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).
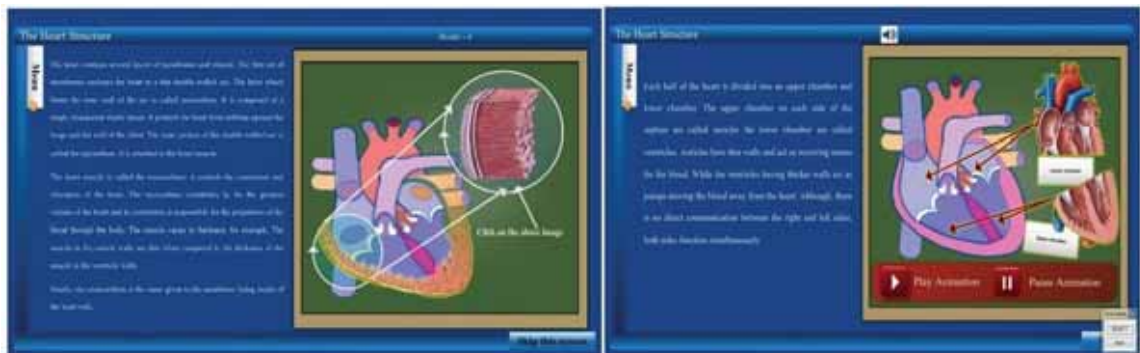

Figure 1: Left side image is the screen shot of interactive visual with action phase screen design and right side image is the screen short of continuous animated visual design.

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 ρ = .00 < 0.05, ηp^2 = 0.24, Terminology test F (1/358) = 11.84, ρ = 0.00 < 0.05, ηp^2 = 0.03, Comprehension test F (1/358) = 5.63, ρ = 0.01<0.05, ηp^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.

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