Reducing Information Load through Pre-lecture Assignments to Improve Secondary Level Students' Understanding in mathematics

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Various studies in the past explored a positive correlation between information load and students' understanding difficulties. In the topics where the information load exceeded the working memory limit the performance in terms of understanding declined quite spectacularly. The capacity of this part of the brain is determined genetically fixed. However, the room for efficient use of this part is open largely through experience. In this study pre-learning strategy was practiced to minimize the load on working memory in order to improve students' understanding in mathematics. To follow the strategy, twenty pre-lectures were developed from year 9 and 10 mathematics textbooks followed by twenty post-tests. A sample of 212 students was taken from two FG schools in Peshawar Cantt. The outcome was focused in terms of understanding and procedural learning. No changes were made in the curriculum content, time allocation and the teachers. The results depicted significant improvement in students' understanding and procedural learning in the stipulated topics. The results are consistent with previous studies in very different contexts, which highlighted significant importance of pre-learning practices.

Keywords: Information load; Working memory capacity; Understanding difficulties; Pre-lecture; post-test

Procedural learning and understanding in mathematics

Learning mathematics is a complex task. In fact procedural learning is widely confused with what is meant by understanding in mathematics. This type of learning usually lack conscious mental representation behind the procedure. Skemp (1976) defined procedural learning in mathematics as knowing "rules without reasons". A student can readily carry out a multiplication calculation, but does he really understand multiplication? Similarly students readily learn the procedure to rationalize a "binomial surd", but do they really know about rationalization, the concept of surd, the concept of binomial or trinomial surds and why the surds are rationalized.

According to Skemp (1976) understanding in mathematics concern both "what to do" and "why" (Orton, 2004). It's a mental representation working behind the procedure. Similarly a richer conceptual context facilitates better understanding of the fact (Nickerson, 1985). In short understanding in mathematics is a conscious effort to make connections between mental representations of mathematical concepts. It's a process of internalizing ideas with various cross references (Johnstone, 1997a). Understanding is a dual task procedure of holding and processing ideas. Hitch & McAuley (1991) find a relationship between the dual tasks procedures such as to retain and process information at the same time and the children poor mathematical skills.

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In Pakistan procedural learning in mathematics is widely rewarded in internal and external examinations (Bashir 2002, Shah & Afzal, 2004). Due to the said reason the teachers in traditional setups mainly stress the external representation rather than the internal. Therefore the scope of learning of this subject is a limited one. Teacher in traditional setup assume that the students are following what he/she see behind the procedure. However, it is more problematic to assume that the connections taught explicitly are internalized by the students (Hiebert and Carpenter, 1992).

To let the students learn each sub component of a concept with an internal representation during limited lecture hour is tedious and time consuming job. It can be practiced but bombardment of bulky information in a single time overloads the working memory of the learner. Therefore there must be some strategy to reduce information load on the one side and let the students to follow the procedure with internal representation on the other. A detail description of the strategy employed in this study is given under the pre-lecture heading.

Information load phenomenon

According to Reid (2011), information load is defined as the number of pieces of information which the learner has to hold at the same time in order to perform the task successfully. Miller (1956), finding in this regard is definitely a big breakthrough in the field of cognitive psychology. His finding was the measurement of a key part of the brain later known as working memory. An adult average capacity is 7 pieces of information and mostly possesses a capacity between 6 and 8 (Reid, 2011). According to Baddely (1986), not only could its capacity be measured but it was found to be fixed genetically, growing with age up to age of sixteen.

In this part of the brain we do our main cognitive processes such as reasoning, understanding and problem solving. The working memory is the part of brain where we hold temporarily, manipulate, rearrange, bring together the information, and understand it (Reid, 2011; Baddeley, 2002). Johnstone (1997a) holds the opinion that, in the light of information drawn from long term memory thinking and problem solving take place and now it is known that the capacity has to accommodate not only the items of information to be held at the same time but also to have space to carry out the necessary processing of that information. Therefore due to limited capacity, it is easily overloaded. There is a positive relationship between working memory capacity and information load (Johnstone & El-Banna, 1989).

As Load Increased the Success Rate Dropped Dramatically

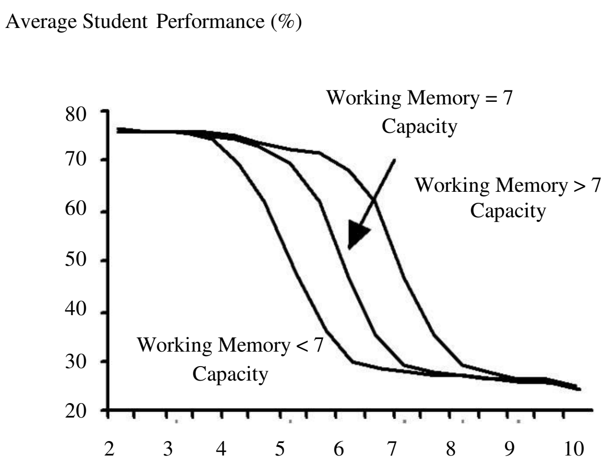

Figure 1. Performance collapse as information load increases Johnstone & El-Banna (1989)

From the above figure, it is clear that as soon as the question demand exceeds the working memory limit the performance in terms of understanding declined quite spectacularly. The dual task procedure such as holding and processing information at the same time has a direct relationship with limited working memory space (Johnstone et al, 1989).

According to Reid (2011) understanding requires the young learner to hold too many ideas for their limited working memory. Tsaparlis (1998) found that if the information load in solving a problem is less than the working memory space then the chances of success to solve the problem would be greater, contrary to this if information load is greater than the working memory space, a learner would be unsuccessful in solving that problem. The capacity of working memory was found to be fixed genetically (Miller, 1956). The only workable option we have, to reduce the load on working memory, so that more space could be available for processing new information.

The strategy of reducing information load worked quite successfully in understanding difficult areas in other subjects. For example Danili & Reid (2004) recorded a considerable improvement in students' understanding by redesigning some difficult portions in the subject of chemistry. Similarly Hussein & Reid (2009) redesigned some large portions of the chemistry curriculum in the way that the working memory demand was lowered. They recorded 13% improvement in students' understanding.

The importance of pre-requisite knowledge for understanding new concepts

Mathematical concepts are usually based on pre-requisite various sub concepts. Gagne (1965) finds that prior knowledge of the sub components of a concept is of crucial importance in learning mathematics. In his findings a student must have fully grasped the concept of several pre-requisites such as adding and counting and recognizing numerals and drawing them with pencils prior to learn the concept of multiplication of natural numbers. Similarly to learn the concept of "Rationalization of Binomial Surds" based on two immediate sub concepts such as;

- Conjugate: For example (a-b) is conjugate of (a+b), similarly the conjugate of $3+\sqrt{7}$ is $3-\sqrt{7}$
- How we get difference of two squares $(a-b)(a+b)=a^2-b^2$

It is a well established fact that the contribution of Gagne to learning mathematics in an organized way is a substantial effort. The idea of readiness is quite appealing to mathematics' teachers. The sequential order enhances the quality of learning mathematics. The idea of sequential order can successfully be used for what is meant by understanding in mathematics, if it is linked to the underlying ideas of mind preparation of well established research of Ausubel (1968) and Johnstone (1997a). So in this way new mathematical concepts can be understood in a meaningful way.

The novice and expert phenomenon is quite important in the process of learning. According to Johnstone (1984), an expert by dint of previous knowledge and experiences organize the incoming information but this is not the case for a novice learner. The understanding requires the learner to analyze the information coming in and organize it for himself. Without these active processes he resorts to take on teacher's information and structure, which certainly end at rote memorization. A novice usually lack anchoring schema in the mind for imbedding new ideas; therefore, it is indispensible to attend all the information. Contrary to this an expert by dint of existing schema attempt to what is important.

Admitting new information to our mind is a selective process. An expert attends to what is important or of interest or of greater impact, whereas, a novice attends to all the incoming information due to lack of anchoring units of information in the long term memory. The selection process is driven by the criteria which are already available in the long term memory of the expert. His previous experiences, knowledge, interest and misconceptions control the perception filter (Zaman, 1998). There are some important predictions from the Johnstone (1997a) information processing model.

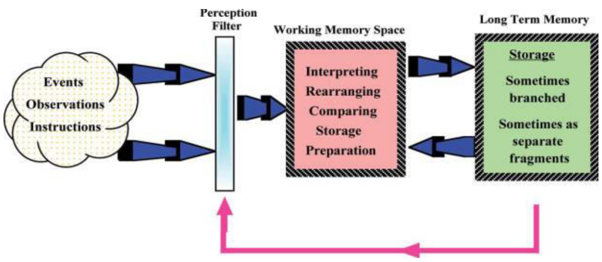

Figure 2. A model of information processing (Johnstone, 1997a). By Reid (2011)

The above model shows that the perception filter is driven and controlled by what is held in the long term memory. Moreover, if the perception filter works in an efficient way then the working memory load is less likely. Johnstone (1997a) shows that the already held information in the long term memory is of crucial importance for learning new material. Ignoring this prediction of the model may lead the learner to rote learning. To follow the same, pre-learning strategy was employed in this study with the assumption to help out the learner to focus on relevant information. Thus, the load on working memory would be reduced. Further, the students' understanding in mathematics would be built up.

Pre-lecture and pre-lab practices were highly effective in building up students' understanding in different subjects at university level (Dawson, 1978; Ebenezer, 1992; Johnstone, 1997a, 1997b; Johnstone *et al*, 1994; Kristine, 1985; Sirhan *et al*, 1999). Sirhan *et. al* (2001) found a greatest benefit of pre-lecture activities on learning of least well qualified students. Brown and Sternberg (2008) observed that the students who prepared pre-lecture quizzes in statistics were well prepared for, and had less exam phobia. Moreover, they believed that pre-lecture quizzes helped them keep up the course reading. In physics at grade 10^{th} level a significant difference was observed between the performance of the students with and without pre-lab (Safdar, 2010; Zaman and Awan, 2006).

Purpose of the study

In the light of previous research in this area we hypothesized that the instructions through pre-lecture assignments would improve students' understanding in mathematics. Thus, we predicted that the pre-lecture assignments will improve students' understanding in mathematics at secondary level. Second we hypothesized that increasing students' understanding will lead to gains in their procedural ability. Thus, we predicted that students who receive instructions through pre-lecture assignments will generate a correct procedure.

Research Design and Procedure

This study involved two groups. The selection of the groups was made on the basis of their previous results in the subject of mathematics in internal and external Board exams. For example the year 9 students previous annual results secured at year 8 level in regional Board examination in the subject of mathematics were taken and analyzed. No significant difference was found between the previous results of the two groups. Similarly previous results of year 10 students secured in year 9 external Board examination were taken. After analyzing the results no significant difference was found between the mathematics results of the two groups. The students in the experimental group got instructions through pre-lecture assignments (constituted conceptual knowledge) i.e. they were coming to the lecture after completing their pre-lecture assignments. The students in control group got instructions through traditional teaching methods i.e. without pre-lecture assignments. A positive correlation exists between the students' attitude and their achievement in mathematics (Farooq and Shah, 2008). Therefore an attitudes questionnaire was also administered on the sample before employing research plan. This was for the purpose to analyze any significant difference between the attitudes of the sample. After employing chi-square test, no significant difference was observed between the attitudes of the two groups.

Sample of the Study

To assess the impact of pre-lecture assignments, a sample of 212 students was taken from two Federal Government schools in Peshawar Cantt. There were 114 students from year 10 (78boys and 36 girls). Further they were equally divided into with and without pre-lecture groups. From year 9 there were 98 students, 43 boys (22 with and 21 without) and 55 girls (31 with and 24 without). The students were aged between 14 and 16 years old, belonging to lower middle class civilian and low ranked armed forces families.

Content of the Study

Twenty topics each from year 9 and 10 mathematics text books were selected on the pattern of the topic selection criteria duly employed by Federal Board for the annual examinations. For this purpose five years previous papers were thoroughly screened out and finally the topics were selected. In this way the concentration diverted to the key topics of various chapters.

Procedure & Time Table of the Study

This study was continued approximately for 20 weeks of the academic session 2011-12. One week before the scheduled lectures, pre-lectures were handed over to experimental group and they were instructed to complete the preparatory work before coming to the lecture. On the alternate day of the scheduled lectures, twenty minutes post-test was conducted for both groups. In one of the two sampled schools i.e. in boys section the researcher himself conducted lectures with the boy students. In the girl section there was only one female math teacher responsible to conduct the routine classes at secondary level. She was given two days training prior to implementation of research plan. The regional authority of the schools was taken into confidence and hence found co-operative in this regard. The data analysis was made in two phases. In the first phase post-test mean scores of the two groups were analyzed. These tests were specifically designed to check the students understanding in the taught topics. In the second phase the Federal Board annual examination 2012 results in the subject were analyzed, to find out any significant difference between the procedural knowledge of the two groups.

Instruments

In this study three instruments were used for data collection. The first instrument used in this study was the attitudes questionnaire before conducting the experiment. This was used to find out any difference between the attitudes of the sample with and without pre-lecture. The other instrument was pre-lectures handed over to the experimental group time to time in accordance with the scheduled syllabus to be taught. Similarly post-tests were conducted to both the groups in order to find out the effectiveness of the new methodology. The detail of each one is given below;

Attitude Questionnaire

Studies reveal a positive correlation between students' performance and achievement in mathematics. To assess this factor in detail an attitude questionnaire was developed on the five points Likert (1932) format. The questionnaire was composed of 20 items. An attitude scale should yield consistent result (Sommer *et. al,* 1997). Therefore to ensure the reliability, the attitude questionnaire was developed in two parts. The first ten items designed to point towards different competencies in mathematics positively, whereas the other ten items pointing the same in negative form. The second part was constructed to check the consistency of the responses between the positive and negative statements of the attitude questionnaire.

Pre-lecture

The mind preparation of the learner is an important step, which allows the perception filter works efficiently. Thus, extra load on working memory is reduced, ultimately it leads to understanding. Pre-learning especially in laboratory work showed considerable improvement in students' understanding (Zaman, 1996, 1998; Safdar, 2010). Keeping in view these ideas, twenty pre-lectures were developed with the assumption that the students will focus internal representations of the on going topics. Hence students' understanding will be built up. For the background knowledge related to each key topic few questions were included. This was for the purpose to prepare the mind of the learner.

A pre-lecture sample on "Rationalization of Binomial Surds" is presented here.

What does binomial mean?

Bi means two. A binomial is an expression having two terms. For example 5x+3, 2x+3y, $3-\sqrt{7}$

What is a surd?

An expression which involves at least one irrational number is called a surd.

$$\sqrt{5}, \sqrt{2}-\sqrt{5}$$

The number in square roots are usually irrational.

What is a binomial surd?

An expression is called a binomial surd if it consists of two terms in which at least one term is a surd. For example $3-\sqrt{7}$, $\sqrt{5}+\sqrt{7}$

What do you get when $(a+b)(a-b)$ = ---------------

What do you get when $\sqrt{3}\times\sqrt{3}$ = -------------

What do you get when $(3+\sqrt{5})(3-\sqrt{5})$ = ------------

What does rationalization mean?

Post-tests

To assess what the students in both groups had learned during the class work, the researcher developed twenty post-tests each of ten marks for the stipulated topics. It was assumed that the post-test would provide a closer overview to the students regarding their performance in the subject of mathematics. It was also assumed that the post-test would provide an opportunity to the students to think critically in analyzing their mistakes, drawing conclusions and develop skills in problem solving.

The post-tests items were developed keeping in view the cognitive domain of the Bloom's Taxonomy. In this way the test items were helpful in assessing students' understanding not only in lower cognitive levels such as knowledge, skills and comprehension but also in higher cognitive levels such as application, analysis, synthesis and evaluation. The development of post-test items on this criterion was quite helpful in assessing how the students focused internal representation of various concepts.

Results and Discussion

The overall performance of the experimental and control groups is compared. There were two phases in this study. The phase-I compares the post-test mean scores of the sample with and without pre-lecture, where as the phase-II compares the mean scores of the said groups in Federal Board Annual Examination (2012). Two students of the control group couldn't appear in Board examamination, therefore, the data analysis was confined to the Board results of 210 students. Table 1 shows the performance of the two groups in both phases. An independent samples *t*-

test was used to compare the mean scores of the two groups in respective phases.

Table 1
Post-test data analysis

Phase	Groups	*n*	Means	SD	*t* value	Probability
I	With	110	5.49	1.19	9.26	$P < 0.001$
	Without	102	3.87	1.35		
II	With	110	52.16	16.78	3.04	$P < 0.01$
	Without	100	44.78	18.36		

The statistical significance appeared as $p < 0.001$ and $P < 0.01$, which clearly indicates that the experimental group performed much better. The results are consistent in very different contexts with the studies of *Johnstone et al, (1994) and (1998), Sirhan & Reid (2001), Zaman (1998), Zaman et al, (2006), Safdar (2010)*, who found a remarkable improvement in understanding using pre-lecture assignments, overtly aimed to reduce working memory overload.

Conclusion

The new teaching approach used in this study improved students' understanding and procedural knowledge in mathematics at secondary level as indicated by post-tests and Federal Board results. The Phase-II results show an increase in performance of both groups in the Board Examination as indicated through lower *t* value. This confirms that Board Examination mainly measure learning at lower cognitive levels such as procedure and recall. Hence, it confirms consistency with *Bashir (2002) and Shah & Afzaal (2004)* studies. Moreover the results are consistent with a similar study of *Safdar (2010)* in the subject of Physics theory and practical. Further it can be concluded that the new method aided to the procedural knowledge of the students.

Discussion

In this study, no changes were made in the content taught, no extra time was given in teaching. However, the experimental group used pre-lecture assignments. Similarly both groups got instruction from same teachers. The pre-lectures were arranged in a more stepwise fashion. The order of presentation was changed by improving signals (see pre-lecture above). The aim was to minimize the demand on working memory. To a greater extent efforts were made to avoid biasness, therefore the indicator of performance for procedural learning was extended to Federal Board Examinations.

Recommendations

The school administrators of the population concerned are suggested to stress internal representation of mathematical concepts to improve students' understanding in this subject and the same can be achieved while keeping in view the information load and students' working memory limitations. This study also explored that the mathematics text-books has a lot of noise in the content. In this way a lot of effort is required by the concerned authorities to make arrangements in order to set the textbooks in accordance with the psychology of the learners. The Federal Board authorities are recommended to focus meaning behind the procedures by making changes in examination system specifically in paper pattern of mathematics at SSC level. This study may be conducted in other science subjects at secondary level in Cantt and other parts of Pakistan to find out the effectiveness of pre-lecture practices on students' understanding and procedural learning.

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Received: Feb, 4th, 2014
Revisions Received: Nov, 2nd, 2014