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Unfolding Students' Cognition and Meta-Cognition Skills in Mathematics Problem Solving

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ABSTRACT

The goal of education is to help students acquire knowledge and develop skills which are compatible with their understanding and problem-solving capabilities at different ages. The study was conducted to examine the level of grade 7 high school students' cognitive and meta-cognitive awareness in mathematics problem solving using Piagetian Paper Pencil Test of Bakken and the revised scoring procedure of Bird and Meta-cognitive Awareness Inventory of Schraw and Dennison. Data were gathered from 323 participants. Results showed majority (56.04%) of the students were in pre-operational level and only few (4.95%) were in formal operational level. Moreover, students were found out to be high in both the two components of meta-cognition as knowledge of cognition and regulation of cognition. Likewise, only on subcomponent of meta-cognitive awareness planning was found to have a statistical significance on predicting students' mathematics problem solving performance. However, the high meta-cognitive awareness level on procedural knowledge, information management strategies and debugging strategies have practical impression on students' performance in mathematics problem solving.

Keywords: Mathematics Education, Piaget's cognitive development theory; metacognition, cognition skills;

INTRODUCTION

In a fast-paced, unstructured world of the knowledge economy, the only powerful force is the depth of one's erudition and the ability to use it. Mathematical competence is one of the keys that will give man the flexibility he needs in order to adapt to this changing society.Hence, mathematics as a subject, therefore, must be learned comprehensively and with much depth (K to 12 Curriculum Guide, 2012). Filipino high school graduates are deficient in mathematics. Among the Asian neighbours, these graduates have been assessed far below the Japanese, South Koreans and Singaporeans in the mastery of mathematics (Bilasano, et. al.,2008). Due to this trend, teachers in the Philippines struggle in helping children learn mathematics (Culaste, 2011). Results of the 1999 and 2003 Trends in International Mathematics and Science Study (TIMSS) showed that the Philippines performed miserably- third from the bottom among the 25 countries in the fourth grade and fifth from the bottom among 45 countries in the eighth grade (Culaste, 2011).

Similarly, the 2008 TIMSS-Advanced results showed that in general, Philippines

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performed least among the ten countries in mathematics, in overall and as well as in specific content areas and cognitive domains, that is, in terms of average scale score and percent of correct responses (Ogena et. al., 2010). Furthermore, the data showed that the Philippines has not improved its ranking since 1999 and did not participate in the 2007 and 2011 Regular TIMSS.

Aside from the international measures of proficiency, the National Achievement Test (NAT) is administered by the Department of Education (DepED) to elementary pupils and secondary students nationwide to determine the students' capacity of learning. The NAT results also showed that almost two-thirds of the country's schools fared poorly, getting below average scores.

According to the data released by National Education Testing and Research Center (NETRC), the NAT's mean percentage score of the fourth year high school students in mathematics for the school year 2011-2012is 48.90%, an improved performance compared with the previous years, 44.33% in 2006 and 46.80% in 2005. And yet, this improved NAT performance is far below the 75% benchmark required by DepED.

The low mathematics achievements of the students as evident in the TIMSS and NAT results speak of the need to identify specific determinants of students' poor mathematics performance particularly in problem solving.

McLeod (2009) cited Piaget's theory which placed a paramount importance of "readiness." Readiness is based upon biological maturation and stages; hence, children should not be taught certain concepts until they have reached the appropriate stage of cognitive development. Among many other research findings affirming Piaget's ideas, Culaste (2011) particularly stated that the measurement of students' specific cognitive skills and meta-cognitive dimensions as one solutions to the Philippine education scenario.

Thus, this in-depth analysis on the level of students' cognitive and meta-cognitive skills in mathematics, particularly in problem solving using Piagetian Stages of Cognitive Development by Bakken (1995) and Meta-cognitive Awareness Inventory of Schraw & Dennison (1994). Results of this study can provide scientific bases for teachers, educators, school administrators and government officials in making proposal for remedial measures; hereby, making students' attainment of standards in terms of content and performance a critical evidence of learning.

Theoretical Framework of the Study

This study is mainly anchored on the theory of cognitive development by Jean Piaget and the meta- cognitive theory of Gregory Schraw and Rayne Sperling Dennison.

Piaget Cognitive Developmental Theory

Jean Piaget theorized that the development of a child occurs through a continuous transformation of thought process. A developmental stage consists of a period of time when certain development takes place (Reedal, 2010 and Gonzalez – Mena, 2008).Piaget did not claim that a particular stage was reached at a certain age - although descriptions of the stages often include an indication of the age at which the average child would reach each stage(McLeod, 2009).

McLeod (2009) added that Piaget believed that the four stages of cognitive development are universal - i.e. that the same sequence of development occurs in children all over the world, whatever their culture.

The four stages of cognitive development based on Piaget's theory are sensorimotor, preoperational, concrete operational and formal operational. Accordingly, in each developmental stage, distinct cognitive styles emerged particularly in mathematics (Wade and Tavris, 2008, Ojose, 2008, and Zimbardo and Gerrig, 1996). Similarly, the research study of Bird (2005) concluded that Piaget's cognitive development served as predictors of students' mathematics performance.

Several authors of psychology books and researchers like Reedal (2010), Gonzalez-Mena (2008), Wade and Tarvis (2008), Ojose (2008), Amina and Sabandar (2011) explained Piaget's four stages of cognitive of development in detail. Accordingly, during sensorimotor stage (age: 0-2),the major accomplishment is object permanence, the understanding, which develops throughout the first year of a child that an object continues to exist even when he cannot see it nor touch it. Thus, children's ability to link numbers to object has already developed in this stage.

In preoperational stage (2-7), the characteristics of this stage include an increase in language ability, symbolic thought, egocentric perspective, and limited logic (Ojose, 2008). Thus, the ability of the children to represent objects mentally that are not physically present has improved. Children are able to solve one-step logical problems but still are primarily limited by working with concrete materials. Ojose said further that there is lack of logic associated with this stage of development; rational thoughts make little appearance. Furthermore, the child links together unrelated events, sees objects as possessing life, and cannot reverse operation. According to Dugan (2006) the preoperational stage is broken into two sub-stages, both cause children's minds to become disorganized thus forcing children to restructure the way they think. She added that the first stage is labeled egocentric (2-4 years) and the second sub-stage is labeled intuitive (5-7 years). The names of each sub-stage are derived from the child's mind works at each stage. According to Crain (2005) children in the egocentric sub-stage cannot understand another person's point of view. While during the period of intuitive stage the child's thinking is based on perception and restricted to one aspect or dimension of an object at the expense of other aspects. Thus, the critical task of the child during preoperational stage is to develop rational solutions to concrete problems.

In concrete operational stage (7-11 years), two logical operations develop during this stage. These are the *seriation* and *classification* - both are essential for understanding number concepts. Seriation refers to the ability to order objects according to increasing or decreasing length, weight, or volume. On the other hand, classification refers to the ability to group objects

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on the basis of a common characteristic. According to Dugan, there are four elements of logical thinking: (a) the logic of classes, (b) the logic of relations, (c) the principle of conservation, and (d) the reversibility of thought processes. Thus, Muus (1996) in Dugan (2009) said that the "four concrete group-like structures" are beginning to emerge: (a) combinativity, (b) reversibility, (c) associatively, (d) identity or nullifiability and occurs at the same time. These group-like structures are the cognitive processes that would enable logical thinking. Neither the logical thinking nor the cognitive processes could occur without the other; they are developed simultaneously.

Finally, in formal operational stage, teenagers become capable of abstract reasoning and they use this ability to solve abstract problems in a logical manner. They understand that ideas can be compared and classified, just as objects can. They are able to reason about situations they have not experienced firsthand, and they can think about future possibilities. They are able to search systematically for answers to problems. In addition, Piaget assumed that the child at this stage is capable of forming hypotheses and deducing possible consequences, allowing him to construct his own mathematics. The theory of Piaget shows that individuals are formal thinkers by ages 11 to 16 to adult age. So, as the students attain formal thought, they are able to apply mental operations not only to concrete objects, but to objects, situations, ideas, and concepts that are not directly perceived.

Jean Piaget's theory of cognitive development provides implications for teachers of the 21st century learners. Teachers who possess basic understanding of Piagetian concepts can structure their lessons so that they are teaching in ways suited to their student's cognitive levels. However, in order to do this according to Dugan (2006), teachers have to know his or her students' level of development. Dugan recommended that a paper pencil test will enable teachers to find out what stage of development each of their students is functioning.

Bakken's Test of Piagetian Stages of Cognitive Development

Crain (2005) stressed that the way students learn and process information is dependent upon their cognitive ability. In order to determine what stage of cognitive development a person is functioning, Piaget developed a series of tasks which he used to assess children's levels of cognitive abilities. Dugan (2006) and Bird (2005) said that Bakken (1995) developed a 21-item multiple choice paper-pencil test based on Piaget's tasks which can be used by classroom teachers who wish to determine students' stage of cognitive development.Furthermore the research findings of Bird (2005) suggest that Bakken's Test of Piagetian Stages is a valid assessment of students' cognitive thinking and is advantageous as it can be grouped administered and does not require the extensive time and professionals needed by the personal interview technique. However Bird made revisions in the scoring procedure made by Bakken (1995) and Bakken et al. (2001). From the original 21-item multiple choice test, it was cut out to 17 items. Items 14, 15, 16 and 17 were eliminated due to its extreme difficulties (Dugan, 2006).

The Bakken's Test of Piagetian Stages composed of Piagetian tasks that will help teachers to classify as to what developmental stages students are operating: pre-operations, concrete operations: substage one, two, or three or formal operations: sub stage one or two among

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seventh and eighth grade students. The test items composed of questions on conservation of numbers, area, liquid, length, weight and volume. Some test items also include problem solving involving classification, right-left relationship, perspective-thinking, reasoning, and logic. Other test items were visually displayed to help in describing the proposed problem.

According to Dugan (2006) and Bird (2005), in the Piagetian paper pencil test, concrete operational tasks included conservation of number, continuous quantity, length, area, mass, weight and volume. Right-left hand relationships, classification, and perspective taking were also assessed. Three different sub-stages of concrete operations were assessed. Sub-stage 1 required 4 of 5 correct responses on conservation of number, continuous length and area, and on two of the right-left relationship questions. Students who failed to correctly answer 4 out of 5 of these questions were classified as preoperational. Concrete operations, sub-stage 2 required correct answers for sub-stage 1 plus 4 correct answers on mass, weight, right-left relationships, and classification. To be classified as concrete operations sub-stage 3, students must respond correctly to those questions assessed in sub-stage 2 as well as respond correctly to questions regarding volume and classification.

Moreover, they added that the test also assessed the formal operational tasks that includes reasoning, propositional logic, possibilities, and hypothetical-deductive reasoning. In this stage, students were further as classified formal operational sub-stage 1 or 2 for early and late formal operations. They further stressed that in order to qualify for formal operations. Students need a score of 10 or 12 on the concrete operations plus 2 and 4 correct items to qualify for formal operation sub-stage 1 and 2 respectively.

Furthermore, Wood, et al. (2007), emphasized that in their findings, the content of instruction needs to be consistent with the developmental level of the learners since people cannot learn information that is presented in a manner that is too complex for their level of cognitive understanding. Thus, it is imperative for teachers to know student's cognitive ability so that instructional materials can be presented to students in way that are appropriate for the individuals' level of cognitive understanding (Dugan, 2006).

Meta-cognition Theory of Gregory Schraw & Rayne Sperling Dennison

Meta-cognition is a multidimensional set of skills that involve "thinking about thinking" or "knowing about cognition" (Hines III, 2008; Lai, 2011; Lai & Viering, 2012). It is domain-general in nature (Schraw, 1998). As cognition comes into play whenever we operate intellectually in any domain, the same can also apply to meta-cognition. Thus, although meta-cognition can be construed as domain specific knowledge, it should be remembered that its domain spans all others.

Meta-cognition plays a critical role in problem solving because it helps the problem solver to monitor his or her thinking process and it helps to develop expertise (Sternberg, 1998 in Lee &Teo, 2011). A general definition of meta-cognition includes two components: knowledge of cognition and regulation of cognition (Flavell, 1987; Schraw & Dennison, 1994; Sperling, Howard, Staley, et al., 2004). These two component areas are constantly informing and eliciting one another during the course of a cognitive task (Papaleontiou-Louca, 2008).

Knowledge of cognition includes declarative knowledge (about self and about strategies), procedural knowledge (about how to use strategies), and conditional knowledge (about when and why to use strategies) and can be referred to as how much learners understand about their own memories and the way they learn (Sperling et al, 2004 in Lee & Teo, 2011). On the other hand, regulation of knowledge contains subcomponents such as planning, evaluating, monitoring, debugging, information management strategies (Schraw & Dennison, 1994 in Lai, 2011; & Lee &Teo, 2011).

Aminah & Sabandar, in 2011, cited that meta-cognition can help in solving challenging tasks in mathematics, and has been claimed to affect positively the mathematical problem solving ability. It helps to compensate for deficits in intelligence or prior knowledge of a subject during problem solving (Prins, Veeman, &Elshout, 2006) in Lai, &Viering (2012). Similarly, Ozsoy& Ataman (2009) in their study concluded that there is sufficient evidence that meta-cognition plays an important role during each level of mathematical problem solving. Failure in meta-cognitive skills ensures the corresponding failure in mathematical thinking and problem solving (Goos, et al., 2000). Thus, Desoete (2009) recommended that meta-cognition needs to be taught explicitly in order to develop and enhance mathematical problem solving skills. Meta-cognition is a "tool of wide application' and its development gains additional importance and interest because of this fact.

Meta-cognitive Awareness Inventory of Schraw, and Dennison (1994)

The Meta-cognitive Awareness Inventory (MAI) developed by Schraw and Dennison in 1994 was used to assess meta-cognitive knowledge and meta-cognitive regulation which they referred to as the knowledge of cognition factor and the regulation of cognition factor. The MAI consists of 52 questions tapping into these two components of meta-cognition. There are 17 items assessing knowledge about cognition - 8 items of declarative knowledge, 4 items of procedural knowledge, and 5 items of conditional knowledge. On the other hand, there are 35 items assessing regulation of cognition that consist of 7 items of planning, 10 items of information management strategies, 7 items of comprehension monitoring, 5 items of debugging strategies, and 6 items of evaluation. The instrument demonstrated high reliability.

Reflective aspect of learning involves knowledge about cognition that corresponds to what students know about themselves, strategies, and conditions under which strategies are most useful. While Declarative, procedural, and conditional knowledge can be thought of as the building blocks of conceptual knowledge (Schraw, G. and Dennison, R.S., 1994).Furthermore, they theorized that the control aspect of learning involved regulation of cognition that corresponds to knowledge about the way students plan, implement strategies, monitor, correct comprehension errors, and evaluate their learning.

Since researches showed that there was a strong correlation between knowledge and

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regulation of cognition, Schraw, G. and Dennison, R.S. suggest that these two factors must work in unison to help students become self-regulated learners. If students are taught meta-cognitive awareness concerning the purpose and usefulness of a strategy as they are taught the strategy, they are more likely to generalize the strategy to new situations. Thus, it is imperative for teachers to teach their students meta-cognitive skills in the classroom.

Relationships of Students' Demographic Profile (Age, Gender and Socio-Economic Status) to their Level of Cognitive and Meta-Cognitive Awareness.

Several researchers like Cross & Paris (1988), Schraw & Moshman (1995), Nennessey (1999), Schneider & Lock (2002), KGuhn & Dean (2004), and Schneider (2008) in Lai (2011) concluded that like cognitive development, meta-cognitive abilities also appear to improve with age.

Another determinant of students' cognitive and meta-cognitive abilities is socio-economic status. In the study of Edge (2009), findings showed that there is a significant difference between the numbers of high school economically disadvantage and economically advantage students completed. This is also supported by the studies of Trent (2007), Pettigrew (2009), Mosley (2006), White (2000) and Blevins (2009) which revealed a significant difference between socio-economic status and their academic achievement on types of standardized test. Further, they explained that if a student qualifies for free or reduced meals, they are more likely to perform lower than a student who does not qualify for free or reduced meals.

Moreover sex or gender is another variable that affects cognitive and meta-cognitive skills of the students. Spelke (2005) on her article review considers three claims on cognitive sex differences. Account revealed that the different representation of men and women in high-level careers in mathematics and science showed that (a) males are more focused on objects from the beginning of life and therefore are inclined to better learning about mechanical systems; (b) males have a profile of spatial and numerical abilities producing greater aptitude for mathematics; and (c) males are more variable in their cognitive abilities and therefore dominated the upper part of mathematical talent. On the contrary, Spelke mentioned that cognitive development in human infants, preschool children, and students at all levels fails to support these claims. Instead, it provides evidence that mathematical and scientific reasoning develop from a set of biologically-based cognitive capacities that males and females share. These capacities lead men and women to develop equal talent for mathematics and science.

On the other hand, Freeman (2007), Newlin (2006) and Williams (2007) concluded in their studies that there was a significant relationship between gender and math academic achievement. A parallel study of Kwiatkowski, et al. (1993) showed that men had more interest and chances to enroll in mathematics courses. Their findings suggest that men have more positive attitudes and perceptions toward mathematics than women. Lastly, Schunk and Zimmerman (2007) explicated that cognitive skills and meta-cognitive skills are two variables that play a critical role in the teaching-learning process.

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The Department of Education has unceasingly searched for a better pedagogy, methods and strategies in imparting knowledge to the learners. As a matter of fact, curricula have been reviewed, revised and amended according to the needs of time. Teachers are trained and monitored on the implementation of the department's programs.

To intensify its campaign for quality education which is accessible to all, the Secretary of the Department of Education, Bro. Armin A. Luistro, issued memorandum number 158, s. 2011 dated July 15, 2011 with the subject Pilot Adoption of Standards-Based Assessment and Rating System at the Secondary Level for SY 2011 – 2012. The said memorandum capsulate the theory of cognitive development by Piaget and the meta-cognitive theory of Schraw, Dennison, et al. as it states that assessment shall be used primarily as a quality assurance tool to track student progress in the attainment of standards, promote self – reflection and personal accountability for one's learning, and provide a basis for a profiling of student performance.

Hence, this research study was conducted to determine the cognitive and meta-cognitive awareness and their predictive value to mathematics problem solving.

MATERIALS AND METHODS

Design

The methods of research used in this study are qualitative and quantitative since this study analyzed the cognitive and meta-cognitive skills of the grade seven students. The adopted Piagetian paper-pencil test developed by Bakken et al.(2001) was used to determine at what cognitive developmental stages the students are operating and the revised scoring method of Bird (2005) was used. While Meta-cognitive Awareness Inventory (MAI) by Schraw and Dennison (1994) was used to determine students' meta-cognitive awareness both in knowledge and regulation. The data gathered were organized, analyzed and interpreted so as to ensure in-depth assessment of students' level of cognitive development and meta-cognitive awareness in mathematics problem solving.

Participants

Grade seven (7) night students at National High Schools in Central Visayas were invited to participate the research. They were asked to voluntarily complete the instrument of the study during school year 2013-2014. The students were given 90 minutes to answer the tools on Piagetian Test of Stages of Cognitive Development and Meta-cognitive Awareness inventory by Schraw(1994). Three hundred twenty three students completed the research instruments. The characteristics of the students can be seen in Table 1.

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Table 1. Student Characteristics

Gender	Age	Father's Occupation	Mother's Occupation
Male	20-22	Professionals	Professionals
59.13%	**.92%**	26.31%	30.65%
Female	17-19	Technicians	Technicians
40.87%	**3.09%**	21.98%	11.76%
	11-16	Skilled Workers	Skilled Workers
	95.97%	46.75%	5.57%
		Jobless	Jobless
		4.94%	67.49%

Materials

The researcher used a standardized test instruments like: 17 multiple-choice items, objectively scored Piagetian based paper-pencil test by Bakken (1995). The Piagetian based paper-pencil test was used to determine at what stage of cognitive development a student is operating: preoperational, concrete operational or formal operational.

To establish the validity and reliability of the Piagetian Paper Pencil Test by Bakken (1995) a study was administered to 80 grade seven students from a parochial school in a metropolitan area. Statistically significant correlations were found for concrete operations and formal operations. The study revealed that reliability indicates that the paper pencil test is weak to moderately reliable for grade seven students. However, Bird (2005) restructured the scoring method made by Bakken to increase the reliability and validity of the instruments. Thus the revised scoring method introduced by Bird was used in this study.

On the other hand, the Meta-cognitive Awareness Inventory (MAI) by Schraw (1994) was used to assess students' level of meta-cognition before, during and after solving mathematics problems. This is composed of 52 questions all answerable by true or false.

Procedure

The data gathering process was carried out in two phases: phase 1 was the administration of the two different instruments (Piagetian Paper Pencil Test by Bird and Meta-cognitive Awareness Inventory (MAI) by Schraw & Dennison (1994) to the respondents and phase II was the checking and tabulation of the results.

Before the administration of the different instruments, a written permission to conduct the study was secured from the Cebu City Schools Division Superintendent and from the principals of the four participating schools. As soon as the approval was secured, the actual gathering of data followed.

The assessment of the students' level of cognitive development and meta-cognitive awareness in mathematics problem solving was administered personally by the researcher.

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The respondents were given 90 minutes to answer the tools on Piagetian Test of Stages of Cognitive Development and Meta-cognitive Awareness Assessment.

After all the respondents of the four participating schools answered the test instruments, these were retrieved, checked and tabulated. It was then tallied, summarized, analyzed and interpreted.

Data Analysis

Editing and filtering of the retrieved questionnaire was done during the data processing which resulted to discarding of 17 questionnaires out of 340 retrieved ones.

Responses of the students were then processed. In scoring the test, the students received one point for a correct response or zero point for an incorrect response as shown in Table 2.

Table 2: Revised Scoring of Each Cognitive Developmental Level

Cognitive Developmental Level	Score
Pre-operational	Failure to correctly answer four questions out of items 1, 3, 4, 7, 8 (score: less than 4)
Concrete Operational	correct answers from 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 & 13 (score: equal to 4 or 12 or between 4 to 12)
Formal Operational	Above, plus correct answers for items 12,14, 15, 16, 17, 18, 19, 20, 21 (score: equal to 13 or 21 or between 13 to 21)

To determine the students' level of meta-cognition the Meta-cognitive Awareness Inventory (MAI) developed by Schraw& Dennison (1994) was used. In scoring, for each true answer a student was given a 1 point otherwise a 0 point was given for every false answer.

Table 3: Interpretation of Students' Level of Meta-cognitive Awareness

Range	Description
76% - 100%	Very High
51% - 75%	High
26% - 50%	Low
0% - 25%	Very Low

After data were processed, SPSS was used to analyze for descriptive statistics and multiple regression analysis. Descriptive statistics was used to summarize the student characteristics while multiple regression analysis was used to determine the predictive value of cognition and

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metacognition to the performance in mathematics problem solving.

RESULTS and DISCUSSION

Student's Cognitive Skills Development

The stages of cognitive development the grade seven students are operating is shown in Table 4.

Table 4. Students' Cognitive Skills Development

Level of Cognitive Development	Frequency	Percentage
Pre-operational	181	56.04%
Concrete Operational	126	39.01%
Formal Operational	16	4.95%

Results signify that majority (56.04%) of the grade seven students at this level have acquired symbols or language skills. Memory and imagination skills are also developed, however, the thought processes are limited only to nonreversible and non-logical thinking. They can understand, represent, remember, and picture objects in their mind without having the object in front of them. They showed intuitive problem solving skills. They can see relationships and can grasp concept of conservation of numbers, length and areas. However the students at this level have difficulty seeing the viewpoint of others. This implied that students who belong at this level are egocentric. These cognitive skills manifested by the students conform with the characteristics of children on pre-operational stage as mentioned by Piaget based in the research of Bird (2005) and Dugan (2006) and in the article of Ojose (2008).

Moreover, concrete operational garnered 39.01% of the respondents. The students who belong to concrete-operational level have the ability to solve problems on conservation of number, continuous length, mass, weight, volume and area. They also showed ability to solve problems on right-left relationships and serial ordering and classification. This implied that students who have reached to concrete operational levels have utilized their senses in order to know; they have considered two or three dimensions simultaneously instead of successively as mentioned by Piaget in Foster (2009), Ojose (2008), Dugan (2006) and Bird (2005). This finding suggests that the students at this level can perform mental operations such as seriation, transitivity, classification, decentering, reversibility and conservation as cited by Piaget in his cognitive developmental theory. They have developed their skills on logical thinking even more. Thus, the students' results on concrete operational level showed logical and systematic form of intelligence. They can manipulate symbols related to concrete objects. They already have the ability to perform reversibility and can take the role of another. They are able to grasp concepts on conservation. Thus, operational thinking prevails as well as nonreversible and egocentric thinking.

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Lastly, only 4.95% of the total respondents have advanced to formal operational level. This result denotes that these students whose level of cognitive development is formal operational can handle problems on logical reasoning, propositional logic, possibilities and hypothetical-deductive reasoning as evident in their answers to items 13 to 18. These students have developed their ability to think abstractly and meta-cognitively as well as to reason hypothetically.

The results of the assessment of the students' level of cognitive development showed sufficient evidence to support the hypotheses of Piaget that individual undergo a series of sequential cognitive development. His description of the different developmental tasks of individuals under formal operational stage also agreed with the result as well as the claims that not all individuals whose age reached 11-16 years old to adult age have reach formal operational stage. Furthermore results also proved the claims of McLeod (2009) as he said that Piaget did not claim that a particular stage was reached at a certain age - although descriptions of the levels often include an indication of the age at which the average child would reach each level.

Generally, results entails that majority of the students in Grade seven are not yet formal thinkers and they are not capable of deducing hypotheses. Above all, these students can hardly apply mental operations not only to concrete objects, but to objects, situations, ideas, and concepts that are not real. This means, their higher order cognitive skills are underdeveloped.

Students' Meta-Cognitive Awareness Level

The Students' Meta-Cognitive Awareness level which are categorized into two (2) major components is shown in Table 5. The first component is knowledge of cognition with sub-scales as declarative knowledge, procedural knowledge and conditional knowledge. The second component is regulation of cognition with component skills of planning, information management strategies, comprehension monitoring, debugging strategies and evaluation.

Table 5. Students' Meta-cognitive Awareness Level

Knowledge of Cognition	Average Score	Interpretation
Declarative Knowledge	71.90	High
Procedural Knowledge	67.96	High
Conditional Knowledge	69.04	High
Regulation of Cognition		
Planning	74.13	High
Comprehension Monitoring	74.79	
Information Management Strategies	67.49	High
Debugging Strategies	62.72	High
Evaluation	73.27	High

The results signifies that the grade seven students were high on all three(3) components of knowledge of cognition and on all five (5) components of Regulation of cognition.

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The high awareness level on knowledge of cognition suggests that the students have high belief on their knowledge about oneself as a learner and about what factors can influence their performance in mathematical problem solving. Moreover, the findings indicate that students already have high knowledge about how to implement learning procedures or strategies in solving mathematical problems which further implies that students can perform task more automatically. Likewise, the results implies that students' awareness level on determining under what circumstances specific processes or skills should transfer, knowledge about when and why to use learning procedures, and application of declarative and procedural knowledge with certain conditions presented is already developed among grade seven students.

The awareness of regulation of cognition and its five (5) components are shown in Table 5. The findings would mean that students have high awareness level on planning, goal setting and allocating resources prior to learning as posits by Cross & Paris, (1988), Paris & Winograd (1990), Schraw et al. (2006), Schraw & Moshman (1995) and Whitebread et al. (2009). Besides, the over-all average result of students' awareness level on comprehension monitoring indicates a high level of meta-cognitive regulation awareness. The result entails that the grade seven student is very much capable of doing assessment of one's own learning. This further suggests that these students have developed their skills on the use of strategy in before, during and after solving problems as proposed by Cross & Paris (1988), Paris & Winograd (1990), Schraw et al. (2006), Schraw & Moshman (1995) and Whitebread et al. (2009). Results also agreed with Flavell (1979) as he named monitoring or regulating as cognitive experiences.

Furthermore, the results of the assessment implies that grade seven students have developed their abilities on strategies used to correct comprehension and performance errors of the students while solving math problems. Additionally, results suggest that students have high level of development in terms of analysis of performance and strategy effectiveness after solving math problems. This affirms the ideas of Cross & Paris (1988), Paris & Winograd (1990), Schraw et al. (2006), Schraw & Moshman (1995) and Whitebread et al. (2009) as they all considered meta-cognitive regulation on evaluation as assessing the processes and products of one's learning, and revisiting learning goals.

Relationship of Students' Mathematical Performance, Student Characteristics, Cognitive level of Cognition and Meta-Cognitive Awareness Level

There are several predictors that are taken into consideration in this study and these are age, gender, parental occupation, meta-cognitive knowledge (declarative knowledge, procedural knowledge and conditional knowledge) and meta-cognitive regulation (planning, comprehensive monitoring, information management strategies, debugging strategies, planning and evaluation). Each of these predictors is correlated to the performance of students in mathematical problem solving.

Table 6 present the relationship between the students' performance in mathematical problem solving and set of independent variables: age, gender, parental occupation, level of cognition, meta-cognitive knowledge (declarative knowledge, procedural knowledge and

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conditional knowledge) and meta-cognitive regulation (planning, comprehensive monitoring, information management strategies, debugging strategies, planning and evaluation).

It was hypothesized that there is no significant relationship between students' performance in mathematics problem solving and their characteristics (age, gender and parental occupation), level of cognitive development and level of meta-cognitive awareness. To determine whether the obtained correlation is significant, the regression analysis was used to test the null hypothesis at 0.05 level of significance.

Table 6. Results of the Regression Analysis

Source	DF	SS	MS	F	P
Regression	12	439.79	36.65	3.29	<.001
Residual Error	310	3456.69	11.15		
Lack of Fit	307	3311.19	10.79	0.22	0.996
Pure Error	3	145.50	48.50		
Total	322	3896.48			

The results in Table 6shows that the disclosed computed F-value of regression model is less than .001. Comparing this computed p-value of regression model, it is lesser than the critical p-value of 0.05. This result means that the model is statistically significant. The result implies that regression model is used for determining the variables that are significant predictors of students' performance in mathematical problem solving.

Table 7. Results of the Analysis of Significant Predictors of Mathematics Performance

Predictors	T- Value	P- Value	Interpretation
Age	- 0.94	0.349	Not Significant
Gender	1.13	0.261	Not Significant
Mothers Occupation	0.14	0.889	Not Significant
Fathers Occupation	- 1.62	0.106	Not Significant
Declarative Knowledge	1.17	0.241	Not Significant
Conditional Knowledge	0.77	0.441	Not Significant
Procedural Knowledge	1.89	0.060	Not Significant
Planning	2.37	0.018	Significant
Comprehension Monitoring	0.42	0.677	Not Significant
Information Management Strategies	- 1.72	0.086	Not Significant
Debugging Strategies	1.76	0.080	Not Significant
Evaluation	- 0.07	0.941	Not Significant

S = 3.33925 R-Sq = 11.3% R-Sq (adj) = 7.9%

Coefficient of Determination

For the 323 respondents in the sample, almost 11.3% of the variation in mathematical performance could be attributed to the variation of age, gender, and parental occupation, cognitive and meta-cognitive abilities. The rest of the 88.7% is chance variation.

Table 7 shows the regression analysis of the variables involved in this research study. Among all the independent variables involved, the variable which has a lesser computed p-value than the critical p-value of 0.05 is planning that has a computed p-value of 0.018. The data in Table 6 reveals that among all the independent variables considered as predictors that significantly related to students' improved mathematical performance in problem solving; only planning is found to be statistically significant. However, the other variables such as procedural knowledge (0.060), debugging strategies (0.080) and information management strategies (0.086) indicate that they are practically significant.

The result implies that students' high awareness level in planning has an impact to their mathematical performance in problem solving. This further implies that developing students' ability to appropriately select strategies and allocate resources that affect task performance will improve their skills in problem solving which will results to a better math performance. The results generally support the findings of Aminah and Sabandar, 2011), (Prins, et al, 2006), Ozsoy and Ataman (2009) that all claimed that meta-cognition positively affect the mathematical problem solving ability of the students; and the findings of Akthar et al (2011) that meta-cognition improves cognitive performance especially in mathematics.

CONCLUSION

Different students will progress at different rates, depending on their abilities. The cognitive and meta-cognitive skills development of the students is significant variables in the mathematics performance of the students. Teachers must take into consideration the content and teaching strategies - they must match their lesson and activities with the cognitive level of the students, and all instruction processes will include the instruction of meta-cognitive skills. Hence, for students operating in pre-operational level, the teachers should employ effective questioning about characterizing objects. Teachers must engage students in discussion or interaction that can stimulate student's discovery of the variety of ways to group objects, thus helping the students think about the quantities in creative ways. Moreover, the critical challenges in mathematics teaching are to help students make connections between mathematics concepts and activity. For students operating in concrete operational level, teachers must provide opportunities for students to present mathematical solutions in multiple ways. Teachers can use symbols, graphs, tables, and words to develop students' understanding of conservation, identity, and serial ordering. While in formal operational level, the major accomplishment of the students is abstract reasoning and ability to compare and classify ideas. To develop these cognitive skills of the students, teachers should require students to identify and analyze elements of a problem, allowing them to decipher the information needed in solving a problem. By encouraging students to extract relevant information from a problem statement, teachers can help students enhance their mathematical understanding. In every math activities, teachers should employ higher order thinking skills so as to develop students' critical thinking skills.

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