

# 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 than 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 below 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
<sup>1</sup> Mental Effort		
<sup>2</sup> 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 2<sup>nd</sup> 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.

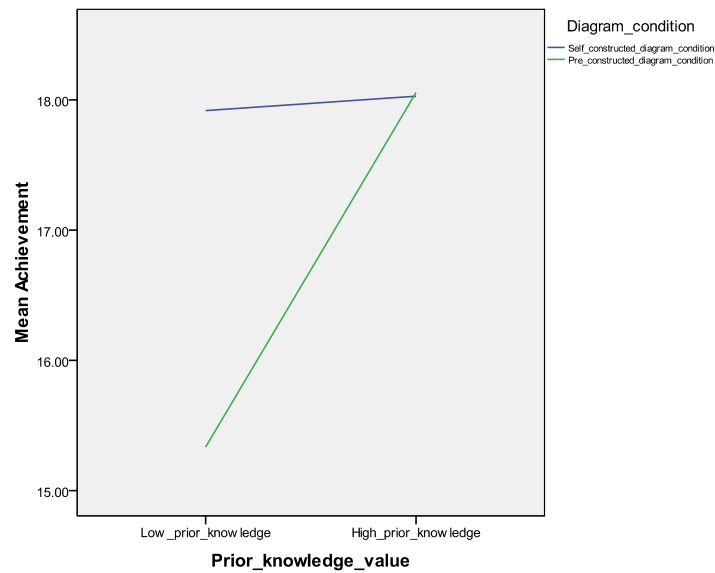


Figure 1: Post test score as a function of prior knowledge and diagram condition

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.

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