THE INFLUENCE OF SHORT-TERM AND LONG-TERM MEMORIES IN LEARNING ALGEBRA IN A DISTANCE EDUCATION SYSTEM

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Abstract

This study investigated the influence of short-term and long-term memories in learning algebra for a group of adult undergraduate students undergoing a Bachelor in Mathematics Education course at the Open University Malaysia (OUM). These students were interviewed in order to identify their learning attitude and method which may relate to the short-term and long-term memories. The students' response during the discussion with the tutor and other course mates in a tutorial was also observed. Furthermore, their performance in solving an algebra problem involving the index properties, symbolic representation of exponential function, simplification of polynomial expressions, and forming and solving quadratic equations was studied. The results show that the performance of the students practicing self-learning and elaborative rehearsal is better than that of their typically achieving peers. This study suggested that the short-term and long-term memories greatly influenced the students' achievement on algebra.

Keywords

Short-term memory, long-term memory, algebra, maintenance rehearsal, elaborative rehearsal

1. Introduction

1.1 Role of Algebra

Currently algebra is conceptualized as the branch of mathematics that deals with symbolizing general numerical relationships and mathematical structures and with operations on those structures (Kieran, 1992). Several researchers have proposed that algebra be viewed as a strand in the curriculum from elementary level onwards. Burns (1999) examined an algebra lesson in elementary school and suggested that children will gain valuable skills for future success if they have built a solid foundation in algebraic concepts. National Assessment of Educational Progress evaluated secondary school students in terms of basic algebraic and geometric concepts and skills since that knowledge is important and is a prerequisite in problem-solving situation (Brown *et. al*, 1988). These studies illustrate the important role of algebra. Since a primary responsibility of teachers is to express and explain their understanding of algebra, they should feel comfortable and confident in their algebraic knowledge. Usually, teachers are not only required to understand fundamental algebraic concepts, but also to know algebra at the university level.

1.2 Algebra Learning

This study concentrated on the algebra learning at tertiary level of a group of teacher-undergraduate students at Open University Malaysia (OUM). Many factors constrain algebra learning. Lack of understanding of and practice in using algebraic methods usually are the major causes of the mistakes arising in students' work. However, most students from the teacher-undergraduate group are concerned about the memory factor. Most of them are not satisfied with their poor memories since they have reached middle age. These adult students are primary school teachers who left secondary school a long time ago. They may have forgotten what they had learned of basic algebraic concepts such as pattern, equivalence and variables. Furthermore, they seldom practice nor did they use mathematics at that level in their careers and lives. They feel that they would do better if they could remember well the algebraic concepts, rules and procedures.

1.3 Learning and Memory

Learning and memory are separable domains but one cannot occur without the other. There can be no learning without memory and converse. Learning refers to changes in behaviour and knowledge through experience, whereas memory has been conceptualized in terms of an internal record or representation of some prior event or experience (Purdy *et. al*, 2001). Actually, memory fulfils many functions and holds diverse kinds of information. Memory substantially affects the learning process. Many studies have been conducted to relate the memory and learning. Male (1996) suggested that children without learning disabilities choose specific strategies that reflect more sophisticated memory knowledge. Children with mathematical disabilities depend more on the use of fingers or verbal counting than on recall of answers directly from memory (Swanson & Rhine, 1985). These researchers found that memory play a main role in improving math achievement. Learning may also affect memory. Keeler and Swanson (2001), for example, proposed strategy knowledge that influenced working memory in children with mathematical disabilities. Hence, it may be that adult students could improve their algebra performance if made aware of effective memory strategies. Most of these adult students believe that memory might weaken with age. Some studies suggest that the link between working memory and mathematics ability is stronger in children than in adults (Campbell and Charness, 1990; Geary *et. al*, 1991). Recently this argument has been challenged by Wilson and Swanson (2001). They contend that the links between working memory and computation skill are driven by domain-general as well as domain specific working memory systems and that these links are fairly constant across a broad age range.

1.4 Short-Term and Long-Term Memories in Algebra Learning

Geary (1993) argued that poor working memory resources leads to inadequate representation of arithmetic facts in long-term memory, which in turn leads to poor performance in mathematics. According to Atkinson and Shiffrin (1968, 1971), the human memory system is best conceptualized as a series of memory systems through which information must pass, before the memory of that information can be permanently stored. A basic assumption of this model is that information is processed differently in each of these various memory systems. The purpose of this study is to determine how the process of short-term memory and long-term memory influenced the students' learning and performances in algebra. This may help to overcome the problem of most of the elementary teachers who are not comfortable with their own memories of algebra. Furthermore, they will become secondary teacher who carry a responsibility to build up a solid foundation of algebra for the students as a preparation for more sophisticated work in algebra in the higher level.

2. Short-term and Long-term Memories

2.1 Characteristics of Short-term and Long-term Memories

In the Atkinson-Shiffrin Model, the first time an individual becomes aware of an input is when the input enters the short-term memory store. The decision-making occurs in short-term memory when the person thinks consciously of the information. For this reason, several researchers have called short-term memory the working memory store. Only a limited number of items can be considered at one time since the short-term memory is believed to have a limited storage capacity. Furthermore old information in the short-term store will automatically be displaced by new information. Hence, a short-term trace is fragile and subjected to rapid decay, unless the information is maintained through rehearsal so that the information can be kept permanently in the long-term memory. On the other hand, a long-term trace is more durable over time and has greater memory strength. It is capable of holding as many memories as we can acquire in lifetime. Even so the information can only be transferred into the long-term memory store if the information has been processed in the short-term store.

2.2 Maintenance and Elaborative Rehearsals

Short-term store is the location for conscious manipulation of memories. The capacity for actively processing information is limited, but people are capable of processing selected memories in a variety of ways (Craik & Lockhart, 1972). Maintenance rehearsal refers to storing a memory in conscious awareness for a period of time, whereas elaborative rehearsal involves relating the new information with old information in memory so that it can be recalled for a long time. In fact, elaborative rehearsal involves more effort than maintenance rehearsal. Thus, elaborative rehearsal is conducive to firm memory. This is in line with the suggestion of some of the researchers that the effects of processing level depend on the amount of effort involved in encoding a memory (Craik & Simon, 1980; Ellis & Hunt, 1993).

2.3 Representations of Short-term and Long-term Memories

Usually short-term memories may be represented in term of acoustic codes. Humans even translate visual stimuli into acoustic codes for short-term processing (Sperling, 1960; Conrad, 1964), but humans are also able to use short-term codes of other kinds. If information is not continually rehearsed in a meaningful way, that information will decay over time. Meaningful processing contributes to better retention because it increases the distinctiveness and uniqueness of the memory item. Hence, information in the long-term storage is stored in terms of meaning-based codes. Meaning codes are easily recalled because they are more distinctive. As concluded by Hunt (1995), a distinctive item is remembered at a higher level than category-consistent words occupying the same serial position.

2.4 Cycle in a Memory System

Information will be kept in the long-term memory storage after encoding. Different people store memories in different ways. Some may organize information in systematic ways; some may link information together, some may arrange information in some logical hierarchy. When the memory is searched, information should be remembered, that is, brought to awareness from the recesses of long term memory into a more active and conscious state. There are two factors that may affect the degree of memory activation: strength of the memory representation and effectiveness of retrieval cues. It is easier to remember a clearly represented stored item. Otherwise, a cue is needed to recall a weakly representation from the long-term memory.

3. Research Methodology

3.1 Mediums of Instruction in a Distance Education System

3.1.1 Self-Learning

In the distance and tutorial web based system adopted by the Open University of Malaysia (OUM), students were supplied with a learning module as a material for self-learning. Self-learning is defined as a condition where the student understands and encodes particular information based on available resources without the lecturer's or tutor's guidance.

3.1.2 Tutorial and Online Discussion Sessions

A module consists of five units, one unit of which is discussed between a tutor and students in a tutorial session. Since the tutorial session is conducted every fortnight, the students have two weeks' time to study and prepare before attending the tutorial. They can clarify their doubts with their tutor in the tutorial session or in online discussion session with the facilitators. A half-hour quiz based on the content of that unit was given at the end of the tutorial. This quiz was administered in order to evaluate the improvement of the students on a certain topic.

3.2 Algebraic Concepts

The investigation of this study was focused on the topic of algebra and in particular on a question posed on the quiz: $5^{x^2} - 25^{6-2x} = 0$. Based on this question, the index properties, symbolic representation of exponential function, simplification of polynomial expressions, and forming and solving quadratic equations were discussed. In addition, some basic concepts were also examined such like pattern, equivalence and variables.

3.3 Adult and Distance Learners

A group of adult undergraduate students undergoing a Bachelor in Mathematics Education course at the Open University Malaysia (OUM) were focused. Then, 20 students from a selected class were interviewed in order to investigate their learning process or learning attitude. Their responses during the discussion in the tutorial and their performance in the quiz were observed.

4. Learning Styles

From the result of interview, the 20 students can be categorized into three groups:
Group 1: 12 students involved in self-learning and elaborative rehearsal.
Group 2: 3 students involved in self-learning and maintenance rehearsal.
Group 3: 5 students were not involved in self-learning.

Fifteen students (Groups 1 & 2) had studied the provided module before they attended the tutorial. When they first read the interpretation of index for a to the index n, which is written as $a^n = \underbrace{a \times a ... \times a}_{n \text{ times}}$, they attempted to repeat it to themselves. The visual information is transformed into sounds or acoustic codes once the interpretation of index has entered the short-term memory. The three students from Group 2 apparently engaged in the repetition of the to-be-remembered item over and over in short-term memory. The students in Group 1 managed their rehearsals by relating the interpretation of the index to several examples, such as $2^1 = 2$, $2^2 = 2 \times 2 = 4$ and $2^3 = 2 \times 2 \times 2 = 8$. Likewise, the index properties were also processed by the Group 1 students by substituting numbers for indices. Specifically, the structure of the algebraic expression $\left(a^m\right)^n = a^{mn}$ was described as $\left(2^3\right)^2 = 8^2 = 64 = 2^6$. Thus, this index property was highly distinctive. By doing this, a set of distinctive memory codes were formed. The more distinctive an item to be encoded, the more effectively it will be distinguished from other representations. Moreover, a meaningful item is more memorable because it is distinct.

5. Discussion during Tutorial Session

In the discussion during the tutorial session, all Group 1 students still remembered the interpretation of index and the index properties, whereas the three students from Group 2 were unable to recall the information on index and index properties. The way an individual chooses to process short-term memories determines the likelihood of these memories being stored permanently in long-term memory. The three students from Group 2 had lost their memories from short-term store simply because they have ceased rehearsing the information. In addition, the meaning code representations are longer lasting than physical-feature codes.

6. Performance in Index Problem Solving

In solving the selected problem in the quiz, only six out of twenty students had completed their solution from the first step to the final answer whereas the rest stopped halfway or made some mistakes (Appendix 1). Half of the students from Group 1 were well aware that they had stored the information of index in their long-term memory. In the interview, they could easily show three index properties and apply them in different situations. They could differentiate these properties since they had encoded these items distinctively. Some of them even could sketch out representations of these index properties in their mind in a flow chart (Appendix 2). The others were not confident of remembering all the index properties they have learned. Nevertheless, they were able to apply index properties when simplifying the index equation $5^{x^2} - 25^{6-2x} = 0$ to a quadratic equation. Actually, they did not organize their memories of this information, but they had become familiar with it through exercising.

6.1 Step 1: Index Interpretation

All of the students from Group 1, one student from Group 2 and three students from Group 3 were able to express $5^{x^2} - 25^{6-2x} = 0$ as $5^{x^2} - (5^2)^{6-2x} = 0$, where $(5^2) = 5 \times 5 = 25$. The student from Group 2 realized that maintenance rehearsal reflects a poor memory, which was shown during the discussion in the tutorial. Thus, at the same time he had tried to rehearse the information of index at a depth processing level by practicing it in solving some questions in the exercise. This allows that item to be transferred and stored in the long-term storage. In contrast, two students from Group 2 who did not process information meaningfully made the mistake by expressing $5^{x^2} - 25^{6-2x} = 0$ as $5^{x^2} - (5^5)^{6-2x} = 0$. In fact, $(5^5) = 5 \times 5 \times 5 \times 5 \times 5 = 3125$. The correct expression should be $(5^2) = 5 \times 5 = 25$. Due to the weak memory representation of index interpretation, they have recalled the previous information on the multiplication of the arithmetic, that is $5 \times 5 = 25$. This situation is caused by interference where the competition of earlier learning with later learning occurred.

All of the students from Group 3 first encounter the interpretation of index during tutorial session. Only three students from this group have put some effort to apply the index interpretation in a numerical situation ($(2)^3$, $(-3)^2$, (4^2), ...). Usually, effort and memory are closely linked. The more capacity used and the much time spend on to encode a data, the better the data will be recalled. Therefore their retention is improved through a deeper processing.

6.2 Step 2: Index Properties

The one student from Group 2 and three students from Group 3 had had no chance to practice the other algebraic concepts during the tutorial session because the time was limited. Due to limited short-term memory capacity, the old information would be displaced by the other incoming information. For this reason, these students were forced to stop their solution at the first step. Some may not have recalled the information index properties and some were confused with so many index properties. For example, one student expressed $5^{x^2} - (5^2)^{6-2x} = 0$ as $\frac{x^2}{6-2x} = 0$. The index property of $(a^m)^n = a^{mn}$ became an unrecognizable representation and the student failed to distinguish that property from the other index property, $a^m \div a^n = \frac{a^m}{a^n} = a^{m-n}$.

Four students were unable to attempt solution of the problem. In the interview, they said that they knew that they should apply the index properties and their mind was full with symbolic representation of index properties. But they failed to recall the right one. This is due to the limited capacity of short-term memory. They had registered one representation of index interpretation in short-term storage, and when the other representation of index properties was formed, the second representation tended to displace the first representation from the storage. Whenever multiple representations of index properties reside in short-term storage at the same time, these representations tend to alter or distort each other. The more representations were formed, the harder it is for a target memory to be recognized.

6.3 Step 3 – 5 : Equivalence

Algebra is sometimes referred to as generalized arithmetic since it is based on the writing of general statements representing given arithmetic rules and operations (Booth, 1984). This was shown when students needed to judge equivalence without computing. In particular, add 5^{12-4x} at both of the side of $5^{x^2} - 5^{12-4x} = 0$ so that $5^{x^2} = 5^{12-4x}$. Next, compare both of the sides since the equal sign as an induction that quantities have the same value. Then get $x^2 = 12 - 4x$ because the bases at both sides are the same. Eight students from Group 1 obtained a quadratic equation in the form of $x^2 + 4x - 12 = 0$ whereas the rest produced $x^2 + 12 - 4x = 0$. Due to the lack of awareness of equivalence, these students tended to transform the expression into an incorrect equation. They have noticed a similar solution without any practicing. Thus, an item encoded at a shallow level reflects a failure to activate or maintain that information in storage.

6.4 Step 6 – 7 : Solving Quadratic Equation

Three methods can be used to solve a quadratic equation. 6 students successfully factorized the obtained equation to $(x+6)(x-2)=0$. Then, they found the solution to this index expression as $x=-6$ atau $x=2$. They had practiced the factorization method for several quadratic equations. This memory was highly retrievable since it had been used many times. The understanding of the method was improved and a strong representation in the long-term memory was created. The strength of the memory representation was weak for the other two students who factorized $x^2+4x-12=0$ as $x(x+4)=12$. A student always relates two sets of brackets to the procedure of factorization of a quadratic equation. This cue was presented to help him reinstate the memory trace or access previously forgotten information.

7. Conclusion

This study investigated the influence of short-term and long-term memories on algebra learning. The present study produced two results on this issue. First, students involved in self-learning and elaborative rehearsal performed better in the discussion during the tutorial session and showed excellent achievement when solving an index problem in the quiz. In contrast, students involved in self-learning and maintenance rehearsal, along another group of students that did not engage in self-learning, failed to recall the related information in the discussion during the tutorial session and were unable to gain a score in the quiz. The performance of students that did not apply self-learning is approximately the same as the performance of students involved in self-learning and maintenance rehearsal. This shows that students practicing effective working memory strategy may achieve adequate representation of algebraic concepts in long-term memory, consequently resulting in good performance in the quiz. Contrarily, the information is failed to be stored in the long-term memory if that information does not process well in the short-term memory. Long-term memory provides important information for the students and therefore promises a good mathematics result. Nonetheless information may not be maintained or kept in the long-term memory without effective and actively processing in the short-term memory. In summary, the effectiveness of algebra learning may only occur when the algebraic concepts, rules and procedures have been completely processed in short-term memory and consequently stored in the long-term memory.