FORM TWO STUDENTS' IDEAS OF SOLVING ALGEBRAIC EXPRESSIONS: A CASE STUDY AT SECONDARY SCHOOL IN SARIKEI DISTRICT.

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This project is submitted in partial fulfillment of the requirements for a
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ABSTRACT

FORM TWO STUDENTS' IDEAS OF SOLVING ALGEBRAIC EXPRESSIONS

Wong Huang Yew

This research is carried out to investigate Form Two students' ideas of solving Algebraic Expressions. Algebraic Expressions is defined as Mathematics objects with one or more variables together with other components such as number and signs. Algebraic Expressions is second topic in Form Two Mathematics syllabus and every student has to learn the topic. This research is to investigate what are the students' ideas in solving the questions about Algebraic Expressions. Data collection involves three types of data collected, they are think aloud data where students talk aloud what they think while solving the questions given, written documents and interviews data. Six questions from topic Algebraic Expressions are chosen and used to investigate Form Two students' ideas of solving Algebraic Expressions. The analysis of the collected data indicated that there were common ideas used by the students. The ideas are categorized into ideas that are relevant and not relevant to standard Mathematics views. The findings generate thirty two models of Form Two students' ideas of solving Algebraic Expressions. This research benefits teachers, students and Mathematics education.

ABSTRAK

IDEA-IDEA PELAJAR TINGKATAN DUA DALAM PENYELESAIAN UNGKAPAN ALGEBRA

Wong Huang Yew

Kajian ini dijalankan untuk mengenalpasti idea-idea pelajar Tingkatan Dua dalam menyelesaikan soalan yang berkaitan dengan topik Ungkapan Algebra. Ungkapan Algebra didefinisikan sebagai objek Matematik yang mempunyai satu atau lebih komponen lain seperti nombor dan tanda-tanda Matematik. Ungkapan Algebra merupakan topic kedua dalam Sukatan Pelajaran Matematik Tingkatan Dua dan semua pelajar perlu mempelajari topic tersebut. Kajian ini bertujuan mengenalpasti idea-idea yang ada pada pelajar semasa pelajar tersebut menyelesaikan soalan-soalan mengenai Ungkapan Algebra. Dalam proses pengumpulan data, pengkaji menggunakan tiga jenis cara iaitu cara '*think aloud*' di mana pelajar tersebut harus bercakap tentang pemikirannya semasa menyelesaikan soalan-soalan yang diberi, dokumen bertulis dan temubual. Enam soalan daripada topik Ungkapan Algebra dipilih dan digunakan untuk mengenalpasti idea-idea pelajar Tingkatan Dua dalam penyelesaian soalan-soalan tersebut. Daripada analisis dapatan data, pengkaji mengenalpasti beberapa idea yang sama dalam kalangan pelajar tersebut. Idea-idea tersebut dikategorikan dalam dua kumpulan iaitu idea yang releven dan tidak releven kepada pendapat standard Matematik. Hasil kajian membolehkan pengkaji menghasilkan tiga puluh dua model tentang idea-idea pelajar dalam penyelesaian soalan-soalan yang berkaitan dengan Ungkapn Algebra. Kajian ini memberi manfaat kepada guru-guru, pelajar-pelajar dan juga pengajian Matematik.

CHAPTER 1
INTRODUCTION

1.1 Introduction

Education is very important as it determines the status of Malaysia and its socioeconomic development. The realization that an adaptive and educated populace is essential to Malaysia's push for knowledge based economy has led to the adoption of various strategies in the educational sector (Yahya Abu Hasan, 2000). Many plans have been structured, such as ninth Malaysia plan with the slogan "Education for Everyone" in order to become a developed and educated residents by the year 2020. Today's teaching and learning environment has changed from traditional 'chalk and talk' by teacher to inculcating technology in Mathematics teaching. According to Yahya Abu Hasan (2000), Malaysians put a lot of efforts to fast forward the education sector to be in line with other developed nations.

For the education system in Malaysia, children with ages 7 – 12 will enter primary school and complete the study after UPSR. The result of UPSR is the determinant to attend secondary school, with the age 13 – 17. After going through the public examinations, the student has options to enter workforce or institution of higher learning or university. In primary school, education emphasizes on reading, writing and understanding. Children can say more than they realize and it is through the understanding of what is meant by what was said their cognitive skills develop (Sutherland, 2007). In secondary school, there are various changes in the syllabus, and more innovative techniques had been tried in the class. Schools emphasize on discrete mathematics like statistics and linear programming, but now they are more to using software in solving mathematical problems (Yahya Abu Hasan, 2002).

According to Osman, Salihin and Lazim (2003), *"the uniqueness of mathematics and the reluctance of people to go in-depth about mathematics seem related to the way they perceive and believe what mathematics is all about"*. Students' belief in Mathematics will judge their behavior towards the whole idea of Mathematics. Osman, Salihin and Lazim (2003) defined 'belief' as personal principles constructed from an individual's experience and often unconsciously interpret new experiences and information. Students' belief plays a significant role in directing human's perceptions and behavior where it can shape their cognition and thinking processes in the classroom. Behavior of the students during learning processes will greatly affected the knowledge acquisition of Mathematics. In Mathematics learning, students' belief about the nature of Mathematics and factors related to the learning are two components that are always the main concerned of Mathematics educators (Osman, Salihin & Lazim, 2003).

Students learn Mathematics in school for many possible purposes. The possible purposes could be about learning to become informed citizen, or learning to be grateful for mathematics that always growing along to twenty-first century, for example in the growing of computer games industry (Sutherland, 2007). Besides, it could be about education for the world of work, for higher education after the school or about education for everyday life. One of the most important elements in learning Mathematics among Malaysians is its importance as a passport either for higher institutions acceptance or to guarantee a better paid job in government or private sectors (Marzita Puteh, 2002). Hence, parents should encourage their children to engage in Mathematics and to achieve excellence in this field.

1.2 Background of Study

Mathematics is rooted in the human cognitive structure and should be treated as a developmental discipline with an empirical component that free with its essentially theoretical and speculative bases (Kaufmann & Nuerk, 2005). Mathematics, because of its abstract nature, is applicable to almost any discipline, since it identifies patterns that are common to many different areas. It originated as a systematization of the solutions of practical problems in areas, such as land surveying, construction, war and commerce. It is fundamental, not only too much of science and technology, but also to almost all situations that require an analytical model-building approach, whatever the discipline. In recent decades, there has been an explosive growth of the use of Mathematics in areas outside the traditional base of science, technology and engineering, for example, in finance, biology and computer science.

There are several overviews about current issues and future development in numerical development. Firstly, children already master the core concept of numerical, such as magnitude, counting and number conservation before they are exposed to explicit school mathematics (Kaufmann & Nuerk, 2005). There is evidence that few months old infants are capable of discriminating small sets of objects and 11 months old infants do demonstrate ordinal numerical knowledge (Kaufmann & Nuerk, 2005). Because of this, some researchers believe that numerical development correlated with the genetic of child but this issue is not resolved until today.

Secondly, some researchers claimed that arithmetic ability constitutes a specific cognitive domain that dissociates from linguistic ability. There is converging evidence that some aspects of arithmetic are associated with specific language skills (Kaufmann & Nuerk, 2005). The example provided by Kaufmann and Nuerk (2005) is that when a child solves a simple mental calculation, she starts counting verbally and counting her fingers. Finger counting strategies are important in order to understand numbers and simple calculations (Kaufmann & Nuerk, 2005). This concluded that Mathematics learning cannot stand alone without cognitive domain.

Another issue is about the order of acquisition of numerical abilities. According to Piaget and post-Piagetian researchers, arithmetic development follows a hierarchical sequence of acquisition (Kaufmann & Nuerk, 2005). This means that specific numerical skills should be mastered before others. This was argued by a research which tested the hypothesis that acquisition of multiplication facts interferes with previously learned addition problems (Kaufmann & Nuerk, 2005). The result shows that addition performance deteriorated after multiplication knowledge was established. They concluded that acquisition of new skill is not based on previously mastery skills but depends on capabilities learned earlier in life (Kaufmann & Nuerk, 2005).

In this case study, the researcher discusses Human Information Processing Model. According to Dwyer (1987), additional information flowing through several sensory channels from environment likes haptic, visual, and auditory will provide a multiplicity of stimuli that assists learners to organize and structure their perceptions, thereby ensuring more complete learning. Students receive some information from their direct physical experience as interface with the immediate environment, such as school and classroom, and others experienced through media, such as films and television program, or through symbolic modes such as words or figures. The information or knowledge that students learned will enter the process of information processing. It explains how students obtain information, store, and sort; organize the information and how they retrieve such information when it is needed. This could be clearly defined in some models of human information processing like Atkinson and Shiffrin (1968) models that would be discussed next.

1.2.1 Theories of Human Information Processing

There are a lot of scientific research on human memory and how human process information. According to some researchers, quantity processing is controlled by parietal brain regions (Kaufmann & Nuerk, 2005). Kaufmann and Nuerk (2005) projected that number processing is mediated by three parietal circuits which are (i) the horizontal segment of the intraparietal sulcus which mediating numerical quantity processing, (ii) the left angular gyrus managing verbal counting, verbal retrieval of number facts and (iii) bilateral posterior superior parietal system which manages attention and spatial orientation. A research done upon training monkeys in time discrimination tasks found that there was increased blood flow in parietal regions. This concludes that parietal regions play important role in time and magnitude perception.

One of the most influential researches on human memory and information processing is multi-store model that was proposed by Atkinson and Shiffrin in 1968. The model is also called as modal model or the dual process model. They suggested that memory is made up of a series that contains three stores which are the sensory memory, short-term memory and long-term memory.

Atkinson and Shiffrin (1968) describe human memory by using the *"flow of the information through the system"*. An incoming stimulus item first enters the sensory buffer where it will reside for only a brief period of time and then transferred to the memory buffer (Atkinson & Shiffrin, 1968). The sensory buffer as the initial input of the stimulus item into the nervous system and the amount of information transmitted from the sensory buffer to the memory buffer is assumed to be a function of the exposure time of the stimulus and related variables. While the information enters human processing system via channels that connect to human sense organs, the information will not be processed immediately. The information has to be stored at a temporary store before being dealt with at higher levels of processing. Sensory memory is the store for storing the sensory information. Information flows from the environment through a series of very brief sensory memories that are perhaps best regarded as part of the perceptual system and into a limited capacity short-term store (Atkinson & Shiffrin, 1968). If the information is attended, it will enter another store called short-term memory. The information will only enter the store when human is conscious about the information and can work with it (Atkinson & Shiffrin, 1968). The information then enter long-term memory with condition, the information is rehearsed. Otherwise, the information will be forgotten by displacement or decay.

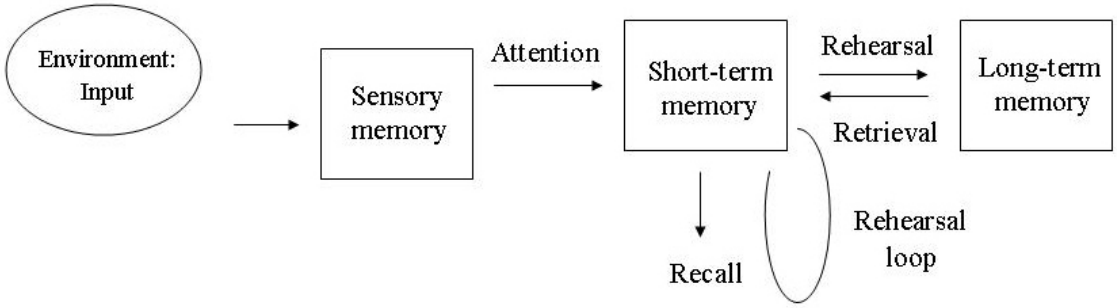

Figure 1 Human Information Processing (McLeod, 2007)

Cited from http://www.simplypsychology.pwp.blueyonder.co.uk/index.html

(a) Sensory memory

The environment output, such as light, sound, smell, heat and cold are transformed by special sensory receptor cells to electrical energy that will be only understood by the human brain. The result of this transformation or change, a memory is created. This memory is very short, less than ½ second for vision; about 3 seconds for hearing (Huitt, 2003). Huitt (2003) posited that information is attended in order to transfer it to short term memory based on two major concepts. First, individuals are more likely to pay attention to a stimulus when it is interesting. Second, individuals are more likely to pay attention if the stimulus activates a known pattern. For example, a teacher always requires students to recall relevant prior learning before a class starts.

(b) Short term memory

Short term memory is also called working memory and it is created when paying attention to an external stimulus, an internal thought or both. Short-term memory initially last somewhere around 15 to 20 seconds unless it is repeated or called as maintenance rehearsal at which point it may be available for up to 20 minutes (Huitt, 2003). For example, while answering questions in an exam, the information must be brought into working memory to be manipulated, and then the answers are generated from working memory. According to Huitt (2003), short-term memory is of central importance in the memory process, because short term memory is in many respects the "bottle-neck" of the memory process. It is very limited in terms of both its capacity and amount of information it can hold and duration which is the length of time it can hold information.

(c) Long term memory

Med Terms Dictionary (2004) defines long term memory as *"a system for permanently storing, managing, and retrieving information for later use"*. Items of information stored as long term memory may be available for a lifetime. Anderson and Mayer (1990) posited that long term memory is of three different types which are (i) episodic memory, (ii) semantic memory and (iii) procedural memory. Episodic memory refers to human ability to recall personal experiences from the past. For example, recall certain incidents that happened during childhood, what was NTV7 program shown last night; all of these employ long term episodic memory where the information is stored as images. Semantic memory stores information in networks or schemata. Schemas are mental models of the world. Information in long term memory is stored in interrelated networks of these schemas and the related schemas are linked together, and information that activates one schema also activates others that are closely linked (Clark, 2004). This makes human easily retrieve information when information is needed and it also helps to accept and store additional information in the future. Procedural memory refers to the ability to remember how to perform a task or to employ a strategy (Anderson & Mayer, 1990). Procedural information is stored in steps, while retrieving the information from procedural memory involves retrieving just one step and that will trigger another step until whole information is retrieved.

1.2.2 Conceptual and procedural knowledge in Mathematics

Conceptual knowledge is “an integrated and functional grasp of mathematical ideas” (Rittle-Johnson & Star, 2007). This knowledge is flexible and not ties to specific problem types and is therefore generalizable although it may not be verbalizable. Star (2000) define conceptual knowledge or declarative knowledge as the knowledge of facts, the meanings of symbols and the concepts and principles of a particular field of study. They posited that this kind of knowledge is rich in relationships. Pieces of knowledge, existing knowledge about the field and learned skills are connected together in this knowledge. The relationships encompass individual facts and propositions in order to link all pieces of knowledge of certain field of study together (Star, 2000).

Procedural knowledge is defined as the ability to execute action sequences to solve problems, including the ability to adapt known procedures to novel problems (Rittle-Johnson & Star, 2007). The procedures are step-by-step, sequentially ordered and deterministic instructions for how to solve a given task. Star (2000) describe procedural knowledge as *"composed of the formal language, or symbol representation system ...and the algorithms, or rules, for completing mathematical tasks"*. They continue to assert that procedural knowledge is meaningful only if it is linked to a conceptual base. Students learn mathematics by understanding the concepts of a topic and try a lot of examples in textbooks in order to master the concepts without considering which knowledge comes first. This is supported by Star (2000) who agreed that knowledge of concepts and knowledge of procedures are positively correlated and that the two are learned in tandem rather than independently.

Both procedural knowledge and conceptual knowledge are the knowledge that involved in mathematics learning. In the recent research, according to Schneider and Stern (2006), mathematics learning frequently involves conceptual knowledge that provides an abstract understanding of principles and relations between pieces of knowledge in a certain domain, while procedural knowledge enables learners to solve problems effectively. Alibali (2001) explains knowledge based on two theories which are (i) concept-first theory and (ii) procedures-first theory. For concept-first theory, students will listen to the explanation from teachers, understand the concept, practice it, and derive procedural knowledge from it. According to procedures-first theory, students will initially acquire procedural knowledge by trial-and-error for instance, and then gradually learn the concept by reflection.

The third possibility is the Iterative Model which believed that there must be links between conceptual and procedural knowledge (Schneider & Stern, 2006). A research which was done by measuring students' conceptual and procedural knowledge in mathematics before and after an intervention found that students' initial conceptual knowledge predicted gains in procedural knowledge, and gains in procedural knowledge predicted improvement in students' conceptual knowledge (Schneider & Stern, 2006).

New York State Education Department (2005) distinguishes conceptual and procedural knowledge in Mathematics as follow:

"Conceptual understanding consists of those relationships constructed internally and connected to already existing ideas. It involves the understanding of mathematical ideas and procedures and includes the knowledge of basic arithmetic facts. Students use conceptual understanding of mathematics when they identify and apply principles, know and apply facts and definitions, and compare and contrast related concepts. Procedural fluency is the skill in carrying out procedures flexibly, accurately, efficiently, and appropriately. It includes, but is not limited to the step-by-step routines needed to perform arithmetic operations."

(Schneider & Stern, 2006)

From the research, both conceptual and procedural knowledge are important in mathematics learning and increase in one knowledge then increase in the other knowledge (Schneider & Stern, 2006).

According to Engelbrecht, Harding and Potgieter (1999), learning begins with actions on existing conceptual knowledge. Students solve mathematics task by internalizing the procedures that are involved. Thus, conceptual knowledge changes to procedural knowledge. The process of changes depends on the existing concept in their knowledge and the conceptual knowledge exists based upon repeated use of procedures. Conceptual knowledge and procedural knowledge are always link together.

1.2.3 Algebraic Expressions

Lim and Noraini Idris (2006) defined algebra as a tool for problem solving, a method of expressing relationship, analyzing and representing patterns and exploring mathematical properties in a variety of problem situations. Algebra provides a reasonably accurate way to measure students' mathematical knowledge towards other mathematics concept, such as number and space (Chinnappan & Thomas, 2004). Christou, Vosniadou and Vamvakoussi (2007) defined an algebraic expression as *"a mathematical object that contains one or more variables together with other symbols, such as numbers or signs"*. Algebraic expressions involve two important knowledge which are algebra knowledge and basic mathematical knowledge, such as addition, subtraction, multiplication, division and fraction.

In the past, algebra was an important knowledge that should be learned by learners as it represents students' first sustained exposure to the abstraction and symbolism that makes mathematics powerful (Rittle-Johnson & Star, 2007). However, algebra is difficult for most school students (Banerjee & Subramaniam, 2005). The researchers posited that students' difficulty in algebraic expressions solving correlated with their algebraic solving abilities and their ideas of concept of algebraic expressions.

1.2.4 Central Feature of students' ideas of solving Algebraic Expression

In learning algebra, student faced the difficult task of assigning meaning to new symbols and assigning new meaning to old symbols that are used in the context of arithmetic (Christou, Vosniadou & Vamvakoussi, 2007). When students connect an algebraic expression with literal symbols to the world of numbers, they would give a referential meaning to the algebraic expressions which will affect their performance in other mathematical tasks (Christou, Vosniadou & Vamvakoussi, 2007). The researcher suggested that a number of misconceptions that students have with the used of literal symbols in algebraic expressions is the result from the inappropriate transfer of prior knowledge about numbers in arithmetic to interpretation of literal symbols in algebra.

There are differences about natural numbers in arithmetic and literal symbols in algebra. In arithmetic, numbers are expressed in a series of digits such as 1, 2, 3, 4…, whereas variables are expressed as letters, such as a, b, x, and y (Christou, Vosniadou & Vamvakoussi, 2007). Natural numbers are positive numbers as they are not assigned negative sign that is attached to a number. On the other hand, variables may have a *"phenomenal sign"*, that is, the variables can be negative or positive based on the specific numbers that are substituted for the literal symbols (Christou, Vosniadou & Vamvakoussi, 2007).

Natural number has its uniqueness in symbol representation whereby different symbol represents different number (Christou, Vosniadou & Vamvakoussi, 2007). For example, 3 stand for number three only. On the other hand, literal symbol in algebraic notation could stand for a range of real numbers. For example, literal symbol x could represents any real numbers such as 5, 0.001, or $1\frac{1}{2}$. By these, Christou, Vosniadou and Vamvakoussi (2007) predicted that incompatibility between the use of literal symbols in algebra and students' prior knowledge of numbers would result errors. The errors could be explained by students' tendency to use their prior knowledge of number in arithmetic to interpret literal symbols in algebra (Christou, Vosniadou & Vamvakoussi, 2007).

1.2.5 Students' ideas of solving Algebraic Expressions

Kriegler (2007) in his article *Just what is Algebraic thinking* defines students' ideas of solving algebraic expression as the development of mathematical reasoning within an algebraic frame of mind by building meaning for the symbols and operations of algebra in terms of arithmetic. Students' understanding of the concept of variable and expression; represent situations and number pattern with tables, graphs, expression or equations, and explore the interrelationships of these representations; analyze it and apply algebraic method to solve a variety of related mathematical problems and the real-world problems.

According to Lim and Noraini Idris (2006), *"the introduction and development of algebraic solving abilities can be viewed from different approaches such as generalization, modeling and functional"*. In generalization approach, Lim and Noraini Idris (2006) posited that students develop ideas of solving algebraic questions when they are engaging in the investigative processes, such as i) finding a pattern ii) generalizing a formula by using algebraic symbols, and iii) applying the formula to solve the problem (Lim & Noraini Idris, 2006). In modeling approach, the pictorial representation is used to analyze the relationship among the quantities in a problem. Modeling approach consists of two phases where the first phase involves the investigation of some relationship between variables. The second phase is about series of mathematical transformations or operations that lead to an expressed model such as symbolic expressions, graphs or tables (Lim & Noraini, 2006). On the other hand, functional approach involves the representation of variables as quantities with changing values for different function rules (Lim & Noraini, 2006). The application of these approaches to algebra would provide concrete model and concrete experience that can leads to better understanding of the algebra concept and connect the experience with the abstract symbolic algebra (Lim & Noraini, 2006).

1.3 Problem Statements

One of the difficulties in learning Mathematics is the abstract nature of Mathematics. According to Konyalioglu et al. (2003), *"since mathematical concepts are abstract, students learn mathematics by memorizing. One of the most important problems associated with the teaching of mathematics is raised from the students' understanding difficulties in establishing the relationship between their knowledge and intuition about concrete structures and abstract nature of Mathematics"*. In mathematics learning, it is hard to find concrete examples of mathematical concepts.

In order to carry out this study on the Form Two students about their ideas of solving algebraic expressions, the researcher did some observations during his teaching practice in the school. Students did not know how to simplify an expression in the correct form or a more simplified form. Some students oversimplified the questions until they are evaluating the expressions even though the questions asked for simplification. According to Hall (2000), equations with a solution by line beginning "variable =", a student will know this signifies the end of the problem. But when there are several mathematically satisfactory places to stop the simplification on particular expression, several pupils evaluating the answer, breaking the concept of simplification of algebraic expression. Students may continue simplification until they arrive at one acceptable answer for them (Hall, 2000).

Apart from that, when the questions are in different structure, students are easily confused. According to Tall and Razali (1993), symbol manipulation and procedural skill among secondary school students might serve to prolong the interpretation that algebra is an area of disconnected rules to deal with different contexts (Lim & Noraini, 2006). For example, a question asked *"There are 65 chalks in a box, Aini takes k chalks. Rani takes 2k chalks. And, Marry takes* k^2 *chalks. How many chalks are left in the box? Form an algebraic expression and simplify it."* Students were unable to write the expression based on the question, instead of giving direct question as *"Simplify* $65\text{-}k\text{-}2k\text{-}k^2$*"*.