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Problem Solving In Mathematics-Role of Worked Examples in Reducing Cognitive Load and Improving Scholastic Performance

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ABSTRACT

Mathematics is a compulsory subject at school level across the globe. It is also considered as a difficult subject. Reducing the cognitive load and improving the scholastic performance are the main concerns in the teaching learning process of mathematics. The present study is an attempt in this direction by using cognitive load theory. The study is intended to analyze the role of worked examples in learning mathematics and to design and conduct an intervention to reduce the cognitive load and improve the performance of students in mathematics. Sample comprised of 76 students of 6th grade. The sample was divided in to two groups of control and treatment conditions. There were two phases in the intervention namely learning phase and test phase. At Learning phase students were taught according to either a traditional procedure or according to worked examples effect of cognitive load theory. At test phase all students (control condition and treatment condition) were presented a common test (Scholastic Achievement Test). During the learning phase student's performance in the form of errors committed and cognitive load experienced were recorded. During the test phase student's performance and cognitive load experienced were recorded. The study revealed that students who studied worked examples committed fewer errors and experienced low cognitive load. Students who studied worked examples performed better and experienced less cognitive load than students who solved the same number of problems. It is recommended to give more emphasis on worked examples to improve the performance of children in mathematics and to reduce the cognitive load experienced by students in mathematics.

Keywords: *Mathematics Learning, Cognitive Load, Worked Examples*

While considerable progress has been made in independent India in providing schooling facilities to all children, children's learning (especially in 3 R's-Reading, Writing and Arithmetic) at primary and elementary level remains a tenuous area. The committee constituted by Ministry of Human Resource Development in November 2015 to formulate a draft national

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education policy observed various evaluation studies showing a decline in learning levels among school children. National Achievement Survey confirms the findings from a number of other studies such as ASER, Educational Initiatives etc. and identifies poor learning out comes as the biggest challenge facing Indian education (Government of India, 2016).

Mathematics-Major Concerns

Mathematics is a compulsory subject at school level. But unfortunately not only it is still a subject that is considered difficult (high level of cognitive load) but also the performance is not satisfactory. Various studies evidence of very poor learning levels among children in mathematics (ASER, 2015: Education Initiatives, 2010; Pratham, 2005-2010; NCERT, 2008).Even though some curricular reforms based on NCF, 2005 have been implemented there is still an urgent need to improve it further. The present study is an attempt in this direction by using cognitive load theory.

Cognitive Load Theory- Reduction of Cognitive Load-The worked example effect

Cognitive load theory (CLT) is one of the most influential and a highly effective guide for the design of multimedia and other learning materials (Plass, Moreno & Brunken, 2010).The aim of CLT is to use our knowledge of human cognition to provide instructional design principles (Sweller, Ayres & Kalyuga, 2011).We process information in working memory. Processing imposes a load. Cognitive load refers to the total amount of load imposed on working memory while processing or performing a task. If the cognitive load exceeds the limit of working memory capacity then the learning process affected (Yuan et al, 2006).

According to Plass, van Moreno, & Brunken (2010) in discovery and problem solving based instructional procedures learners experience high cognitive load. According to Sweller (1988) conventional problem solving imposes high cognitive load. Learning from worked out examples is better than a single example followed by problems. Learners should be presented with several examples rather than a single example, as it is commonly the case (Alexander& Robert, 2010).The paired alternation strategy of worked example was employed in the present study. Sweller and Cooper (1985) first adopted this strategy. Many laboratory experiments and some classroom studies provide support in favour of worked examples (Renkl, 1997; 2002; Sweller ,1999; Sweller and Cooper ,1985; Ward and Sweller ,1990).Worked out examples have shown to be superior to conventional problems (Sweller, 1988).

Objectives

1. To analyze the role of worked examples in learning mathematics.
2. To design and conduct an intervention to reduce the cognitive load and improve the performance of students in mathematics.

METHODOLOGY

Sample

Sample comprised of 76 students of 6th grade from social welfare schools of Ranga Reddy district of Telangana state.

Research tools

Students' personal data sheet

Students' personal data sheet was used to collect information like age, gender, community etc,

Short Self Report Instrument (SSRI)

Short Self Report Instrument (SSRI) is related to children's learning experiences while learning various subjects and various concepts in mathematics. Short self report instrument was used to measure cognitive load experienced by students while learning problem solving in mathematics.

SSRI was a self rating scale based on subjective rating scale developed by Pass to assess cognitive load directly. Paas assumed that the mental effort during learning and test stage may be an index of cognitive load which can be obtained from learners through introspection. Learners were asked to rate the mental effort on a 9-point Likert scale with very, very low mental effort(1) to very, very high mental effort(9). The reliability of the scale was found high (Pass, van Merrienboer, & Adam, 1994).Pass (1992) found the internal consistency coefficient (Cronbach's Alpha) of the scale as 0.90, according to Pass & Van Merrienboer(1994) it was found as 0.82.Self rating scale of Pass emerged as the most sensitive measure of cognitive load. According to Sweller, Ayres & Kalyuga(2011) subjective measures can be obtained easily and quickly and it is easy to administer.

Pass self rating scale was widely used by many researchers with modification of wording like asking learners to rate their learning experience as how easy or difficult instead of mental effort. Modified version of the scale was used in the present study. It requires children to rate their learning experience on a 9 point scale ranging from extremely easy (1) to extremely difficult (9)

Exercise (Practice Material-Intervention)

It was related to multiplying 3 numbers (ranging from 1 digit to 4 digits) by using commutative and associative properties.

Scholastic Achievement Test (Post -Test)

Scholastic Achievement Test was used to assess post test performance and cognitive load experienced at test stage of experimental and control groups after intervention.

Design and Procedure

The study was conducted on the children from social welfare schools of Telangana state after taking permission from the government. The secretary, Telangana Social Welfare Residential Educational Institutions Society (TSWREIS) has given formal permission to interact with the students and mathematics teachers to collect the data. After fixing the tentative time schedule for the study consent was obtained from the concerned school principals, mathematics teachers and students. The sample was divided in to two groups of control and treatment conditions. Students were randomly allotted to either the treatment or control condition. In order to control the differences of dependent variables a pre test was given before intervention. After an intervention a post test was administered to both groups.

Intervention

There were two phases in the intervention namely learning phase and test phase. Learning phase is also known as acquisition phase. During this phase children were taught according to either a traditional procedure or according to an innovative procedure (worked examples effect).

Students in the control group were simply asked to solve 6 problems as one might ask students in a home work assignment (exercise) in typical mathematics teaching. Students in the treatment condition alternate between 3 pairs of worked examples and problems. In the class beginning the teacher had a discussion around a concept. After the discussion an example solution was presented followed by solving a problem on their own in small groups. The teacher then directed the class back to studying an example. After studying this worked example, the students are given a second problem to solve. Again, this follows the principle worked example –problem pair. It was observed that by having problems to solve in between the worked examples, students are motivated to pay more attention to the worked example because it helps them prepare for the next problem.

A second phase which is known as the test phase followed the learning phase in which all children (control condition and treatment condition) were presented a common test (Scholastic Achievement Test) to see if there were any differences in learning outcomes related to performance and cognitive load experienced. During the learning phase children's performance in the form of errors committed and cognitive load experienced were recorded. During the test phase children's performance and cognitive load experienced were recorded.

RESULTS

Table 1 Comparative Mean performance of Students

Performance indicator	Control Group	Experimental Group
Errors committed at Concept acquisition stage	18	4
Score achieved at Scholastic Achievement Test stage	8.4	18.4

Table 2 Mean Cognitive Load experienced by students

Cognitive Load	Control Group	Experimental Group
Concept acquisition stage	5.0	2.2
Scholastic Achievement Test Stage	4.7	2.6

Table 3 Comparative cognitive efficiency

Group	N	Cognitive Efficiency (Mean)	Standard Deviation
Control Group	37	9.3	9.0
Experimental Group	39	10.8	8.9

DISCUSSION

Students who studied worked examples committed fewer errors (table 1) and experienced low cognitive load (table 2) than students who solved the same number of problems at learning phase. Students who studied worked examples performed better (table 1) and experienced less cognitive load (table 2) than students who solved the same number of problems. Mean cognitive efficiency of the Experimental Group is higher than the mean cognitive efficiency of the control group(Table 3).Efficiency of a method can be calculated as a ratio of test performance and invested mental effort (cognitive load) (Pass &Van Merrienboer,1993).The benefits of worked examples for improving learning efficiency and learning outcomes have been demonstrated in many previous studies (Cooper and Sweller,1987; Kirshner, Sweller & Clark ,2006; Renkl ,1997: Ward & Sweller ,1990).

Mathematical educators have started recognising the importance of worked examples in problem solving. Department of education, USA in its report Organising Instruction and Study to Improve Student Learning recognised the importance of worked examples, the report says: ” When teaching mathematical or science problem solving, we recommend that teachers interleave worked example solutions and problem-solving exercises—literally alternating between worked examples demonstrating one possible solution path and problems that the student is asked to solve for himself or herself—because research has shown that this interleaving markedly enhances student learning” (Pashler,et al.,2007 ,p 20).The report recommended (as recommendation-2) worked examples strategy in the teaching learning process with the following checklist..

1. Have students alternate between reading already worked solutions and trying to solve problems on their own
2. As students develop greater expertise, reduce the number of worked examples provided and increase the number of problems that students solve independently (Pashler, et al.,2007 ,p 15).

CONCLUSION

The findings of the present study have clear implications for mathematical educators. There is an urgent need to give more emphasis on cognitive load effects such as worked examples to improve the performance of children in mathematics and reduce the cognitive load while learning mathematical problem solving.

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