F at 0.01 level= 7.08. Neither F is significant which shows that the experimenter was quite successful in getting equivalent groups. In the next step M_{yx} was calculated.

Source of	df	SSX	SSY	Sxy	SSY.X	MSY.X(VY.X)	MY.X
Among Means	1	3.75	1540.2	76	799.46	799.46	
Within Groups	49	755.23	5480.73	4655.439	3452.332	605.95	5.55
Total	50	758.98	7020.93	4731.439	4251.792		

Table 4: Calculation of Myx

Now, testing the difference for df = 49, $t_{0.05}$=1.99; $t_{0.01}$= 2.44 M_{yx} (difference) = 5.55 is much greater than 2.04 at 0.01 level, hence experimental group differs significantly from control group at .01 level. Hence null hypothesis (Ho2) is rejected. Thus it shows elevation in the achievement for experimental group students.

FINDINGS OF THE STUDY AND DISCUSSION

The study attempted to resolve some lingering questions in the ever elevating debate surrounding the efficacy of Google apps, focusing on college level utilization. The students using Google classroom only, did not show any remarkable elevation in achievement. While only interacting through Google classroom there could be a lack of personal touch or belongingness. Using Google classroom only may be mechanical or machine like with the human element missing to certain extent. As far as students'perspective, outcomes are important and hence Google classroom could serve as a boom for the education community when combined with conventional mode of face to face learning. The real question for consumers and educators is whether the quality of online learning is comparable to that offered in a traditional face-to-face classroom setting. However In this study it is found that Google classroom when combined with face to face learning had an impact which was much more than that when applied separately thus bringing about synergistic effect. This synergism plays an important role in bringing about steep change in attitude towards learning through Google classroom. Another aspect that adds on to this synergism is extent of usefulness of Google classroom in teaching-learning from operational point of view.

The findings revealed from the questionnaire and interviews were –

65% of the respondents feel that it is an easy way to submit assignments, because assignments are just to be uploaded and posted and if it is already uploaded on Google Drive, then there is no need to even upload it, one just need to select the material or assignment and post.

64% of the respondents found that it is a useful platform for sharing ideas with classmates by writing on wall. Google Classroom has an excellent feature by which one can write on the wall which can be viewed by the other members also.

79% of the respondent feels that it can be used as Flipped Classroom. As flipped classroom groundwork of any concept that is instructional content can be delivered through Google Classroom, and activities, including those that may have traditionally been considered homework, can be conducted into the classroom.

67% of the respondents feel that it is an excellent alternative mode of communication for shy students, those who are reluctant to express themselves. Though Google Classroom features mention that it is time saving but as per the survey it is found that Google Classroom is time consuming which is felt by 55% of the respondents. The probable reasons are as follows: Problem experienced while uploading materials, more time is consumed in uploading and posting assignments, submission took lot of time when internet connection is slow. Google Classroom cannot entirely be attributed for this as there can be several external factors also for more time consumption like slow internet connectivity, internet interruptions, firewalls makes the connectivity slow. Speed of internet goes down when many users are connected to one single server at a time, i.e. the utilization is more than the rated capacity, and then there can be jam in the line which happens especially in colleges where there are multiple users.

60% felt that it is difficult to evaluate the submitted assignments. On the Google Classroom 'students' page the list of students goes on indefinitely. To evaluate any assignment one has to select the file, download to, check it and then again upload it and then send it for each student making it time consuming. Moreover we are following credit based grading system, but in Google Classroom there is no provision of giving grade, only numerical can be given which is not allowed in credit based grading system. Next there is no facility to give marks to different sub questions which add up automatically to give the total. In normal correction teacher can scribble, make circle, write comments but in Google classroom there is no such provision. Some sort of technological innovations can be introduced where we would be able to do the same things using digital pens which we normally do while correcting papers.

One of the complaints against Google Classroom is that many don't know how to use it. Students were posting the assignments on the wall which they were not supposed to do. They were supposed to use 'submit' and 'turn in' buttons. Since they were posting on the wall, in the 'Done' list of classroom their names were not appearing, instead their names were appearing in the 'Not Done' list which was misguiding. Consequently the list became very long on the Google classroom wall, which created lots of difficulty in searching materials and files and assignments. Therefore many said there should be a search button which should be used to search files on the Google Classroom Homepage.

Also there was difficulty in logging in. Some sort of guided tour or tutorial system should be provided on student's log in page or some arrows should appear while moving the cursor to guide the navigation or students should be navigated through the process. Some dialogue boxes can appear or feedback should be given in case of any mistake committed or if going on a wrong path. From the survey 67% feels that there should be some sort of orientation towards using Google classroom.

Now it is the age of WhatsApp where everything is there on mobile or tab. Here 89% of the respondents feel that it should be accessible for mobile or tab, Google classroom should be accessible with Android operating system. It should come as mobile app.

67% were saying there should some sort of offline availability, ability to work on it offline, icon should be available in the play store of mobile where one can work offline and when internet connectivity would be there submission can be done. So storing, drafting and saving can be done offline and can be posted later on when internet availability would be there.

In the present system there are some problems in the notification. When teacher is giving any assignment notification should be given by mail to the students or when students are submitting their answers notification should be provided to the teacher. Survey showed 86% of respondent s felt the requirement of notification. In the present system there is some problem in the notification system. It would be nicer if notification is given by SMS. Recently an inclusion of the notification feature was observed on Google Classroom.

Regarding availability of Google classroom for accounts other than Google Apps for Education presently Google Classroom is available only on education domain. 85% wants it to be available or accessible on other email accounts also.

90% of the respondents feel the requirement of a tutorial menu at the login page of Google classroom. This will serve as an online guide to proceed through at an initial instant.

75% feels that Google classroom could be made more user friendly so that it is accepted by student community in totality.

Concept Map is an excellent tool for representing any concept in an organized manner. At least 65% of the respondents feel that there should be in built provision to make concept map.

64% believe that there should be better security features. At present one code is given which is passed on to the whole class. If the code is passed on to anyone who is not authorized then there could be safety issues. Therefore security features to be more strengthened. When one posts something on the wall that becomes visible to all, thus some security feature can be incorporated or more privacy can be included.

Some More Points which Surfaced out after Experiencing Using Google Classroom are: Requirement of facility to create collaborative teaching or creating one classroom by more than one faculty; Requirement of feedback from users i.e. statistics about usage of the materials uploaded; Option to invite students or groups separately for different assignments; Facility to give different assignments to different set of students; Facility to generate report card featuring report of students' score in all assigned assignments; Sharing /setting of assignments by multiple teachers not possible. This may be required when multiple teachers are taking same subject; Faculty should have an option to choose graded marks visible or not visible at students wall; Facility for selective activation of course material and assignment links; Addition of features for faculties like messaging or communicating some notice or data with each other; There can be provision that when a material is given that should be rated, like star rating indicating how many times was this material viewed, how much was it useful etc. Some statistics can be created and shown to the teacher to find out the usability of the material.

CONCLUSION

The role of technology is to provide a differentiated teaching, learning and assessment tools, which offers the possibilities of personalized courses of study based on constructivism bases (Voogt & Knezek, 2008). Synergism was experienced when combining Google classroom with conventional face to face learning giving positive signal towards its acceptability and effectiveness. Google Classroom can be used as Flipped classroom by giving content materials, videos, activities, links beforehand and then discussing the content in the classroom. Moreover assignments could be made paperless. Class notes could be perpetuated in a paperless manner saving tons of paper and ultimately our trees.

References

About Classroom. (2014). Retrieved from https://support.google.com/edu/classroom/answer

Arbaugh, J. B. (2010). Sage, guide, both, or even more? An examination of instructor activity in online MBA courses. *Computers & Education, 55*(3), 1234-1244.

Ashby, J., Sadera, W. A., & McNary, S. W. (2011). Comparing student success between developmental math courses offered online, blended, and face-to-face. *Journal of Interactive Online Learning, 10*(3), 128-140.

Beqiri, M. S., Chase, N. M., & Bishka, A. (2010). Online course delivery: An empirical investigation of factors affecting student satisfaction. *Journal of Education for Business, 85*(2), 95-100.

British Council India (2014). *Understanding India: The future of higher education and opportunities for international cooperation*. Retrieved on 26/5/15 from https://www.britishcouncil.in/sites/default/files/understanding_india.pdf

Edmonds, C.L. (2006). The inequivalence of an online and classroom based general psychology course. *Journal of Instructional Psychology, 33*(1), 15-19.

Elvers, G. C., Polzella, D. J., & Graetz, K. (2003). Procrastination in online courses: Performance and attitudinal differences. *Teaching of Psychology, 30*(2), 159-162.

Fillion, G., Limayem, M., Laferriere, T., & Mantha, R. (2009). Integrating information and communication technologies into higher education: Investigating onsite and online students' points of view. *Open Learning, 24*(3), 223-240.

Gecer, A., & Dag, F. (2012). A blended learning experience. *Educational Sciences: Theory and Practice, 12*(1), 438-442.

Hemmati, N., & Omrani, S. (2013). A comparison of internet-based learning and traditional classroom lecture to learn CPR for continuing medical education. *Turkish Online Journal of Distance Education, 14*(1), 256-265.

Hollister, K. K., & Berenson, M. L. (2009). Proctored versus unproctored online exams: Studying the impact of exam environment on student performance. *Decision Sciences Journal of Innovative Education, 7*(1), 271-294.

Jaggers, S. S. (2011). Online learning: Does it help low-income and underprepared students. *CCRC Working Paper No. 26.* Assessment of Evidence Series. Community College Research Center, Columbia University.

Jensen, S.A. (2011). In-class versus online video lectures: Similar learning outcomes, but a preference for in-class. *Teaching of Psychology, 38*(4), 298-302.

Key Results of the AISHE (2011-12) (Provisional). *All India survey on higher education 2011- 12.* Government of India, Ministry of Human Resource Development, Department of Higher Education, New Delhi, 2013.

Kim, J., & Lee, W. (2011). Assistance and possibilities: Analysis of learning-related factors affecting learning satisfaction of underprivileged students. *Computers & Education, 57*, 2395-2405.

Kirtman, L. (2009). Online versus in-class courses: An examination of differences in learning outcomes. *Issues in Teacher Education, 18*(2), 103-116.

Lim, J., Kim, M., Chen, S. S., & Ryder, C. E. (2008). An empirical investigation of student achievement and satisfaction in different learning environments. *Journal of Instructional Psychology, 35*(2), 113-119.

McDonough, C., Roberts, R. P., & Hummel, J. (2014). Online learning: Outcomes and satisfaction among underprepared students in an upper-level psychology course. *Online Journal of Distance Learning Administration, Volume XVII*(3), Fall 2014.

McGready, J., & Brookmeyer, R. (2013). Evaluation of student outcomes in online vs. campus biostatistics education in a graduate school of public health. *Preventive Medicine*: *An International Journal Devoted to Practice and Theory, 56*(2), 142-144.

Stowell, J. R., & Bennett, D. (2010). Effects of online testing on student exam performance and test anxiety. *Journal of Educational Computing Research, 42*(2), 161-171.

Summers, J. J., Waigandt, A., & Whittaker, T. A. (2005). A comparison of student achievement and satisfaction in an online versus a traditional face-to-face statistics class. *Innovative Higher Education, 29*(3), 233-250.

Terry, N. (2007). Assessing instruction modes for Master of Business Administration (MBA) courses*. Journal of Education for Business, 82*(4), 220-225.

Voogt, J., & Knezek, G. (2008). *International handbook of information technology in primary and secondary education.* NY: Springer Science+Business Media, LLC.

Waschull, S. B. (2001). The online delivery of psychology courses: Attrition, performance, and evaluation. *Teaching of Psychology, 28*(2), 143-147.

Yudko, E., Hirokawa, R., & Chi, R. (2008). Attitudes, beliefs, and attendance in a hybrid course. *Computers & Education, 50*(4), 1217-1227.

QUANTIFIED CLOSED-LOOP INTERNALIZATION OF MATHEMATICS

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Approaches to education that use New Media often focus on the front-end, which is presenting interactive material to the student. To complete the learning approach using such media, it is essential to integrate the back-end, which includes (i) assessing and tracking the student's internalization of a concept, (ii) tracking each teacher's attainment of learning outcomes for her students, and (iii) realigning the content using the tracking information. Our approach has done this, and has been tested on over 20,000 students for over 5 years. This paper presents our closed-loop method, the issues encountered and resolved, as well as quantified results that this approach yields.

INTRODUCTION

Over the past 20 years, there have been several approaches that use technology to enable learning. Connecting students and instructors across locations has been studied (Welsh et al., (2003; Johnson, Hornick and Salas, 2008). The time element is addressed by web-based approaches (Sendall, Ceccucci & Peslak, 2008; Chester & Gwynne, 2006) as well as applications on personal devices (Tremblay, 2010; Terras & Ramsay, 2012). Broadcasting the same material to an entire class in conjunction with a teacher is solved using classroom technology such as Oliver, Osa and Walker (2012), and increasing engagement via gamification of learning is an approach used extensively (De Castell, 2011). There are approaches to enable a teacher to connect with a student either individually (Sharma & Hannafin, 2007; Rekkedal & Qvist-Eriksen, 2003) or as a Massive Open On-line Classroom (MOOC) (Hu, 2013), and there is peer-to-peer learning (Courts & Tucker, 2012; Tarasowa et al., 2013). While the above mentioned approaches focus on delivery of content, there are others that focus on testing and assessment, which could be either assessment of a student using technology (Eisenberg, 2008), or assessment of the technology itself (Fletcher, 2013).

While current approaches focus on one aspect of education chain, technology offers the scope of addressing the complete problem of creating an engaging action space, presenting material integrated with the curriculum, assessing internalization, tracking student progress, tracking teacher efficacy, tracking efficacy of the tool itself, and finally making necessary adjustments and going back to the first step. A recommendation for an adaptive learning system has been made by the U.S. Department of Education (U.S. Department of Education, 2012). Such a closed loop system is a powerful use of Information and Computer Technology (ICT) in the educational space, enabling an experiential and constructivist approach with quantifiable learning across students of different backgrounds (age, gender, economic level, rural/urban, etc) (U.S. Department of Education, 2012; Warschauer & Matuchniak, 2010). Moreover, there is an increasing recognition that continuous feedback and re-orientation is needed for the teacher as well (Harris, Mishra & Koehler, 2009; Hattie, 2009). The general realm of cognitive psychology and how it influences instructional design has been considered (de Jong, 2010), and needs to be complemented with various other factors to ensure long-term learning happens (Termos, 2012).

The focus of our study was to implement some of the recommendations made by the U.S. Department of Education (2012) as well as take into consideration some of the suggestions offered by other researchers (Johnson et al., 2011; Siemens & Baker, 2012). While most of the problem is solved using technology, human factors also play a small but pivotal role (Cobb, Yackel & Wood, 2011).

The study was conducted in several small groups of 8 learners of varying ages working under the supervision of a teacher, with each learner having an individual laptop. Data collected was used to refine the content and pedagogy and the system itself, to make learning more effective.

TECHNOLOGY AND THE STUDENT

Overview

While developing technology for learning, we need to first understand what the inhibitors to e-learning are (Muilenbeurg & Berge, 2005). Factors influencing learning in school children include level of engagement, learner motivation, social interaction (Vygotsky, 1978), academic skills and support for individual needs (McCombs & Miller, 2008). Further, for e-learning, accessibility and ease of use are also to be considered. Adoption of new media for learning is slow also because many students still prefer traditional ways of learning using pen-paper, as well as time with a teacher (Gorra et al., 2010). It is not often clear to the instructor whether the student got the answer right by guessing or 'romancing' the answer (Piaget, 1973), by memorization, or by applying mathematical principles. Further, when a student needs more questions of a particular type, the instructor is often limited by the questions provided in the text book. The pitfall is that the student tends to retain the answers in memory, and finds it difficult to have an unbiased view towards the question the second time over. Finally, when a student struggles at a particular question, it is not clear to an instructor why the student is struggling. Johnson et al have reported the usefulness of 'Learning Analytics' to monitor and predict student performance, hence spot potential issues early and take appropriate corrective measures (Johnson et al., 2011).

Dependencies across Years

Mathematical concepts covered by the student in the current year depend on concepts covered in earlier years (see figure 1). If a brick at the bottom of the pyramid is loose, cementing the top does not help. It is essential to identify which brick is loose and to fix it. This requires the content to be very fine-grained and tagged with appropriate dependency requirements. It also presents two requirements to the technology: identification of weak areas and remedy for the weaknesses.

In all of the content developed for this system, at most one new concept is introduced at each level. Moreover, at the point where a new concept is introduced, numbers are kept very simple, with a focus on first internalizing the concept (see the section on “Measuring Internalization”). Once the new concept is internalized, the next level introduces larger numbers with the same concept. The next stage is to expose the student to questions that combine this new concept with other concepts already internalized so that the learner is able to construct a connection between concepts (Ausubel, 1967).

Technology Interaction

The interaction of the technology with the student is illustrated in figure 2. The computer first decides what level this particular student is at, then explains a concept to the student, and presents questions associated with the concept explained. The student works on the questions, and the computer both grades his work as well as times how long he has taken. In addition, the system computes a quantified metric for internalization of concepts, and decides what should be done next.

If the concept is not yet internalized, the system continues to expose the student to questions at the current level. Once the concept is internalized, the student's level is incremented, and the system moves the student up to viewing the explanation of a new concept, and starting questions in that concept. In addition to interaction with the student, the technology is also used to give feedback to the teacher as well as the content developer. This concept is also illustrated in figure 2, where two outputs of the system are later used.

Measuring Internalization

Our empirical approach measures internalization of a concept using three parameters: Accuracy, Speed, and Consistency. Clearly, the student has to solve the problem accurately, and correctness of his solution is essential. Having solved the problem correctly, it is necessary that he accomplishes this within the stipulated time.

Getting the problem correct and within average time is not sufficient. The student has to exhibit *consistency* which ensures that accuracy has not been achieved by fluke. This additional requirement is that the student exhibits accuracy and speed, 9 *times in a row*. This is shown in figure 3. The student started with low percentage and high time, and after attempting it several times, finally got the timing to less than 2 minutes and percentage above 90%. Long-term retention is also measured.

Constrained Randomization

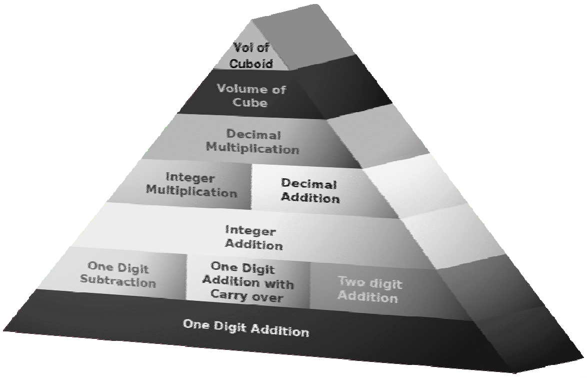
One issue that invariably arises when using a text book is that the student is able to memorize the answers to a particular question. A patented method of constrained randomization (Moni, & Moni, 2012) has been employed to ensure that the student is presented with the same question but with different numerical values, until the concept is internalized. Problems based on various concepts are presented in random order to the student, coaxing the student to apply thinking and reasoning skills.

All teachers agree that mastering mathematics requires practice. Our system has automated the creation of questions at that exact nuance of the topic in that precise level. In many specific topic-level combinations, many millions of questions can be generated. Thus, even if the student needs 50, 100, or 200 distinct questions to master a particular idea, these questions are readily generated for the student.

Note that in figure 4, all questions are exactly the same, except the numerical values vary. Moreover, the variation of numerical values, in this case, has been constrained to be at most 2 digit. Additionally, the coefficient of “x” in any of the expressions is constrained to be non-zero. A further constraint that has been imposed is that the answer is an integer. This is somewhat of a deep constraint, since we need to work backward from the answer to formulate a question that meets these requirements. The details of this approach may be seen in Moni and Moni (2012). In figure 5, the theme of the problems are the same but the problems use different operations. These appear in random order when a child is working on word problems.

Binary Search for Incomplete Internalization

Automatic identification of weak areas is done using a binary search method. If a student exhibits consistent weak performance in a particular level, the system takes him/her down a notch, and introduces questions in levels that are dependencies of the weak level. For example, Decimal Multiplication depends on Multiplication and Decimal Addition. If the student exhibits consistent weakness in Decimal Multiplication, then the required levels of Integer Multiplication and Decimal Addition will appear.



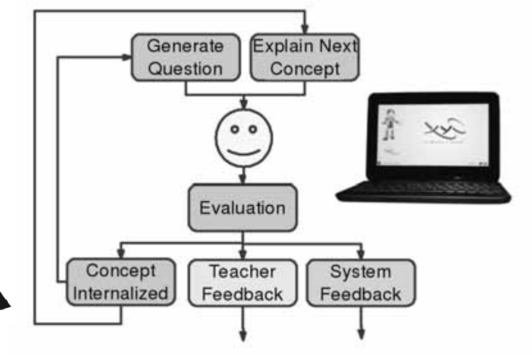


Figure 1: Math of the current year depends in on topics earlier years.

Figure 2: The flow chart to ensure covered internalization of concepts.

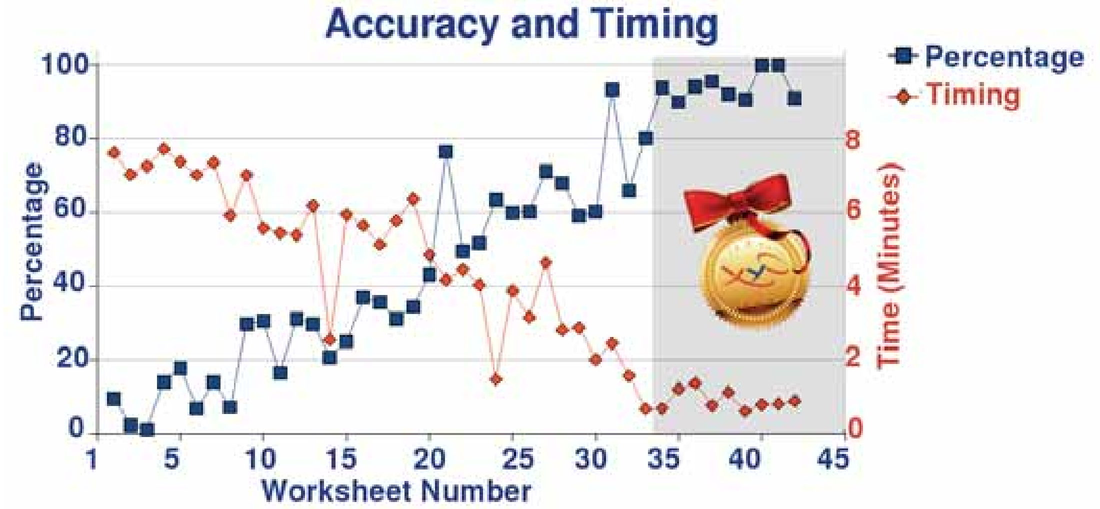


Figure 3: Internalization of a concept requires consistent work, meaning, a high percentage together with a low timing, exhibited 10 times consecutively. This is depicted in the highlighted yellow area along with a virtual medal.

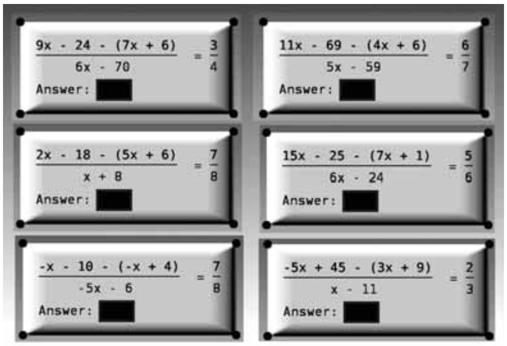


Figure 4: Constrained randomization is used to generate an unlimited number of questions in any topic-level combination.

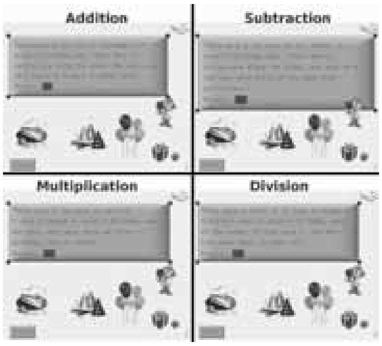


Figure 5. Mixed word problems

TECHNOLOGY AND THE TEACHER

Feedback and formative assessment are essential for constant improvement in the instruction process (William & Leahy, 2007; Shepard, 2008). An example of such feedback is given in figure 6. As seen in the figure, the teacher knows how many hours the student has worked, and the "Work Quotient" (time used for mathematical problem-solving divided by login time). The report includes average percentage, number of questions attempted per hour, as well as snapshot of coverage of topics. There is also a per-student report (not shown in the figure) that gives information on the students, work quotient, time spent on each problem type, time spent "dreaming" (wrong answer, long duration), concepts internalized as well as which problems / concepts were difficult for students to comprehend.

Name	Class	Subject	Login Hours	Work Quotient	Num Questions	Avg	Questions per hour	Coverage Below Class	Coverage At Class	Coverage Above Class
student1	1	Olymp1	17	0.82	701	94	49	61% (52/84)	34% (8/23)	16% (2/12)
student3	3	Olymp3	46	0.73	3058	80	91	72% (91/126)	58% (33/56)	35% (11/31)
student5	5	Olymp5	31	0.71	2030	87	93	76% (92/120)	79% (38/48)	38% (33/85)
student7	7	Olymp7	27	0.86	1699	80	74	55% (66/120)	9% (8/83)	10% (10/100)
student9	9	CBSE_9_SAI	17	0.26	489	97	109	86% (13/15)	48% (58/120)	0% (0/0)

Figure 6: Summary of performance sent to the teacher.

Technology enables feedback to be given to the teacher immediately at the end of each session of work. Considering what teaching methodology works best (Petty, 2009) while taking into consideration individual students' strengths and weaknesses (Black & William, 1998) makes for better teaching methodology. The use of technology in formative assessment leads to instruction which is better aligned to student needs (Johnson et al., 2011; Davis & McCowen, 2007). Our system quantitatively directs this individualistic approach to instruction with optimal support from the teacher.

TECHNOLOGY AND THE CONTENT

Analyzing data on which levels take maximum time for students to master enables the development of required pedagogical content to make comprehension easier. Figure 7 illustrates some of the data used to refine the content. Often students "Skip" a question (get it incorrect in less than 5 seconds). Some of the highest percentage of skipping is seen in certain introductory topics. Although a topic like Addition Word Problems may have 30 to 40 levels in our content, the data indicates which levels encounter frequent resistance and need to be further refined.

Name of topic and level	Percentage Skip	Avg Attempts to Internalization
Intro to Add WP	15.48	54
Intro to Mul WP	15.22	42
Ratio Prop Simple Prob	13.58	55
Area Vol: Perimeter	7.93	29

Figure 7: Example of quantitative metrics used to refine the content.

CONCLUSION

Using technology, it is possible to integrate the front-end (presenting material to the student) as well as the back-end, which is (i) assessing and tracking the student's internalization, (ii) tracking each teacher's effectiveness, and (iii) refining the content using the feedback. This closed-loop approach greatly enhances learning, improves efficiency of the teacher, and creates a productive learning environment where time spent is fruitfully utilized. Using this technology, each student's progress can be tracked and instruction tailored to his need, as if he were the only student in the class. The overall effectiveness of the teacher is significantly enhanced because the technology precisely isolates the problem areas. The long term effectiveness of the system is continuously increasing, since the technology is used to give quantified feedback to improve the technology itself, as well as the content.

References

Ausubel, D. P. (1967). Learning theory and classroom practice. *Ontario Institute for Studies in Education Bulletin*, *1*(31).

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy and Practic*e, *5*(1), 7-74.

Chester, A., & Gwynne, G. (2006). Online teaching: Encouraging collaboration through anonymity. *Journal of Computer-Mediated Communication 4*(2).

Cobb, P., Yackel, E., & Wood, T. (2011). Young children's emotional acts while engaged in mathematical problem solving. In E. Yackel, K. Gravemeijer and A. Sfard (Eds.), *A journey in mathematics education research: Insights from the work of Paul Cobb (Vol 48)* (pp. 41-71). US: Springer.

Courts, B., & Tucker, J. (2012). Using technology to create a dynamic classroom experience. *Journal of College Teaching & Learning*, *9*(2), 121-128.

Davis, G. E., & McCowen, M. A. (2007). Formative feedback and the mindful teaching of mathematics. *Australian Senior Mathematics Journal 21*(1), 19-29.

De Castell, S. (2011). Ludic epistemology: What game-based learning can teach curriculum studies. *Journal of the Canadian Association for Curriculum Studies, 8*(2), 19-27.

de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science 38*(2), 105-134.

Eisenberg, M. (2008). Information literacy: Essential skills for the information age. *Journal of Library & Information Technology 28*(2), 39–47.

Fletcher, S. (2013). Machine learning. *Scientific American 309*(2), 62–28.

Gorra, A., Finlay, J., Devlin, M., Lavery, J., Neagle, R., Sheridan-Ross, J., Charlton, T., & Boyle, R. (2010). Learning with technology: What do students want? In I. Ismail (Ed.), *Proceedings of the 5th International Conference of e-Learning*, Universiti Sains Malaysia.

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical integration reframed. *Journal of Research on Technology in Education*, *41*(4), 393–416.

Hattie, J. A. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*, London: Routledge.

Hu, H. (2013). MOOC migration. *Diverse Issues in Higher Education 30*(4), 10-11.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *The 2011 horizon report.* Austin, TX: The New Media Consortium.

Johnson, R. D., Hornick, S., & Salas, E. (2008). An empirical examination of factors contributing to the creation of successful e-learning environments. *International Journal of Human-Computer Studies*, *66*(5), 356-369.

McCombs, B. L., & Miller, L. (2008). *The school leader's guide to learner-centered education.* Thousand Oaks, CA: Corwin Press.

Moni, S., & Moni, S. (2012). A customizable electronic system for education. USPTO Patent Application 13/695,382, Alexandria, VA.

Muilenbeurg, L.Y., & Berge, Z. L. (2005). Student barriers to online learning: A factor analytic study. *Distance Educatio*n, *26*(1), 29-48.

Oliver, A., Osa, J. O., & Walker, T. M. (2012). Using instructional technologies to enhance teaching and learning for the 21st century pre K-12 students: The case of a professional education programs unit. *International Journal of Instructional Media 39*(4), 283–295.

Petty, G. (2009). *Evidence-based teaching – A practical approach*. UK: Oxford University Press.

Piaget, J. (1973). *The child's conception of the world*. London: Granada.

Rekkedal, T., & Qvist-Eriksen, S. (2003). Internet based e-learning, pedagogy and support systems. The role of student support services in e-learning systems. *Working Paper in ZIFF Papiere 121*. Fern Universität: Hagen.

Sendall, P., Ceccucci, W., & Peslak, A. (2008). Web 2.0 Matters: An analysis of implementing web 2.0 in the classroom. *Information Systems Education Journal 6*(64).

Siemens, G., & Baker, R. S. J. (2012). Learning analytics and educational data mining: Towards communication and collaboration. In *Proceedings of LAK12: 2nd International Conference on Learning Analytics & Knowledge* (pp. 252-254). New York: Association for Computing Machinery.

Sharma, P., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments*, *15*(1), 27-46.

Shepard, L. A. (2008). Formative assessment: Caveat emptor. In C. A. Dwyer (Ed.), *The future of assessment: Shaping teaching and learning* (pp. 279–303). New York: Erlbaum.

Tarasowa, D., Khalili, A., Auer, Sö., & Unbehauen, Jö. (2013). CrowdLearn: Crowd-sourcing the creation of highly-structured e-learning content. *5th International Conference on Computer*

Supported Education (pp. 33-42), CSEDU 2013.

Termos, M. (2012). Does the classroom performance system (CPS) increase students' chances for getting a good grade in college core courses and increase retention? *International Journal of Technologies in Learning, 19*(1), 45–56.

Terras, M. M., & Ramsay, J. (2012). The five central psychological challenges facing effective mobile learning. *British Journal of Educational Technology, 43*(5)*,* 820–832.

Tremblay, E. (2010). Educating the mobile generation - using personal cell phones as audience response systems in post-secondary science teaching. *Journal of Computers in Mathematics and Science Teaching 29*(2), 217–227.

U.S. Department of Education, Office of Educational Technology (2012). *Enhancing teaching and learning through educational data mining and learning analytics: An issue brief.* Washington, D.C.

Vygotsky, L. S. (1978), *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Warschauer, M., & Matuchniak, T. (2010). New technology and digital worlds: analyzing zone of proximal development evidence of equity in access, use and outcomes. *Review of Research in Education*, *34,* 179-225.

Welsh, E. T, Wanberg, C. R, Brown, K. G., & Simmering, M. J. (2003). E-learning: Emerging uses, empirical results and future directions. *International Journal of Training and Development*, *7,* 4.

Wiliam, D., & Leahy, S. (2007). A theoretical foundation for formative assessment. In J. H. McMillan (Ed.), *Formative classroom assessment: Theory into practice* (pp. 29-42). New York: Teachers College Press.

USING MULTI-MEDIA AND CLASSROOM COMPUTER NETWORKING FOR EVALUATION AND ANALYSIS

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Classroom computer networking refers to establishing a communication set-up that can be used to make classroom teaching interactive and student-centric. Our classroom networking is different from the conventional classroom communication systems (CCS) that involve use of the infra-red remote controllers. Our network based system makes use of computers and the networking device called Router. An advantage of this network based system is that it makes use of the installed software-windows operating system, for communication. In this way it proves to be more accessible and economical than other communication devices. A class of about 80 under-graduate students of 2nd semester was divided into 40 groups with two students per group. Each group was assigned a computer terminal for doing analysis and to communicate through the communication device (NETGEAR WGR614 wi-fi N150 router) with the instructors' computer. We proposed an activity namely- Newton's Cradle device, in which the concept of conservation of linear momentum is involved. Animations of this activity was prepared and uploaded on the computers. Based on the activity the students were given a questionnaire to respond and communicate to the instructor in a specified time (about 60 minutes). The questionnaire contained questions that tested a student's knowledge about basic concepts like conservation of momentum and energy etc. The results obtained by different groups of students were compiled and then analyzed. The entire procedure of evaluation was carried out in paper-less environment.

INTRODUCTION

In the under-graduate curricula, concepts of conservation of linear momentum in collisions are taught prominently in theory classes. We thought that it would be a good idea to introduce students an apparatus or an activity in which these concepts are applied. The aim of the presented work is to showcase such an apparatus and introduce an innovative method of testing students' skill of analyzing a practical physics problem. Such a method, (Wadhwa, 2013) can be very useful in analyzing various concepts of physics which require more imagination and visualization than mere theoretical or mathematical model. Moreover with the aid of animation and respective videos one can easily visualize difficult concepts which require precise experimental work to comprehend. We selected Newton's Cradle apparatus for demonstrating the concepts of multi-body collisions and the law of conservation of momentum in such systems. We constructed the actual apparatus for the activity and then made animations of the experiments along with a questionnaire. These were uploaded on 40 computers in a classroom and a computer network was established using a router.

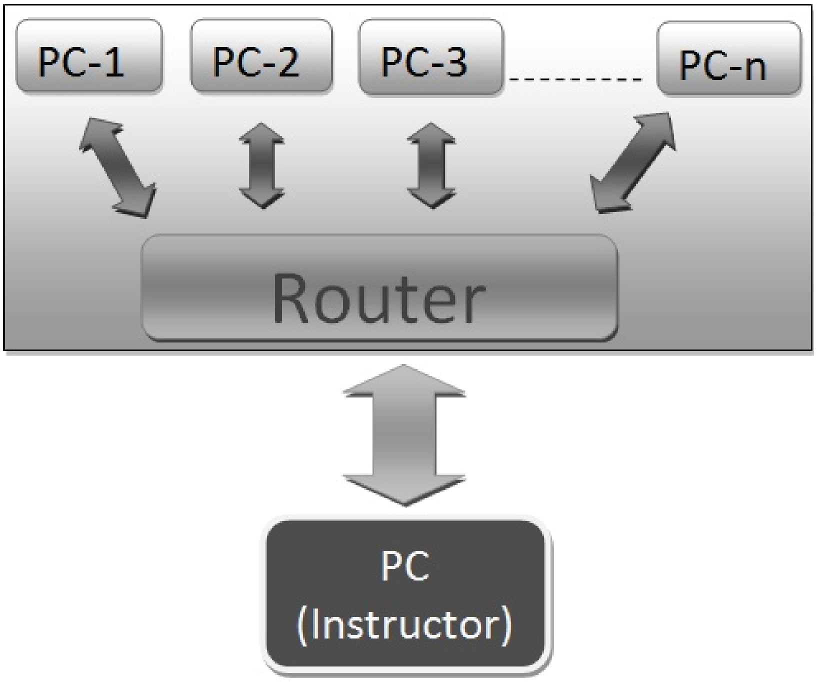

Figure 1: Classroom networking system

Each computer terminal was assigned to a group of two students who were asked to observe the two animations, analyze them and then record their answers in a text file. The text file containing answers from each of the forty terminals was communicated to the instructor's computer terminal through the local network. The arrangement of the networked system is shown in figure (1).

Previous Works

Levy et al., (2003) used the Jeliot 2000 program animation system to teach introductory computer science to high school students. They conducted a series of experiments with two batches of students with almost same intelligence level. One of the group, called animation group was taught using the Jeliot 2000 program, whereas the other group called the control group was taught without any multimedia aid. After the Statistical analysis of the pre- and post-tests, the improvements in the average grades of the animation group were significant, except for the first pair of tests. The average grades in the control group improved but the improvements were not statistically significant. Moreover the Animation Group showed more concrete understanding of dynamics of the algorithm by visualizing it, than Control Group which has to rely merely on their memory and imagination to comprehend the algorithm.

Sentongo, Kyakulaga & Kibirige (2013) used Computer Simulations in Teaching Chemical Bonding. Similar to the Jeliot 2000 experiment, they too considered two batches, namely Experimental Group (EG) and Control Group (CG) for their experiment, where the former was taught using computer simulations while the latter one was taught without it. The results of the post test showed that EG had a better understanding of chemical bonding concepts when compared to traditional hands-on (manual or laboratory apparatus handling) teaching. Computer simulations helped learners to create imaginable representations of chemical reactions much better than traditional teaching did.

Newton's Cradle Apparatus

Newton's Cradle is a device that demonstrates conservation of momentum and energy via a series of swinging spheres. It consists of a series of identically sized metal balls suspended in a metal frame so that they are just touching each other at rest. Each ball is attached to the frame by two wires of equal length angled away from each other. If one ball is pulled away and is set to fall, it strikes the first ball in the series and comes to nearly stop. The ball on the opposite side acquires most of the velocity and almost instantly swings in an arc almost as high as the height of the initial ball. This shows that the final ball receives most of the energy and momentum that was in the first ball.

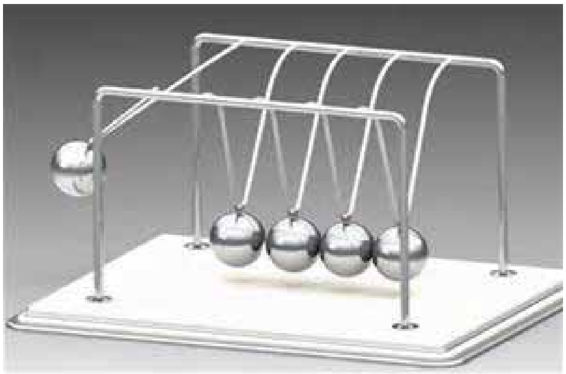

Figure 2: Newton's Cradle

Analysis of Newton's Cradle Experiments

For demonstrating the concepts of collisions and law of conservation of momentum, we chose the Newton's cradle (N-C) apparatus (Hutzler et al., 2004). We used animations of this device in different configurations and prepared a questionnaire on them. The Newton's cradle can be analyzed in two ways - the first and simplified method of analyzing is by assuming that the collisions are elastic and the steel balls always collide in pairs instantly. The second and more difficult approach is to assume elastic collisions of the five steel balls colliding simultaneously at an instant of time. The second approach has been studied using different types of mathematical models (Hinch & Saint-Jean, 1999). But we decided that with the first year college students the first approach should be appropriate. The questionnaire given to the students contained five questions based on theoretical knowledge and the rest five questions to test their practical skills. We uploaded animations of the N-C experiments on each of the students' computers. In experiment #1 of the animation, if ball (1) is taken aside and released to strike the 2nd ball, only the 5th ball from the other side will leave to oscillate. Similarly in experiment #2 of the animation, if two balls (1,2) are taken aside and released then only two steel balls (4,5) together leave from the other side and begin oscillations. Amongst the various explanations given by the students, the most suitable is presented here. In this analysis we can assume that on impact, an unknown mass (M) to leave from the other side. And then determine this mass (M) using the laws of conservation of energy and momentum. For instance considering experiment #2 when two steel balls each of mass 'm' are taken aside, according to law of conservation of energy,

$0.5(2m)u^2 = 0.5(M)v^2$ … (1)

where (M) is the unknown mass, u is the initial speed of mass (2m), v is the final speed of (M)

Using the law of conservation of linear momentum we have $2mu=Mv$ … (2)

From (1) and (2) we get $v = 2mu/M$ …(3)

Using (3) in (1) we get $M=2m$

This shows that two balls of total mass M would leave from the other side to oscillate. Similar analysis can be applied to other cases involving three and four masses. Students were encouraged to give critical comments on the above analysis and one of these referred to the verification of our assumption that the balls suffered collisions in pairs and multiple collisions took place later on. To verify this we used audio sensor to detect sound signals on impact between the balls.

Student Questionnaires and Evaluation

Students were evaluated on the basis of two types of questionnaires as shown in figure (3). The Type-1 questionnaire contained questions on the basic theory relevant to this experiment; Type-2 questionnaire consisted of those questions that tested their aptitude in applying basic theory to a practical problem. For example, questions such as can we assume a hypothetical model of the colliding steel balls, or what kind of a force-displacement relation exist between finite-sized steel balls. The responses of the students to both types of questionnaires are shown in figure (4). In type-1, about 30% students scored less than the passing 20 marks and 25% could score between 40 and 50 marks out of a maximum 50 marks. About 50% of the students were able to score more than 30 marks which showed good understanding of basic physics. However, the situation became completely different in type-2 questionnaire as shown in figure (3). Now 80% students scored less than passing 20 marks and none could score between 40 and 50 marks out of a maximum 50 marks. About 6% of the students were able to score more than 30 marks as against 50% in type-1 questionnaire.

Type – 1	Type – 2
1. What is an elastic collision? 2. What are the laws of conversation of linear momentum (LCM) and energy (LCE)? 3. Is the LCM or both obeyed in the N-C experiments? 4. Are the collisions in the N-C experiments 1-D, 2-D, 3-D? 5. How can we determine the speed of each steel ball in the experiment?	1. What are the different ways of analyzing the N-C experiment to determine the speed of oscillating steel balls? 2. What can be the equivalent model that can be used for analysis of the N-C experiment? 3. Should we consider the set of steel balls as N-body system or a 2-body system? 4. Can we determine the speed of sound through steel from this experiment? 5. Is there any compression at the point of impact during collision?

Figure 3: Questionnaires

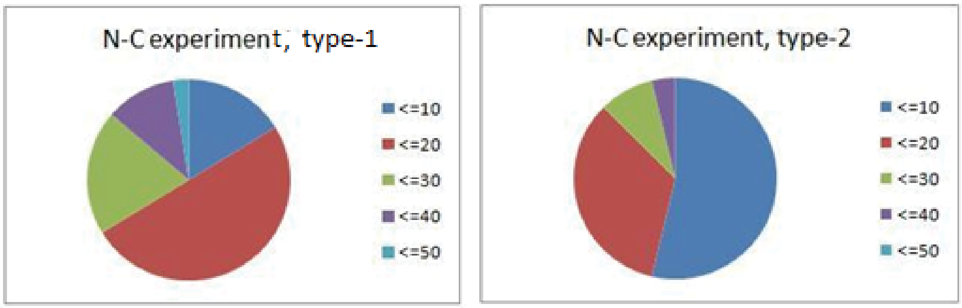

Figure 4: Comparison of student performance in N-C experiments.

CONCLUSIONS

Computer simulation and animation helps learners to create imaginable representation of a physical phenomenon. It is the conjunction with verbal narration provided by the teacher which allows learner to visualize the basic ideas and concepts of any phenomena. Furthermore animation is an educational tool that must be integrated into the classroom for testing and assignment purpose, rather than used as a one-time teaching aid.

We have presented an innovative approach towards enhancing students' learning process in the classroom by taking an example of a physics problem. For the first time animations of experiments are used and communicated in the classroom using networking via a router and existing windows o/s to collect the response of the students for evaluation and analysis.

Our results and findings actually emphasize the importance of multimedia including animation in pedagogy. As discussed in Stasko, Badre and Lewis (1993), the need is to view technology as an instrument that supports students to construct, represent, articulate and discourse about knowledge. This idea has been initiated in our experiment. From our findings we conclude that teaching through multimedia can be very effective in bringing out the strengths and weaknesses of students. By including such activities in our educational curriculum we can make classroom teaching interesting and more student-centric. The student also becomes more attentive and application-oriented in approach towards learning a subject. The communication networking in the classroom induces a sense of belongingness in all the students irrespective of their caliber.

The multimedia method of evaluation used in this work is very useful and economical.

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References

Hinch, E. J., & Saint-Jean, S. (1999). The fragmentation of a line of balls by an impact. *Proc. R. Soc. London. 455*, 3201–3220.

Hutzler, S., Delaney, G., Weaire, D., & MacLeod, F. (2004). Rocking Newton's cradle. *Am. J. Phys. 72* 1508.

Levy, R. B. B., Ben-Ari, M., & Uronen, P. A. (2003). The Jeliot 2000 program animation system. *Computers & Education, 40*(1), 1-15.

Stasko, J., Badre, A., & Lewis, C. (1993). Do algorithm animations assist learning: an empirical study and analysis. *Proceedings of the INTERCHI '93 Conference on Human Factors in Computing Systems.*

Sentongo, J., Kyakulaga, R., & Kibirige, I. (2013). The effect of using computer simulations in teaching chemical bonding: Experiences with Ugandan learners. *International Journal of Education Science, 5*(4), 433 – 441.

Wadhwa, A. (2013). Using class room communication system in physics laboratory. *Proceedings of the conference ICPE 2013*, Prague, Czech Republic.