The Use of Study Strategies on Mathematical Problem Solving

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Abstract

The study focused on differentiating the study strategies (deep, surface, and disorganization) on different cognitive skills in a mathematical problem solving test. Participants included 300 high school students from different high schools in the National Capital Region (NCR) in the Philippines. The participants were given the Students' Study Strategy Questionnaire and a mathematical problem solving test. The One-Way Analysis of Variance (ANOVA) revealed that there were no significant differences on the usage of the three study strategies on the students' mathematical problem solving across different cognitive skills. All study strategies were equally useful in solving different cognitive skills in mathematics. Surface approach was found to be functional for problems that require evaluation skills.

Keywords: Study strategies, mathematical problem solving, cognitive skills

Introduction

In the process of acquiring knowledge, individuals develop and make use simple to complex learning strategies to process information which is an integral part of mental development. In order for individuals to learn effectively, they use various methods and strategies in order to process information at a certain time frame (Sternberg, 2003). A study strategy or learning strategy is utilized depending on the preference and the way an individual approach a given problem (Kay & LeSage, 2009). According to Elliot, McGregor, and Gable (1999), there were three types of study strategies: (1) Deep processing, (2) surface processing, and (3) disorganization. Individuals who use deep processing analyze the deeper meaning of what is being studied (Craik & Lockhart, 1972). A person is considered a surface processor when one simply memorize and rehearse things that he/she is trying to learn (Veenman, Prins, & Verheij, 2003). Lastly, disorganization is seen when an individual is unable to organize one's thoughts and keep a well-structured approach during one's learning (Bandalos, Finney, & Geske, 2003). The three study strategies, or learning strategies are utilized in various ways depending on who used them and the situation. Most often than not, the use of these strategies were more clearly seen in the way students fulfilled their academic requirements. An important difference between a successful student and the student who is struggling is the way they go about learning (Protheroe, 2002). Students who are able to use study strategies effectively are able to be more successful academically. Study strategies have also served as tools to determine the strengths and needs of a certain student.

In a survey of literature done by Bandalos, Finney, and Geske (2003), it was determined that there were very few studies investigating the

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connection of cognitive skills including problem solving and the use of study strategies to the success rates of students. An individual's cognitive style influenced their performance and achievement in learning (Riding & Rayner, 1998). The ease by which an individual solved problems also depended on the study strategy employed. According to Leahey and Harris (1997), a problem occurs when there is a gap that separates a person from his goal. Problem solving is present in several aspects of life, from games to real life puzzles. Zaslavsky (1998) explained that if students were able to connect what they have learned inside the class to the events outside, they are able to better maintain and appreciate information.

Problem solving is also clearly seen in mathematics. In this subject, students are usually asked to comprehend a question, extract the necessary details and form a solution to get the correct answer. To obtain the proper answer, it is important for students to be able to make use of his metacognitive techniques.

The present study investigated the differences of deep, surface and disorganized strategies in solving mathematical problems. Most commonly, studies that used mathematics as dependent measures of study strategies are tested on a single array of domain and generalizations are made for mathematics in general. The present study further looked at the separate effects of study strategies on different cognitive skills in mathematics problem solving using Bloom's taxonomy: Remembering, computation (understanding), applying, analyzing, evaluating, and creating (Byrd, 2002).

Study Strategies

A strategy is a method that would be able to provide some solution to a problem and give information (Best, 1999). Learners make use of strategies in order for them to be able to learn effectively. Study, or learning, strategies were defined by Weinstein and Mayer (1986) as behaviors or thoughts that a learner goes through during the learning process, and that can affect one's encoding, storage, organization and retrieval of knowledge. According to Elliot, McGregor, and Gable (1999), there are three study strategies that students utilize. These three strategies were the deep processing, surface processing, and disorganization. Deep processing is referred to as the understanding of meanings and grasping connections between concepts. Surface processing, on the other hand, involves rote learning or simple memorization. Lastly, disorganization refers to the study strategy that did not follow any structure in learning.

Study strategies were important in understanding problem solving because individuals utilize several strategies in order to come up with a solution to a problem. It is important for an individual to be aware of what strategies to use to solve a given problem due to the fact that some strategies were able to generate answers easier if used correctly. When a person makes a mistake in solving problems, they need to reorganize the information available to oneself and then proceed to attempt in solving problems (Catania, 1998). Like mentioned before, study strategies are used in gauging whether or not individuals will have an easy or hard time in solving various types of problems. However, it was said that not all strategies are useful, or considered the best (Alvermann & Moore, 1991; Anderson & Armbruster, 1984; Devine, 1991). On the other hand, Salovaara (2005) said that the proficient use of learning or study strategies included the easy shifting among the different study strategies and the application of its flexibly in compliance with the demands of the given task. Furthermore, Purdie, Hattie, and Douglas (1996) stated that learning a particular task required a different type of study strategy. One strategy could be used to solve problems better in some particular tasks while it could not be effective in other tasks.

The study strategies model by Elliot, Gable, and McGregor (1999) focused on three types of study strategies, namely deep processing, surface processing and disorganization. This model was used in the present study because of the appropriateness of the content of high school students.

Deep Processing. Deep processing is used when students understand the information that are being studied, while keeping in mind that the small details they received are aids in solving the problem successfully (Biggs, Lai, Tang, & Lavelle, 1999). A deep processor is somebody who look profoundly into the subject matter, analyze them thoroughly and then tries to apply previous knowledge to accomplish his task (Entwistle, 2002). Deep processing is important in problem solving because it allows an individual to use previously learned concepts to find solutions for new problems, especially if the previously solved problems and the new ones have similar characteristics.

For some students, deep processing is strengthened by the fact that it entailed more time in pursuing their own interest since they go through good time management (Prosser & Trigwell, 1999). It can also be a positive experience in education that leads confidence in one's ability to understand and succeed. In addition, deep processing can be seen when one was determined to do well and be mentally occupied in their academic work for the reason that students would be intrinsically curious in the subject matter.

Teachers also played a part in influencing students on whether the latter will use the deep approach as their study strategy or not. When teachers are interested in the subject matter, it would have an impact in the student's choice of study strategy. Teachers might also use tests that required thoughts and ideas be used together (Prosser & Trigwell, 1999). Encouraging students to be active in class and correcting students' wrong beliefs would greatly help students to properly understand the subject matter. Likewise, if the teachers were fair in assessing learning and allowed students to commit mistakes without any possible penalty, such as being embarrassed in class, as well as rewards, such as favoritism, students were observed to be more eager to learn and therefore proceeded to use the deep approach.

In the study of Marton and Saljo (1976) regarding deep and surface approaches to learning, the results showed that deep processing was actually the study strategy that most educators would like their students to develop. Deep processing helped students to develop more elaborate and stronger memories. It was said to lead to good understanding and as well as the achievement of better grades. However, any study strategy, when harmonized with the learner's cognitive strengths, was said to produce positive results and attitudes (Alesandrini, Langstaff, & Wittrock, 1984).

In a study by Lockhart, Lamon, and Gick (1988), they argued that participants should engage in higher conceptual processing for the prior presentation of information to transfer when solving the problems. They argued that the problem should be seen as a puzzle and not as knowledge retrieval, for which the skill of capacity would be needed. This meant that deep processing was needed to develop practical thinking in the sense that similar problems could be solved through the steps and reasoning gained through deep processing.

In another study made by Entwistle (2002), it was shown that the deep approach was more common in departments whose students' rates were in the good teaching and allowed freedom in learning. For the students, good teaching was assessed in the areas of level, pace, structure, explanations, enthusiasm, and empathy. On the other hand, freedom in learning was shown by having the teachers extend their style of teaching in a more creative way. In this way, students were more encouraged to learn and have self-reliance. On the contrary, giving students a heavy workload or tests emphasizing an accurate copy of the lecture were more likely to lead into the use of surface approach.

In relation to the achievement goal theory, deep processing had a positive relationship with the mastery goal orientation (Ford, Smith, Weissbein, Gully, & Salas, 1998). In this type of orientation, one focused on goals such as learning as many as possible, overcoming challenges, and increasing one's level of competence (Wolters, 2004). Individuals who followed the mastery goal orientation utilize the deep approach, one requiring a lot of cognitive effort but lead to better understanding (Ford, et al., 1998).

Bernardo (2002) was able to mention in his study some alternatives to the traditional method of teaching school mathematics. These alternative methods were said to be focused on the active participation of the student, leading to better understanding and not simply memorization. These alternative methods and the deep processing approach were similar due to their focus on letting a student learn the concepts of a subject matter. It was, therefore, believed that students have fully learned mathematics when they were able to successfully explain and prove their answers.

It has been accepted that deep processing was the excellent choice in study strategies for one to obtain a high performance in mathematical problem solving. In view of the fact that mathematical problem solving required people's organized framework to understand different topics, deep processing was to be used, given that deep processing was known to be the approach wherein one will look for meanings and understand the concept being studied and be able to relate it with other experiences (Penger, Tekavcic, & Dimovski, 2008). Being able to connect deep processing and mathematical problem solving, one can solve mathematical problems easily and accurately, and would have higher performance (Busato, Prins, Elshout, & Hamaker, 1998).

Surface Processing. In the surface processing strategy, students study information mainly by what they could observe (Craik & Lockhart, 1972). Bernardo and Okagaki (1994), Baroody and Ginsburg (1986), and Reed, Dempster and Ettinger (1985) observed that several students who were successful in solving a particular type of mathematical problem had difficulty in solving problems that might only have a slight difference from the ones that they were used to solving every time. Students who utilized the surface type of learning focused their attention on data that they felt were important and proceeded to memorize that specific information (Biggs, 1990.). Surface processing can also lead to shallow retention of material in the examinations.

According to the Matthews (2001), surface processing does not enhance understanding in the long-term retention of information and knowledge. He compared characteristics and factors that brought about the use of deep and surface approach. Surface processing caused high anxiety in students. They would rather resort to the use of surface processing either because of too much workload or because they were not given enough time to finish their work. In addition to this, students may have a doubtful view of education, believing that factual recall is the process that best and was required for tests. Students were also evaluators of their own learning, and the evaluations are said to often follow the patterns given by their professors so as to patterns in solving mathematical problems. Surface processors may not involve with learning how to do their tasks the right way and may have not really understood why they did certain processes, which led to more usage of the surface strategy in their studies (Matthews, 2001).

Having interest in the subject matter for both students and the teacher was important in the development of an approach. When teachers looked uninterested and allowed the students to be passive, surface processing had a higher chance of being developed. Aside from this, when teachers imposed that students be always active in class or made low expectations and discouraging statements, students are likely to be less motivated to study, thus the student would study just for the sake of passing. Surface processing results to teachers who keep on rushing lessons so that they would cover a lot

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and also overemphasized things, such as the syllabus, will inhibit high quality learning (Entwistle, 1998).

The surface approach to learning had a positive relationship with performance goal orientation. Individuals who have a performance goal perform a task better than others, making them focus on performing quickly and efficiently. In this case, students resorted to a more shallow approach when it comes to learning (Ford et al., 1998).

Traditional teaching methods in mathematics usually involved repetition of the processes being indicated during the class (Brown, Cooney, & Jones, 1990). Bernardo (2002) mentioned that in this setting, the teacher and the textbooks becomes the main source of information and them alone. In this setting, students were said to have learned their lessons when they were able to obtain the right answers by simply following the instructions given to them. When students only followed their teachers without thinking on their own, students were then adapting a surface approach to learning. They are focused on simple rote learning and repetitions as parts of their study strategies to learning. There is endorsement of surface processing because in reality, tests given to students did not require a deeper level of learning in order for the students to pass their examinations (Sankaran & Tung Bui, 2001).

In another perspective, the study conducted by Rhem (1995) showed that the more the students advanced in their academics, the tendency for them to use surface processing also increased. He mentioned in his paper that the use of surface processing might be due to the traditional teaching styles being used in schools. He also listed a couple of other factors that might have been responsible for students to resort to surface processing: (1) an excessive amount of material in the curriculum, (2) relatively high class contact hours, (3) an excessive amount of course material, (4) a lack of opportunity to pursue subjects in depth, (4) a lack of choice over the method of study and over the subjects, and (5) a threatening and anxiety provoking assessment system.

The emotional consequence to surface strategy was explained in the study by Entwistle and Waterston (1988). They used interviews and questionnaires to determine the comparative strength of deep and surface approaches. The findings showed that deep approach was constantly linked with academic interest in the subject matter and that the individuals who used this kind of approach resulted to be self-confident while surface processing was constantly associated with anxiety and fear of failure.

The study conducted by Prosser and Millar (1989) showed that students who used the deep approach changed their perception of technical materials in ways which the lectures required. Students who relied on the surface approach did not develop the necessary understanding of the technical materials required by the course. Because of this lack of a solid foundation, students who used surface processing had more problems as the course progressed.

Surface processing only used memorization to study, while mathematical problem solving required a certain level of analysis and understanding (Hong & Aqui, 2004). With this, one can see that surface processing do not help individuals maintain different mathematical operations in problem solving because they do not properly understand the concept behind the problem because the individual simply memorized the processes. When teachers arranged the assessments given to the students in a different manner, the latter might not be able to answer the questions appropriately, due to the fact that they only memorized the material and did not understand the concepts behind the material. Schoenfield (1988) mentioned that some students were believed to have understood various concepts when they were able to replicate the exact things that their professors did. However, Schoenfield (1988) stated that there were students in reality who simply went through their studies in a mechanical way, without truly analyzing the things that they studied.

The study by Magno (2009) using Filipino students provided a different perspective for deep and surface strategies in learning. He found in his study that there are equal opportunities for the use of deep and surface strategies when related to ability and metacognition measures. Other studies made by western researchers focus on the advantage of the deep strategy and less for the surface strategy. However, for Filipino students, they see surface strategies as functional in their learning. This result challenges existing models about the consequences of deep and surface strategy use.

Disorganization. In disorganization, an individual has a difficult time in building and/or maintaining a stable and organized way of study that is used for learning (Bandalos, Finney, & Geske, 2003). According to several researches (Bhaskar & Simon, 1977; Chi, Feltovich, & Glaser, 1981), effective problem solving depend strongly on both the nature and organization of knowledge that is within the individual's accessibility (Bransford, Sherwood, Vye, & Rieser, 1986). Given this case, individuals who use the disorganization approach have a hard time concentrating and analyzing problems.

There are only a small number of studies that focused mainly on disorganization as a study strategy. Despite this, the small amount of research showed that disorganization and performance had a negative relationship (Entwistle & Ramsden, 1983). Another point was that disorganization and test anxiety had a positive relationship (Bandalos, Finney, & Geske, 2003). Elliot, McGregor, and Gable (1999) stated that having an unorganized study strategy cause a student to become unprepared for an examination. Unpreparedness then lead to anxiety when the particular student was to be evaluated by other people (Elliot, McGregor, &

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Gable, 1999). In the same way, Al-Emadi (2001) showed a negative correlation in mastery goal and performance goal to disorganization, and a positive relationship to performance avoidance goal.

When individuals use disorganization as a strategy, they have difficulty in maintaining a stable and structured way of learning (Bandalos, Finney, & Geske, 2003). Given that mathematical problem solving use highly structured and organized thinking, an individual who use this kind of approach had difficulty analyzing problems presented to them. In the study of Elliot, Gable, and McGregor (1999), having an unorganized study strategy was a problem for students for the reason that they might be caught unprepared for assessments which involved mathematical problem solving.

Problem Solving

These are instances when individuals especially students are required to show their ability to solve problems (Groome, Dewart, Esgate, Gurney, Kemp, & Towell, 1999). Problem solving is a skill that is considered to be important. It is a skill that could be used throughout the course of one's life not simply in academics but even in getting or retaining a job position. It is considered as the outcome of teaching a content of an activity after a math skill lesson. Although most of the time, problem solving aimed at something as its goal, it does not necessarily mean that this end goal was always achieved (Leahey & Harris, 1997). An investigation done by Neef, Neles, Iwata, and Page (2003) showed that individuals' who solve problems effectively posses the ability to transform the words in a problem into their necessary symbolic counterparts and this was significantly related to one's ability in problem solving. According to the Miller, Hall, & Heward (1995) individuals should be reminded that they cannot arrive at perfect solutions all the time; however, one can create the best possible decision with the information given at hand. Ong, Liao, and Alimon (2009) even mentioned that there were times when difficulties in problem solving arose when individuals jumped immediately in finding solutions to the problems simply because they did not properly identify first the elements needed in the problem.

A number of early studies regarding the cognitive processes involving problem solving had already been done and this was narrated by Groome, et al. (1999). Oswald Kulpe was one of those who took an interest in researching about thought processes. Next, were the behaviorists who claimed that thought processes were due to observable behavior. One of these behaviorists was Thorndike in 1898 who said that it was through the process of trial and error that problem solving was done. Gestalt psychologists agreed that trial and error may play a part in problem solving; however, they still continued to conduct several well-known studies regarding problem solving. Köhler, one of the founders of Gestalt psychology, was able to study problem solving skills while observing apes. Bananas were hung from the ceiling and the ape was observed as it tried to reach for the fruits. After some futile attempts, Köhler discerned that the ape seemed to have insights, because it decided to stack crates in order to make a stairway and reach the fruits. For the Gestalt psychologists, insight, or the sudden understanding of a problem because of reorganization and restructuring of the elements of the problem, was an important constituent for successful problem solving. Insight, for Gestaltists, was an extraordinary method of thinking that was unlike the usual linear processing of information (see Sternberg, 2003).

During the 1960's, a study about human problem solving was headed by Herbert Simon (Dunbar, 1998). In Simon et al.'s investigation, he made use of complex problems which involved several characteristics that might lead to a solution. Next, concurrent verbalizations from subjects were utilized to recognize mental operations, strategies, and representations that individuals used for problem solving. Lastly, Simon et al. made use of computer programs that mimicked human processes in problem solving.

Solutions to problems do not come to a person easily. On the other hand, there were two usual ways being utilized for solving problems. These methods were referred to as algorithms and heuristics.

Algorithms. Algorithms are solutions or strategies being used that were sure to produce solutions (Leahey & Harris, 1997). According to Leahey and Harris (1997), algorithms were best for well-defined highly-structured problems. Algorithms were also commonly used in areas pertaining to the use of computers and other types of technology.

It has been said that algorithms may not always be utilized because of well-structured and ill-structured problems (Best, 1999). Ill-structured problems were defined as those problems without clear solution paths (Sternberg, 2003). Because of this, Best (1999) mentioned that there was no possible way for people to establish an algorithm to solve the problem. Well-structured problems, or those problems with clear solution paths (Sternberg, 2003), may make use of algorithms, but, according to Best (1999), one might be disappointed due to the fact that well-structured problems were usually large. In other words, algorithms may still not be able to fully embrace a lengthy solution to a problem despite it being able to help people in solving simple well-defined problems.

Examples of algorithms used in well-defined or well-structured problems would be geography and mathematics (Sternberg, 2003). The mathematical concept of multiplication could be considered as a process that made use of algorithms, because if one knew the procedure of multiplying numbers, one will surely be able to find an answer to any multiplication problem as long as one followed the given set of rules (Reed, 1996).

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Heuristics. It was not possible to always have a ready answer for every problem. Therefore, the use of algorithms was usually exchanged for the use of heuristics. Heuristics were problem solving strategies that involved the use of experience and gut feelings (Leahey, & Harris, 1997). This type of problem solving strategy was usually used, albeit success was not warranted (Reed, 1996). Heuristics was utilized mainly in many real life situations because there may be none to little algorithms available for one's use (Groome, et al., 1999).

Examples of heuristics would be forming subgoals and using analogy. The first of the two, forming subgoals, was when a problem was divided into several parts (Reed, 1996). A subgoal was defined by Reed (1996) as a goal that served as a solution for a part of the initial problem. This type of heuristic allowed an individual to avoid erroneous paths to the solution due to having an idea of how the solving should be done (Reed, 1996). The drawbacks for this type of heuristic would be that not all subgoals were obvious in problems, and that there were times when subgoals triggered uncertainty instead of giving the solver an easier time with one's work (Reed, 1996).

Another example of heuristics would be the use of analogy. The usage of analogies called for an individual to make use of other analogous problems in order to solve a particular one (Reed, 1996). In order for an individual to be able to do this, one should first recognize the similarities between or among the previous problems and the problem presented at hand. One should also be able to recall the proper solutions to the previous problems and be able to apply it to the present problem (Reed, 1996).

Solving problems was not limited to the usage of algorithms and heuristics; other researches had also focused on the role of creativity in problem solving as well (Sternberg, 2003).

Mathematical Problem Solving

Mathematics is one of the subjects that require cognitive processes and is highly intellectual in nature (Hong & Aqui, 2004). It involved solving simple equations to complicated ones. Despite this, mathematics is claimed not only solving of problems with the use of complicated formulas, but to be a stepping stone on how one should think and apply what one has learned in real life (Naglieri & Gotling, 1995). Mathematics was also an excellent field to determine the success and failure rates of the students depending on the study strategies that they utilized.

Problem solving was not limited to the events occurring in the real world. There are times when problem solving was linked to mathematics because it is an essential part of the latter (March & Cooke, 1996). Mathematical problem solving was said to be a transfer challenge requiring individuals to develop schemas for recognizing novel problems as belonging to familiar problem types for which they knew solutions (Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004). Individuals may also have to learn to make use of synthesis, which was defined by Riley and Greeno (1998) as putting together various elements of a problem, to come up with other solutions.

Mathematical problem solving was said to be pioneered by George Polya (Higgins, 1997). He was able to develop a four-phase model of the problem-solving process. This model involved the following steps: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back. These steps could be explained through Young's (1924) similar problem-solving model. Step 1, understanding the problem, involved an individual getting a clear idea of what information are being asked in the problem. The next step involved the planning stage where an individual decides which information will be useful in his search for an answer and what strategy one must use to get the desired result. In the third step, the person will try to implement his plan. If his first plan does not succeed, he continues to implement other plans until he is able to succeed. The last step, looking back, involved taking a step back and checking whether or not the result satisfies the data being asked in step one.

Some studies done regarding students' performance when it comes to mathematical problem solving were done by Cote and Levine (2000), and Botge (2001). In Cote and Levine's (2000) study, a student's attitude towards mathematics was a factor in their performance. A positive attitude towards math allowed an individual to be more successful at solving mathematical problems, compared to those who had negative views about the subject matter. In Botge's (2001) study, he found that when individuals are able to understand the basic mathematical concepts, achievement was also high. He also found that an individuals' skill in computing was weakly correlated to that of one's achievement. Benedetto-Nasho and Tannock (1999) found that an individual's errors in computations was less likely the reason with regards to poor mathematical problem solving performance, when compared with the amount of errors in the problem representations.

Strategies used in problem solving had been one of the main focus of research regarding mathematics education (Schurter, 2002). Mathematical operations and problem solving make use of algorithms, a type of strategy used by people and which were sure to generate solutions for given problems (Leahey & Harris, 1997). Sternberg (2003) mentioned that a type of mathematical concept that could be considered as an algorithm would be multiplication. Mathematics was a subject matter that involved a number of formulas and equations, and if properly used will yield the results needed without fail. Unfortunately, the field of mathematics requires a lot of thinking (Hong & Aqui, 2004) and was considered as one of the most difficult subject matters. Koller and LeSage (2009) mentioned that the problem with a lot of students was that when it came to mathematics, these students believed that certain problems were unsolvable if they were not able to detect a solution for the problem at once. In mathematical problem solving, one needs several cognitive skills such as identifying the elements, computing, analyzing the problem, synthesizing and evaluating. In Bloom's Taxonomy, problem solving is said to consist of six major categories that start from the simplest to the most complex skill. These categories could be considered as degrees of difficulty and individuals must master the first skill before going to the next. The six cognitive skills are remembering, understanding, applying, analyzing, evaluating, and Creating (Byrd, 2002; Pohl, 2000).

The Present Study

In the present study, the three study strategies of deep, surface, and disorganized are differentiated on solving mathematical problems. There is a string of evidence in previous studies that deep processing was the best study strategy to use in order to perform highly in mathematical problem solving. This was explained by Hong and Aqui (2004) when they said that deep processors got to grasp the entire concept behind various mathematical equations. Moreover it was explained by Busato, Prins, Elshout, and Hamaker (1998) that by having integrated different concepts into one's memory, a deep processor could easily utilize previously learned concepts into new and unfamiliar situations. Since mathematical problem solving was a transfer challenge that required people's schema (set of beliefs that provides an organizing framework that would help us to understand an event, topic, or person) to recognize creatively made problems (Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004), deep processing can be a strategy that might help problem solvers to have a highly desirable output in solving a problem. On the other hand, surface processing give individuals optimal performance at a point in time. However, surface processing does not help individuals retain the method in solving mathematical problems which required a certain level of analysis and understanding (Hong & Aqui, 2004). This implies that without properly understanding the methods involved in mathematical problem solving, an individual will not be able to process the problems once it was different from the ones he memorized. The use of disorganization as a strategy was said to lead to the difficulties of a learner in developing a structured and organized approach in solving problems (Bandalos, Finney, & Geske, 2003). With mathematics being a highly intellectual subject matter, a student with no firm foundation for his/her way of learning will have difficulty in putting information he/she had gathered into actual computation or practice. In relation to test anxiety, having a disorganized study strategy could catch a student unprepared during examination.

The study focused on the different study strategies used on different cognitive skills on mathematical problem solving. It particularly tried to determine which study strategy would best facilitate effective learning in students. High school students are classified according to their dominant study strategy and then a mathematical problem solving test was administered.

Method

Participants

The participants were 300 high school students from two different schools in Manila, Philippines. These two high schools were chosen for their string program on developing high achievers in Mathematics. The participants were fourth year high school students, both male and female students belonging to the 16-18 age groups. High school students were appropriate because of the uniformity of the mathematics curriculum and competencies developed for high school in the Philippine Educational system.

Cluster sampling was then used to enable the proponents to get the 100 representative samples from each of the three learning strategy piles. In the present study, cluster sampling was done through the random selection of sections. The students were categorized according to the study strategy (deep processing, surface processing, disorganization) when solving math problems. Their scores were determined through the Student's Study Strategies Questionnaire (Elliot, Gable, & McGregor, 1999).

Instruments

Student's Study Strategies Questionnaire (SSSQ). The SSSQ was used to measure the study strategy used by the participants (Elliot, McGregor, & Gable, 1999). The questionnaire consisted of 15 items which measures three subscales: Deep processing, surface processing, and disorganization. There were five items that measured each of the subscales. The scaling technique used was a 7-point linear numerical scale. Principal-Components Factor Analysis with varimax rotation was used to uncover the three-factor solution of the item. The three factors, deep processing (eigenvalue=2.62), surface processing (eigenvalue=2.10) and disorganization (eigenvalue=3.31), accounted for 55% of the total variance. Past studies (Elliot & Church, 1997; Elliot & McGregor, 1999) have presented evidence for the construct validity, predictive validity and reliability of these measures.

Mathematical Problem Solving Test. The Mathematical Problem Solving test was constructed to measure the problem solving ability of the students. There were 25 items included in the test that covers high school lessons in mathematics. The coverage of the test included fractions, factoring, simple algebraic equations, and various word problems. These content were based on the learning competencies of the Department of

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Education in the Philippines. The items were only limited in measururing identifying, computing, analyzing, creating and evaluating cognitive skills based on the revised Bloom's taxonomy (see Pohl, 2000). The items were reviewed by a professor in mathematics in a University and a high school teacher teaching mathematics. The mathematical problem solving test was revised based on the review. It was pre-tested among high school students in a private high school to determine the length of time needed by students in answering the entire test. The test had an internal consistency of .84 based on the KR #20. The overall mean of the test performance of the participants in the pilot test was 16.23 with a standard deviation of standard deviation of 5.45. This showed that scores of 17 to 25 were high in problem solving and a score of 15 and below were below average. A standard deviation of 5.45 meant that the individual scores are dispersed. The difficulty of an item was based on the percentage of people who answered it correctly. The index discrimination revealed that there were no marginal items as well as bad items; however, 84% of the items were very good, 2% were good items and 2% were reasonably good items. It was also found out that there were no difficult items presented, although 72% of the items were average and 28% were easy.

Procedure

Approval letters were given to the different high schools to gain permission for the administration of the measures. The purpose of the study was explained and how the school can benefit from the study. The measures were administered during the participants' mathematics classes.

The participants were informed that they will be answering a mathematical problem solving test and the study strategy scale. Instructions for answering the different tests were given orally to the students before they were asked to answer the Students' Study Strategy Questionnaire (SSSQ). In the SSSQ, the participants were asked to choose the most appropriate response to each item on a scale of 1 (not at all true of me) to 7 (very true of me). They were told that they should not spend a long time on an item because there was no right or wrong answer. The participants were assured that their answers will be kept confidential. After finishing the SSSQ, the students were asked to take the mathematical problem solving test. They were instructed to read the sample items first and the instructions on how to answer the test. The students were then further instructed to shade the letter corresponding to the answer of their choice. They were asked not to write anything on the questionnaire since answer sheets were provided. Further questions were not entertained during test taking, except for questions which involved clarification of test questions. The students were given 90 minutes to complete all the questionnaires. After all the students have completed the test, they were debriefed about the purpose of the study.

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Data Analysis

The participants were classified to their dominant study strategy by comparing the scores of each students across the three subscale of the SSSQ. The highest score among the three subscales were considered as the dominant study strategy of a participant. Students are then classified according to the study strategy that they belong. The study strategy was treated as a categorical variable in the present study.

The mean and standard deviation was obtained to determine the performance level of the students in mathematical problem solving. The One-Way Analysis of Variance (ANOVA) was used to determine whether there are significant differences among the use of deep processing, surface processing and disorganization in their mathematical problem solving.

Results

The One-Way ANOVA was used to determine if there were any significant differences among the three learning strategies (deep processing, surface processing and disorganization) on problem solving across its five components (identification, computation, analysis, synthesis and evaluation).

Table 1
One-Way ANOVA Summary Table

	SS	*df*	*MS*	*F*	*p*
Study strategy	27.88	2	13.94	0.773	0.462503
Error	5156.38	286	18.03		

$*p < .05$.

There was no significance obtained in testing for the differences among students who used deep processing, surface processing, and disorganized study strategies on their problem solving as a whole, p=0.46. This means that whatever study strategy a student used, it did not make any difference in their problem solving scores.

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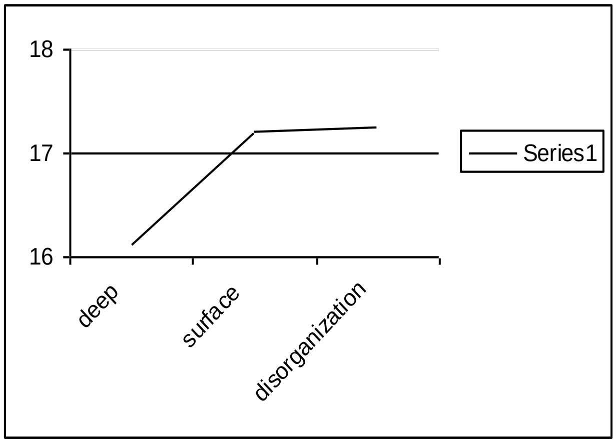

Figure 1. **Line Graph of Problem Solving Mean Scores**

The mean scores of the students who used disorganization (*M*= 16.12, *SD*= 4.15), deep (*M*= 17.24, *SD*= 4.38) and surface strategies (*M*= 17.21, *SD*= 4.13) on problem solving were almost the same. There were no significant differences among the three learning strategies when it came to problem solving in general.

The three study strategies for each cognitive skill of the mathematical problem solving test was also compared. Problem solving was categorized into the five cognitive skills, namely identifying, computing, analyzing, creating, and evaluating.

Table 2
ANOVA Summary Table Comparing Study Strategies across Five Cognitive Skills

Dependent Variable	*SS*	*df*	*MS*	*F*	*p*
Identifying	1.05	2	0.525	0.493	0.61
Understanding	5.28	2	2.64	1.75	0.17
Applying	2.71	2	1.36	0.86	0.42
Analyzing	1.41	2	0.71	0.36	0.70
Evaluating	11.05	2	5.52	3.60*	0.02

*p<.05

In testing for the significant difference among students who used deep processing, surface processing, and disorganized study strategies, no significance was found for identifying, understanding, applying, and analyzing. There were no true differences obtained with the usage of any among the three study strategies on the students' problem solving across the first four skills. A significant difference of the three skills was only found for

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evaluating. As shown in Figure 2, the mean scores of the students who used surface strategy (*M*= 3.97, *SD*= 1.20) was significantly higher than those who used disorganization (*M*= 3.27, *SD*= 1.30) and deep strategies (*M*=2.76, *SD*=1.16) in evaluation with a medium effect size (η=.22). This means that students who used surface strategy were better on the evaluating items of the problem solving test. The students who used surface processing need not think too deeply due to the fact that they can easily check and see if the patterns in the choices match the ones that they memorized before.

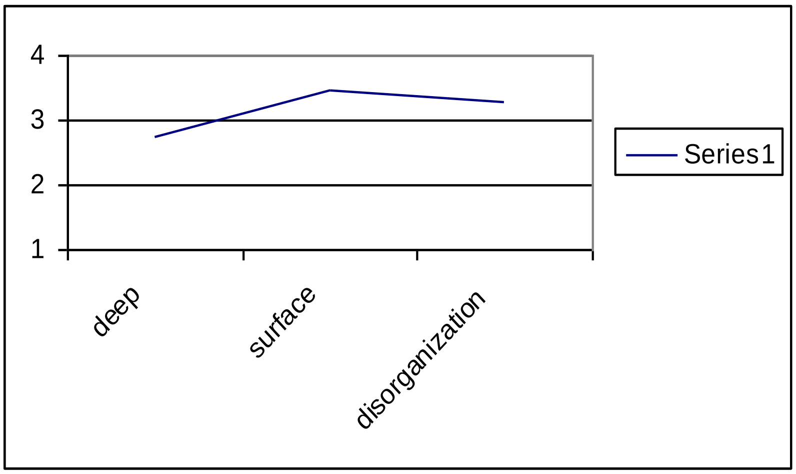

Figure 2. **Line Graph of Problem Solving Mean Scores**

Discussion

The present research tested the differences among the three learning strategies (deep processing, surface processing and disorganization) proposed by Elliot, Gable, and McGregor (1999) on different cognitive problem solving. It also investigated the relationship between metacognition and problem solving. This chapter presents a discussion about the findings of the study.

Deep Strategy

The students who made use of deep processing scored an average of 17.24 in the Mathematical Problem Solving Test. It was found that the use of deep processing is not significantly different with surface and disorganized on the students' problem solving skills in general. This was determined by the fact that the scores for deep processing and surface processing had a variance of only .03 points. A study by Alesandrini, Langstaff and Wittrock (1984) showed that learning was often correlated with capabilities not matching the study strategy used. As such, the results demonstrate the fact that the study strategies used by the students had minimal impact to the final scores in a test administered to determine the extent of their learning.

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Surface Processing

The students who made use of surface processing obtained an average score of 17.21 when they took the mathematical problem solving test. It was found that the use of surface processing was not significantly different with the deep and disorganized on the students' problem solving skills in general. Students who made use of surface processing did not necessarily perform lower than those who used deep processing or disorganization as compared with previous studies. The individuals who used surface processing had almost equal mean scores of those who used deep processing. This supports the results of Purdie, Hattie and Douglas (1996) that rote learning could be useful to some learning tasks and could lead to better understanding and generate acceptable solutions (Salovaara, 2005). However, the information that could be obtained from rote learning may not necessarily be sufficient to raise overall scores in problem solving. Instead, surface processing enabled students to have scores comparable to that of deep processing. Both deep and surface strategies contribute to the overall problem solving performance but they did not constitute the whole of the learning process critical to mathematical problem solving.

Disorganization

The students who made use of disorganization had an average score of 16.12 on the Mathematical Problem Solving Test. It was found that disorganization, when utilized in problem solving produced the same levels of benefits to the overall problem solving performance. Furthermore, the students have used disorganization as a study strategy, but these individuals did not rely on a single strategy during learning. This is especially true since Bhaskar and Simon, (1977); and Chi, Feltovich, and Glaser (1981) found that effective problem solving is a result of the nature and the organization that was accessible to the student at that given time. As such, while these students relied primarily on disorganization as their study strategy, it was feasible that they have also employed surface processing at one time or another because this strategy is not as directed as compared to deep and surface.

Differences among Study Strategies on Problem Solving

The usage of the three study strategies were found to have no differences on their roles in enhancing a student's learning skills, especially in mathematical problem solving. This supports the findings of Alvermann and Moore (1991), Anderson and Armbruster (1984), and Devine (1991) that there was no single type of study strategy that would best empower a student

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when it came to learning different tasks. They consistently explained that the learning strategies that students used depend not only with the type of student who uses it, but also in the situations where learning was going to take place (Alvermann & Moore, 1991; Anderson & Armbruster, 1984). It also supports the explanation of Devine (1991) and Salovaara, (2005) that skillful use of study strategies involved shifting smoothly among different study strategies and applying these strategies flexibly in accordance to the demands of the task given.

The results of the present study do not support the claims of Elliot, Gable and McGregor (1999). They indicated that there are differences in terms of an individual's academic achievement which favors the use of deep strategy. The results showed that deep strategy is not more advantageous than the other strategies in aiding a student's learning process when solving word problems. In the case of this study, the data was not able to show sufficient evidence to prove that those who used deep processing will indeed have better outcomes when it came to their problem solving abilities. This might be because the system of teaching in high school may not have fostered the students' abilities with regards to independent thinking. This supports the explanation of Magno (2009) that Filipino students see the function of a surface approach equally adaptable and useful as the deep approach to learning. Contextual factors in performing a task require rote memorization of information in problem solving which students find useful.

Differences among Study Strategies and the Five Cognitive Skills

The present study expanded the existing body of reviews by looking at the effects of the different study strategies on the five different cognitive skills used in problem solving. These five cognitive skills were identifying, computing, analyzing, creating, and evaluating.

Identifying. Deep processing, surface processing, and disorganization were found to have no significant differences when used on the first component of mathematical problem solving which was identification. Identification in problem solving involves questions that make students to look for the values being asked. The difficulties of problem solvers was not in detecting the elements in the problem, but by jumping straight into trying to figure out the solution without identifying the variables concerned (Kay & LeSage, 2009.). The findings did not support the claims of Riding and Rayner (1998) that a person's cognitive styles influence one's academic achievement and performance.

Computing. The three study strategies were found to have no significant differences on the computation of problem solving. This means that whatever type of study strategy a student uses, it does not affect how well a student controls his or her computational skills. This was explained by Benedetto-Nasho and Tannock (1999) when they said that poor mathematical problem solving abilities may be caused more by the mistakes in representing the problems and less by the errors committed in relation to actually solving the problems. This finding was supported by Naglieri and Gotling (1995) when he found that an individual's skills in computing have a weak correlation with the individual's achievements. He also found that it was essential for students' to have an understanding of the basic mathematical concepts in order to have higher achievements. However, despite the results of Schoenfeld (1988) study, computation was still believed to be an essential component of mathematics. This means that although previous research was found that computation was not directly related with a student's success in academics, it was still an aspect that was explored to see if it was affected by the way a student studies in preparation for an examination in mathematics.

Analyzing. Deep, surface, and disorganization were found to have no significant differences on the third component of mathematical problem solving which is analysis. Wilson (1993) explained that students are believed to understood mathematical concepts as long they simply replicate the exact routine on how their professors have gotten the correct answers to a problem. He also said that in reality, the students may only have mechanically gone through the steps to obtain the final answer. This means that a student's analytical skills in mathematical problem solving may not always rely on the type of learning, or study, strategy that they use depending on the nature of the problem given to them. The act of solving a mathematical problem may involve little to no analysis at all when the same pattern of problem is given (Wilson, 1993). Because of the simple repetition of the Professor's chosen method, students no longer relied on the deep method of disassembling a problem, instead skipping ahead to the formula. As such, no matter what method of study is used, the students displayed no variation in their performance.

Creating/Synthesizing. The results of the present study showed that deep processing, surface processing, and disorganization were found to have no significant differences on the synthesis of mathematical problems. Synthesis required only the conscious act of putting all the information or the elements in the mathematical problem together, then start forming a new solution or equation, among others (Tall, 1991). The use of any of the strategies allowed the student to pick elements needed to be put together in arriving with a solution. As long as the students were able to create their own solutions, there was no variation in their performance in problem solving. The study strategies employed do not affect this process. This finding was supported by Botge (2001) when she suggested that one way that was used to synthesize ideas was simply by making an outline or creating a list of the elements, then putting all the elements and their relations together afterwards. The study strategies granted the students a mental outline of the solution, which the students now then used as a basis for the final answer that they came up with.

Evaluating. The strategies deep processing, surface processing and disorganization were found to have a significant difference on the fifth component of mathematical problem solving which was evaluation. It was found that students who used surface processing were able to evaluate their solution and/or answers well compared to those who used deep processing and disorganization. Since evaluation looks for the right judgment in order to get the right solution or answer, students tend to use their judgment on the best way to arrive with the correct answer. The use of the surface strategy in the in problem solving looks at the value of tacit knowledge which is part of rote memorization (Biggs, 1999). Rote facts and memories are used to scaffold students to solve problems that require evaluation. When evaluating, students find usual patterns on relating two factors: Know-how abilities and problem solving/thinking. Surface processors who made use of memorization also used the patterns to their advantage in evaluation what they have done is correct.

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