Assessing Grade School Students Metacognition in Solving Mathematical Problem

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This study constructed a measure of metacognition that is applicable for grade school students (fourth grade). The constructed measure is domain-specific contextualized in the metacognition of mathematical problem solving. There is a need to construct a more direct and domain-specific measure of metacognition specifically for grade school pupils because of the difficulty in assessment procedures for young children. The test is composed of eight items that measure declarative knowledge, conditional knowledge, procedural knowledge, prediction, planning, evaluation, and two items on monitoring. The test was administered to 280 grade four students in different public and private schools in the Philippines. The reliability of the test using Cronbach's Alpha is .78, indicating acceptable internal consistency of the items. Parallel form of reliability was conducted where it was significantly correlated with another measure of metacognitive skills (r=.21, p<.05). Intercorrelation of the factors showed that planning is negatively correlated with the other components. Confirmatory Factor Analysis (CFA) showed that all components of the measure are significant to metacognition as a latent construct. Adequate goodness of fit indicated that the measure is appropriate for grade four pupils given the eight items. Further implications of the findings on a cognitive development perspective and underlying metacognitive processes are discussed.

Keywords: Metacognition, mathematical problem solving

Contemporary education perspective explains that students become aware of their own learning and eventually control their learning process which leads to better performance. Given this perspective, teachers do not only teach the content but the process on how to learn the content as well. When students are taught to apply the strategies on how to learn effectively, they engage in a process called metacognition. Metacognition is defined by Shimamura (2000) as the ability to evaluate and monitor one's own cognitive processes, such as one's thoughts and memories, so that a reasonable assessment can be made about future performance. There are many studies conducted that involve metacognition and attempted to measure it since Flavell (1976) pioneered the concept. In recent studies, the samples used to measure metacognition involve adolescents and adults since it is most evident in them. Literature showed that the level of metacognition increases as age increases, which probably gave way in using adults as participants in metacognition studies (Galotti, 2004; Sternberg, 2003). There is a growing literature of studies investigating the metacognition of preschool children. Assessing the metacognition of children such as preschool students is essentially different with the way metacognition is assessed for adults. Questionnaires and inventories are commonly used for adults but these may not be appropriate in the case of children.

Metacognition can be investigated in the context of problem solving. Through problem solving, learners will be able to execute the necessary procedures required in metacognition such as procedural knowledge and the regulation of different strategies to arrive with the solution (Veenman, Elshout, & Meijer, 1997). The aim of the present study is to construct an instrument that measures metacognition that is appropriate for grade school students in the context of solving mathematical problems. It is also aimed to describe metacognition among children through the results of the assessment in the instrument developed.

Metacognition

Metacognition is a valuable construct in studies about learning. The concept was introduced by Flavell (1976) in an effort to supply information about problem solving (Schurter, 2002). Metacognition enables learners to adjust consequently to changeable problem solving tasks, demands, and contexts (Allen & Armour-Thomas, 1992; Desoete, Roeyers, & Buysse, 2001; Montague, 1998). According to Winn and Snyder (1998), metacognition as a mental process consists of two simultaneous processes: Monitoring the progress in learning, and making changes and adapting one’s strategies if one perceives they are not doing well. However, Schraw and Dennison (1994) were able to identify not only with two components, but with eight factors of metacognition when they arrived with its measure, which brought contemporary researchers to work and expand on the existing framework. The concept of metacognition composed of multiple dimensions was identified by many researchers in the area of cognitive and educational psychology prior to the construction of various measures. Ridley, Schutz, Glanz, & Weinstein (1992) recognize that metacognition is composed of multiple skills that include taking conscious control of learning, planning, and selecting strategies, monitoring the progress of learning, correcting errors, analyzing the effectiveness of learning strategies and changing learning behaviors and strategies. Ertmer and Newby (1996) specified that the multiple components of metacognition are characteristics of an expert learner. Given various studies on metacognition, Hacker (1997) made three general categories on the studies of metacognition. These are studies on cognitive monitoring, cognitive regulation, and combination of monitoring and regulation. It can be noted that even the studies, when categorized, reflect the multidimensionality of metacognition as a construct and the dynamics on how its dimensions relate with each other. Compared to other models of metacognition, the one by Schraw and Dennison (1994) gives a clear illustration of the factors of metacognition empirically. Not only does it bring clarity in the concept of metacognition but it also confirmed its factors, and different studies proved that the structure proposed is valid (Allen & Armour-Thomas, 1993; Desoete, Roeyers, & Buysse, 2001; Fang & Cox, 1999; Fortunato, Hecht, Tittle, & Alvarez, 1991; Panaoura, n. d.). In the model of Schraw and Dennison (1994), metacognition is composed of two major components: Knowledge of cognition and regulation of cognition. Knowledge of cognition is the reflective aspect of metacognition. It is the individuals' awareness of their own knowledge, learning preferences, styles, strengths, and limitations as well as their awareness that the use of this knowledge can determine how much they can perform different tasks (de Carvalho, Magno, Lajom, Bunagan, & Regodon, 2006). According to Flavell (1987), metacognitive knowledge can be subdivided into three categories: Knowledge of person variables, task variables, and strategy variables. Knowledge of person variables refers to the kind of acquired knowledge and beliefs that concern human cognitive, affective, and emotional functions. Knowledge about task-related variables refers to how the nature of the task encountered affects and constrains how one should deal with it. Finally, knowledge about strategy variables refers to knowledge about the availability and appropriateness of different strategies to the task at hand. In the model, it is composed of three subprocesses that include:

(1) Declarative knowledge – knowledge about one's skills, intellectual resources, and abilities as a learner.

(2) Procedural knowledge – knowledge about how to implement learning procedures (strategies)

(3) Conditional knowledge – knowledge about when and why to use learning procedures.

Regulation of cognition, on the other hand, is the control aspect of learning. It is the procedural aspect of knowledge that allows effective linking of actions needed to complete a given task (de Carvalho & Yuzawa, 2001). Regulation of cognition refers to the procedural aspect of knowledge (know how…) enabling the effective linking of actions needed to perform a given task. It encompasses planning, monitoring, and correction of on-line performance (de Carvalho, 2001). In the framework of Schraw and Dennison (1994), it is composed of the subprocesses that include:

(1) Planning – planning, goal setting, and allocating resources prior to learning.

(2) Information Management Strategies – skills and strategy sequences used on-line to process information more effectively (organizing, elaborating, summarizing, selective focusing).

(3) Monitoring – Assessing one's learning or strategy use.

(4) Debugging Strategies – strategies used to correct comprehension and performance errors

(5) Evaluation of learning – analysis of performance and strategy effectiveness after learning episodes.

According to Desoete, Roeyers, and Buysse (2001), metacognition is also vital in understanding successful performance. There is a rich literature that provides evidence on the effects of metacognition on academic success (Blakey & Spencer, 1990; Corsale & Ornstein, 1980; Kluwe, 1982; Lopez, Little, Oettingen, & Baltes, 1998; Magno, 2009; Schneider, 1985; Rock, 2005), although it is not clearly specified what domains are used as indicators.

Assessing Metacognition

There is a growing literature of studies about the different ways of assessing metacognition among samples using children. Each of the studies are showing consistent framework on the components of metacognition. Veenman (2005) explained that the use of concurrent instruments (administered as the task is performed) is more effective for the assessment of metacognition. Panaoura (n. d.) considered constructing a self-report inventory as a measure of metacognitive ability for very young children who are not able to express their thoughts in detail. Moreover, Fortunato, Hecht, Tittle and Alvarez (1991) reported in their study how they successfully used nine questions to practice metacognition over a wide range of ages. Likewise, a series of metacognitive tests were specifically designed by Desoete, Roeyers, and Buysse (2001) called the 'Metacognitive Attribution Assessment (MAA)' and the 'Metacognitive Skills and Knowledge Assessment (MSA).' These instruments were tested in a pilot study (n = 30) in order to determine their usefulness for preschool students and their sensitivity in measuring individual differences. Analyses showed that students without reading problems could handle the instruments well. Students were interviewed after the test about (a) the reasons they gave for certain predictions and evaluations; (b) their planning and monitoring following the prediction; and (c) the reasons why they thought exercises are difficult or easy. Allen and Armour-Thomas (1993) made a self-report measure of metacognition. It was developed in order to assess the validity of a number of processes of metacognition in a variety of problem-solving situations. The results contribute to a more informed understanding of the nature and function of the metacognition construct in various contexts. Fang and Cox (1999) studied preschoolers' metacognitive behavior and constructed a way of measuring metacognition while they are dictating a self-generated story. All utterances during the dictation that suggested self-management metacognitive functions were distinguished from the story text proper dictated text-and parsed into utterance units. In order to be considered a metacognitive utterance, an utterance has to be an implicit or explicit attempt by the child to strategically plan for dictation/composing (e.g., Now what do I do? Let me think; This is about my field trip), monitor the dictating/composing process (e.g., Did I already say that? Did you already write `because'? Is that the way you spell 'mommy'?), and regulate (through self or the scribe) the comprehensibility of text for a readeraudience (e.g., I don't want you to write that part down; I want to change the word; He cut, he tried to cut; He listen to them, to his 'mommy').

Given the different studies on assessing metacognition, there is a need to construct an appropriate measure of metacognition for children. There is a strong evidence from the studies presented that conducting an assessment in measuring metacognition is deemed more effective and domain-specific (Desoete, Roeyers, & Buysse, 2001; Fang & Cox, 1999). Directly assessing metacognition through performance assessment can spontaneously give the insights of children after undergoing a particular task.

Problem Solving

A person's cognitive style can influence his performance and achievement in learning (Riding & Pearson, 1994). The ease that an individual experiences solving a problem also depends 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 problem solving, from games to real life problems. Leitze and Melser (2005) said that if students were able to connect what they have learned inside the class with the events outside, they were able to maintain and appreciate information better.

Mathematics involves solving simple equations to complicated ones. Mathematics is a field claimed to be not only limited to solving problems with the use of complicated formulae, but a stepping stone on how one should think and apply what one has learned to real life (Aquino, et al., 2003). Mathematics is also a field that determines the success and failure rates of the students depending on the learning strategy they utilized.

Problem solving is not limited to mathematics but it also extends to the events occurring in the real world. There are many studies where problem solving is linked to mathematics (Reyes, 1994). Mathematical problem solving was said to be a transfer challenge requiring individuals to develop schemata for recognizing novel problems as belonging to familiar problem types which they knew solutions for (Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004). Individuals may also have to learn to make use of synthesis, which was defined by Tall (1991) as the putting together of various elements of a problem to come up with other solutions.

Strategies used in problem solving had been one of the main focuses 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 involves a number of formulae and equations, and yields the result needed without failure if properly used. Unfortunately, the field of mathematics requires several thinking (Hong & Aqui, 2004) and considered as one of the most difficult subject matters (Aquino et al., 2003). Garofalo (1985) mentioned that the problem with a number of students was that when it comes to mathematics, they believe that certain problems are unsolvable if they are not able to detect a solution for the problem at once (Jaramillo, 1992). In mathematical problem solving, one needs the application of 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 six major categories (knowledge, comprehension, application, analysis, synthesis and evaluation) that starts from the simplest behavior going to the most complex. These categories could be considered as degrees of difficulty and one must master the first category before going to the next (Clark, 1999).

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: (1) Understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back. These steps are involve: The first one is understanding the problem where an individual gets a clear idea of what information are being asked in the problem. The next step involves the planning stage where an individual decides which information will be useful in his search for an answer and what strategy he 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, involves taking a step back and checking whether or not the result satisfies the data being asked in step one.

Problem solving is manifested in certain field. In mathematics, students are asked to comprehend a question, extract the necessary details and form a solution to get the correct answer (Aquino et al., 2002). Obtaining the proper answer enables an individual to make use of his metacognitive processes. Metacognition, or the knowledge of one's own cognition system and how it is regulated (Flavell, 1979; Kluwe, 1982), is used when an individual is solving a mathematical problem. Metacognitive techniques are important because they ensure individuals to keep track of what they are doing and the things they might do in the near future (Finkel, 1996). Another important contribution of metacognitive techniques would be allowing individuals to make connections between their accumulated knowledge in mathematics and the current mathematical problem they are solving (Finkel, 1996). It is believed that the more an individual makes use of metacognitive processing, the better the individual solved problems in mathematics (Case & Gunstone, 2002).

There is a number of evidence showing the connection between problem solving and metacognition. A research done by Swanson (1990) focused on the influence of metacognitive knowledge and aptitude of a student in problem solving. He investigated whether or not students with low aptitude were able to make up performance-wise if they had high metacognitive skills. Swanson (1990) made use of children from grades 4 and 5 from four different elementary schools. He first administered a modified metacognitive questionnaire by Kreutzer, Leonard and Flavell (1975) and Myers and Paris (1978) in order to assess the students' metacognition in problem solving. After the metacognitive questionnaire, the children were given the problem solving tasks. The research done by Swanson (1990) revealed that students with high metacognitive knowledge and low aptitude were indeed able to obtain scores significantly higher than those with low metacognitive knowledge but high aptitude. It was found that high metacognitive ability could offset one's low aptitude level.

Another experiment done is about the role of metacognition and mathematical problem solving. In the study, Lester, Garofalo, and Kroll (1989) used the cognitive-metacognitive framework made by Garofalo and Lester (1985) in order for them to analyze the metacognitive aspects of 7th-grade students' problem solving performance. Lester, Garofallo, and Kroll's (1989) study showed that those who were able to monitor and regulate their problem solving activities were more successful in problem solving. The characteristic that distinguished successful problem solvers from those who were unsuccessful was the interaction that the students had with both the metacognitive processes and the understanding of the mathematical concepts. Garofalo and Lester (1985) concluded that the students who participated in their study were lacking regulatory skills, which was important especially in mathematical problem solving.

There is no certain guarantee that the use of metacognition leads to better performance in problem solving. Yeap (1997) explained that when an individual knew how to use their metacognitive skills properly, the success rate of their problem solving would increase. The way people utilized their metacognitive knowledge when they require it also determined their attempt in solving problems. Cognitive actions, metacognitive knowledge, and experience were likely to generate good results in problem solving. Consistent with this finding is the study made by Wilson (1999). It was again explained that even with the use of metacognitive actions, problem solving might still end up as failure. This was due to the fact that metacognition was better used with challenging tasks. Less challenging tasks could then be answered successfully without the use of metacognition. Another factor that might have contributed to the failure of metacognition was the inaccuracy of the user's metacognitive judgment, or there were omitted or incomplete data given by the individual.

Objectives of the Study

Given that previous literature stated that there is a need to assess the metacognitive skills of students contextualized in mathematics that is domain-specific and is different from the adults, this study aims for the following:

(1) To construct a metacognitive measure that is appropriate for grade school children.

(2) To determine the reliability of the metacognitive measure using cronbach's alpha, and parallel forms with the 'Metacognitive Skills and Knowledge Assessment' by Panaoura and Philippou.

(3) To determine the convergence of the factors of the metacognitive measure by correlating each of its subscales (declarative knowledge, conditional knowledge, procedural knowledge, prediction, planning, evaluation of learning, and monitoring).

(4) To determine the goodness of fit and significant paths of the seven dimensions of metacognition through confirmatory factor analysis.

(5) To describe the process of metacognition among children using the results of the measure devised.

Method

Participants

A total of 280 Grade four Filipino students were asked to participate in the study. The average age of participants is 9.3 and all possessing the same content and competencies in mathematics. In the Philippines, Grade four students are usually 9 years old and are turning 10 at the end of the school year. These grade school students belong to three public schools and two private schools located in the Southern Luzon region of the Philippines. All students are currently undergoing the same curricular program in mathematics which is the Revised Basic Education Curriculum.

Instrument Construction Procedure

Content Domain. The model is composed of the knowledge of cognition and regulation of cognition. In the knowledge of cognition component, there are subprocesses that include declarative knowledge, procedural knowledge, and conditional knowledge. The regulation component covered prediction, planning, evaluation, and monitoring.

Item Writing. There were eight items constructed to measure each domain of metacognition in the context of mathematical problem solving. A mathematical problem solving involving a three-step operation was introduced at the beginning of the instrument that is appropriate for grade four students. Grade 4 mathematics teachers were consulted regarding the appropriateness of the problem. The follow-up questions were asked so that students can verbalize the processes occurring while undergoing the problem solving task. The follow-up questions reflect the seven metacognitive domains. There is one item for each metacognitive domain (declarative, conditional, procedural, prediction, planning, evaluating, and monitoring) and two for monitoring (See Appendix A). The multidimensional item response theory posits that a single item can be representative of a strong indicator of the domains measured or even a variety of abilities (Antal, 2007). A short form of the measure was constructed considering the length of time in the administration to young children.

Table 1
Table of Specifications

Metacognitive Domain	Description	Scaling Technique	Item number
	Knowledge of Cognition		
Declarative knowledge	Knowledge about self and about strategies	Semantic differential scale	1
Conditional knowledge	Knowledge about when and why to use strategies	Open ended 4-point scale rubric	2
Procedural knowledge	Knowledge about how to use strategies	Open ended enumeration	3
	Regulation of Cognition		
Prediction	Assumed outcome of performance	Multiple choice	4
Planning	Goal setting	Rank Order	5
Evaluation	Analysis of performance and strategy effectiveness after learning episode	Multiple choice	6
Monitoring	Assessment of one's learning and strategy	Open ended 2-point scale	7
		Numerical scaling	8

Scaling and Scoring Technique. Each item was answered by the participants differently. For the first item on declarative knowledge, the semantic differential scale was used to assess whether the problem solving task was easy or difficult in a continuum. For the conditional knowledge item, the rating on the difficulty is justified in a 4-point scale rubric (see Table 2).

Table 2
Rubric for Item on Conditional Knowledge

Points	Description of response
1	If the answer does not sufficiently justify the difficulty given
2	If the answer can be accepted but does not sufficiently support the rating on the difficult
3	If the answer somewhat sufficiently justified the difficulty given
4	If the answer sufficiently justifies the difficulty given

For the procedural knowledge in item 3, the participant is tasked to enumerate the steps for the problem solving. A point is given for each relevant problem solving step that is provided. For the prediction in item 4, the participants assessed if they can solve the problem correctly given 4 options in relation with their correct answer for the problem. The point system is shown in Table 3.

Table 3
Point System for the Item on Prediction

Item	Point system
"I am absolutely sure I can solve the problem correctly"	With correct answer 4 points; with wrong answer 1 point
"I am sure I can solve the exercise correctly"	With correct answer 3 points; with wrong answer give 2 points
"I am sure I cannot solve the problem correctly"	With correct answer give 2 points; with wrong answer give 3 points
"I am absolutely sure I cannot solve the problem correctly"	With correct answer give 1 point; with wrong answer give 4 points

For the planning in item 5, the participant places the correct order on how to proceed with the problem solving given four steps. For the evaluation on item 6, the participant selects how sure he is in his answer given four options. The point system is shown in table 4.

Table 4
Point System for the Item on Evaluation

Item	Point system
"I am absolutely sure I have solved the problem correctly"	With correct answer 4 points; with wrong answer 1 point
"I am sure I have solved the exercise correctly"	With correct answer 3 points; with wrong answer give 2 points
"I am sure I have not solved the problem correctly"	With correct answer give 2 points; with wrong answer give 3 points
"I am absolutely sure I have not solved the problem correctly"	With correct answer give 1 point; with wrong answer give 4 points

Both items 7 and 8 measure monitoring. On the first part (item number 7), the participant gives an answer on the kinds of mistake that students commit in problem solving. Two points is given for an explicit answer and one point for a not explicit answer. For item 8, there are four options and the participant responds to each given four-point scale from 'most important' to 'not important at all.'

Item Review. The procedure and items of the measure was checked and reviewed by experts in the field of metacognition research and education from two universities in Japan and Hong Kong. In the process, the conceptual definition was provided for each domain and the table of specifications indicating the scaling technique and description of the items. The experts have reviewed the appropriateness of the items based on the conceptual definition. Necessary changes were made after and the assessment tool was revised.

Data Gathering. The instrument was administered to Grade four students grouped according to their section. There were three teachers in mathematics that were trained to use and administer the instrument. During the administration, the students were informed that answering the scale is part of their activity in their mathematics class. The scale was administered to each student individually. The teacher records the responses of the students for each item. If a student is unable to answer an item, they are asked further questions to elicit the answer. After answering the devised measure, the 'Metacognitive Skills and Knowledge Assessment' by Panauori and Philipou was administered to the same participants to be correlated with the measure.

Data Analysis

The data was tabulated and scored by three raters. The raters were oriented on the standards of scoring. The concordance of the three raters using Kendal's ω is .78. The Cronbach's alpha was used to determine the internal consistency of the items of the Metacognitive Performance Assessment. The Pearson *r* was used for the parallel form of reliability, and the scores on the devised measure was correlated with the scores on the 'Metacognitive Skills and Knowledge Assessment.' Convergent validity of the devised measure was conducted by correlating the scores for each domain. This technique provides information on the homogeneity of the domains.

To study the factor structure of the seven domains of devised measure, the model was tested using Confirmatory Factor Analysis (*CFA*). The software STATISTICA was used to analyze the data where covariance matrix was used to derive path estimates and goodness of fit. The analysis involves determining the significant paths of the components of metacognition. Confirmatory Factor Analysis was used to establish the model with the closest fit to the data. It applied Structural Equation Modeling (SEM) in items which were associated with a priori factors, and the adequacy of a model was tested through fit indices that measure the degree to which the factor model reproduces the empirical covariance matrix. The models' goodness of fit was also determined using Chi-square, *CFI*, Joreskog, and *RMSEA*. The chi-square statistic (x^2) was used to assess the difference between the sample covariance matrix and the implied covariance matrix from the hypothesized model (Fan, Thompson, & Wang, 1999). A statistically non-significant x^2 indicates adequate model fit. Because the x^2 test is very sensitive to large sample sizes (Hu & Bentler, 1995), additional absolute fit indices were examined. The *RMSEA* is moderately sensitive to simple model misspecification and very sensitive to complex model misspecification (Hu & Bentler, 1998). Hu and Bentler (1999) suggest that values close to .06 or less indicate a close fit. The *RMSEA* is very sensitive to simple model misspecification and moderately sensitive to complex model misspecification (Hu & Bentler, 1998). Hu and Bentler (1999) suggest that adequate fit is represented by values of .08 or less.

Results

Reliability

The analysis indicates that the total mean of the scores of the 280 participants is 22.37 with a standard deviation of 4.78, which means that the scores do not vary that much from the central tendency with a variance of 22.5. The skewness of the scores is –0.56, which tends to be normally distributed, and the kurtosis is -.420. The internal consistency using the Cronbach's alpha is .78 which indicates an adequate consistency of the individual items. Table 6 shows the alpha derived for each item with item deletion and the item total correlation.

Table 5
Item Total Correlation and Alpha with Item Deletion

	M if Deleted	Variance if Deleted	*SD* If Deleted	Item-Total Correlation	Alpha if Deleted
Declarative	15.87	10.80	3.29	0.25	0.36
Conditional	20.64	18.57	4.31	0.22	0.33
Procedural	19.64	19.9	4.46	0.12	0.38
Prediction	19.28	19.62	4.43	0.37	0.31
Planning	21.75	23.84	4.88	-0.23	0.46
Evaluation	19.26	19.66	4.43	0.35	0.32
Monitoring	20.95	21.18	4.60	0.22	0.36
Monitoring	19.19	18.07	4.25	0.21	0.33

Parallel form of reliability was conducted where the total scores of the metacognitive measure and the Metacognitive Skills by Panaoura and Philippou was correlated. The Pearson *r* correlation shows a significant correlation coefficient of .21 (p<.05) for the two assessment forms. The coefficient also showed a positive magnitude where metacognition instrument scores increase with the other scale used. This indicates that the consistency of response of the two tests is not due to chance. Each of the scores for each item of the metacognitive measure was correlated with the total score of Panaoura and Philippou's metacognitive skills as shown in table 6.

Table 6
Correlation of the Factors of Metacognition Measure with Metacognitive Skills Inventory

Factors of Metacognition Measure	Metacognitive Skills Inventory
Declarative	.44*
Conditional	.21*
Procedural	-.11
Prediction	.0021
Planning	-.15*
Evaluation	-.01
Monitoring	-.14*

*p<.05

The correlations between each of the metacognition measure with the total score of the metacognitive skills show significance for most factors except for procedural, prediction, and evaluation components. The coefficients found are mostly low to moderate which is consistent with the results of the parallel form correlation for the total scores of each assessment.

Convergent Validity

The validity of the assessment was established by assessing the convergence of each of the factors. The pattern to which each pair of variables increases and decreases for certain conditions indicates the consistency of the components.

Table 7
Correlation Matrix

	1	2	3	4	5	6	7
(1) Declarative	---						
(2) Conditional	.31*	---					
(3) Procedural	.02	-.02	---				
(4) Prediction	.25*	.03	.04	---			
(5) Planning	-.15*	-.20*	-.10	-.01	---		
(6) Evaluation	.20*	.03	.07	.75*	-.03	---	
(7) Monitoring	.08	.14*	.28*	.16*	-.17*	.18*	---

*$p<.05$

The correlation coefficients showed a pattern where planning is consistently negatively correlated with all other factors in the measure. It is only significant for declarative, conditional, and monitoring. For all other significant coefficients, most of them showed a positive magnitude. Most of the factors converge with declarative knowledge and monitoring since significant correlations were found as compared with other pairs of factors.

Confirmatory Factor Analysis

Since the seven factors (declarative, conditional, procedural, prediction, planning, evaluation, and monitoring) are strongly supported in literature as components of metacognition, these constructs as factors need to be confirmed empirically. The method of estimation used for the CFA is the General Least Squares to Maximum Likelihood. The RMSEA was determined with a point estimate of .09 indicating that the data is close to fit in the model specified. The chi-square obtained is not significant that indicates good fit (χ^2=79.47, df=14). The PGI and CFI indices showed adequate fit with values .96 and .94, respectively. The model estimate showed that each factor is a significant construct of metacognition as shown in Table 8.

Table 8
Parameter Estimate for the Confirmatory Factor Analysis

Factor	Parameter Estimate	*SE*	*t*	*p* value
Declarative	0.73**	0.174	4.222	0.00
Conditional	0.69**	0.084	3.824	0.00
Procedural	0.92**	0.080	8.150	0.00
Prediction	0.69**	0.060	11.531	0.00
Planning	-0.26**	0.046	2.560	0.00
Evaluation	0.68**	0.061	11.166	0.00
Monitoring	0.34**	0.108	3.117	0.00

*p<.05
**p<.01

The parameter estimates showed that all the factors of metacognition are significant. This proves that the factors are indeed components of metacognition. The significance indicates that the factors correspond to prior theoretical notions about the components of metacognition. The data supports the truthfulness of the model proposed.

Since the sample used is only one and the data was only used to confirm the model, single sample fit indices were used to determine the goodness of fit of the model (see Appendix B). The Joreskog (0.92) value reflects an adequate fit since it is close to .95. The Akaike Information Criterion and Schwartz's Bayesian criterion are also large but there is no other nested model to compare them to determine whether the values are smaller or larger. The model was cross-validated using the Browne-Cudeck Cross Validation Index which has the same values with the pervious data.

Discussion

The findings of the present study explained metacognition among children in two aspects. First, there is evidence that grade school children are able to manifest metacognition through the developed measure. Second, the pattern how the metacognition components work among grade school pupils in the context of mathematical problem solving is explained.

The instrument for assessing metacognition of grade school pupils showed appropriate psychometric properties. The reliability of the metacognition measure was determined using the Cronbach's Alpha (.78) and alternate forms (r=.21). The results of the two reliability procedures are consistent in indicating adequate consistencies of the scores. Obtaining a reliability coefficient that is not so high can be a function of the measure consisting of fairly few items. A short form is necessary considering that it is designed for children unlike conventional inventories that is comprised of many items. Having few items in an assessment instrument affects the coefficient since the idea involves the representativeness of items. The correlation between the two measures is just moderate since the scores of the overall score for the devised measure is affected by the different patterns in each of the seven factors measured.

The correlations for the parallel form, declarative, and conditional knowledge are significantly correlated with the metacognitive skills. This shows that declarative knowledge and conditional knowledge are consistent with the other measure and this result is consistent with other studies (Swanson, 1990; Ertmer & Newby, 1996; de Carvalho, 2001). This shows that the overall metacognitive process increases when a learner uses his declarative and conditional knowledge. These findings indicate that the use of one's knowledge of intellectual resources and the need to learn information greatly comprises an increment on metacognitive abilities. The factors regulation of cognition, planning, and monitoring are significantly related to metacognitive skills measure. The magnitude shown by the coefficients are negative, which means that they are not parallel with the metacognitive skill measure. There is a pattern shown in the correlation that both knowledge of cognition factors (declarative and conditional) significantly increase with the other metacognition scale, while the other two regulation of cognition (planning and monitoring) decrease with the said measure. The negative correlations give further differentiation for knowledge and regulation of cognition. This also indicates that the assessment of knowledge of cognition is more accurate than the executive functions of metacognition. This is due to low scores obtained both for planning and monitoring factors where respondents show weakness specifically in the context of mathematical problem solving. The negative correlations indicate that executive skills like planning and monitoring factors among children are not translated into general metacognition skills. This pattern extends developmental theory of metacognition in children where knowledge of cognition becomes more accurate during grade school (fourth grade) while executive processes like planning and monitoring (regulation of cognition) is still developing (Kopp, 1982; Rafaelli, Crocket, & Sheng, 2005).

For the convergence of the factors of metacognition, declarative knowledge is significantly correlated with conditional, prediction, planning, and evaluation. On the other hand, monitoring is also significantly related to all factors except for declarative knowledge. This indicates that the use of one of these strategies increases the use of other strategies. This pattern indicates that children at a young age can already translate one skill to another and use multiple metacognitive skills.

For planning, a negative correlation was found with declarative, conditional, and monitoring. The direction of the relationship is also negative with the other metacognitive factors but they are not significant. This shows the limitation of young children in using metacognition. Considering the age of the participants, the negative correlation indicates that the children are having difficulty implementing their planning across other metacognitive skills. Among adults and adolescents who have developed cognitive skills, all metacognition components increase with each other. This difference can be explained as a developmental trend highlighting the limitation of the metacognition process among children. More specifically, children execute other metacognitive tasks without careful planning. Children, when engaged in a task, usually use trial and error strategies (Flavell, Friedrichs, & Hoyt, 1970). The outcome of the trial and error results to outcomes that are not predicted. The child only determines the success and failure of a task depending on the outcome but there is no foresight on what will be the outcome (Flavell, Miller, & Miller, 1993). Planning as a construct involves higher executive skills such as foresight, organization, and impulse control. Grade school children are characterized to demonstrate impulsiveness and lack of control, which makes them unable to see the clear paths in the outcome of their goal. For example, a child may be aware of what they know (declarative) and when to use such strategies (conditional) but they lack the executive skill of planning and monitoring to accomplish their goals. This relationship is particularly true when undergoing difficult mathematical problem solving tasks. When a grade school child is faced with a difficult mathematical problem solving, the child would just implement courses of action readily taught by the teacher without careful consideration of its appropriateness and the conditions that needs to be met. The child would assume that the strategy will lead to the correct answer. There is no accurate prediction of getting the correct answer. In another account, metacognition works well in tasks where a child has complete mastery and expertise. In cases of expertise in tasks, metacognition components are expected to converge with one another. But in cases of difficult tasks such as mathematical problem solving, the planning stage does not accurately result in other metacognitive components.

The confirmatory factor analysis shows that the components of metacognition are all significant and the data fits the model. This provides evidence that the processes of declarative, conditional, procedural, prediction, planning, evaluation, and monitoring indeed are components of metacognition. The adequate fit indicates that the measurement model fits primary school children. This implies that it is possible to assess the metacognition of children and the instrument is appropriate for them. The adequate fit also solves the issue of the length of the instrument where only eight items were used to measure the metacognition components. The eight items, when structured in the measurement model, turned out to fit the sample indicating that a single item is acceptable to assess metacognition in mathematics problem solving. The findings made not only the assessment of metacognition among children possible but the appropriateness of a measure and procedure for them as well. The process of translating each metacognition component came out as unique among children as shown by the divergence of planning with other metacognition components.

Given the acceptable reliability, significant path estimates, and goodness of fit of the data for the model, the measure for metacognition is useful for research that involves grade school students as participants. Primarily, previous studies usually use adults as participants because of the difficulty in assessing young children on their metacognitive ability. Provided that a measure for metacognition for children is now available, it can be used to assess this variable quantitatively. The assessment procedure can also show the underlying processes of metacognition among children if one component increases or decreases with another. The present study identified how metacognition occurs among children (grade four) in two aspects: A developmental perspective and underlying cognitive process. In a developmental perspective, it was found that declarative and conditional knowledge are assessed accurately and these factors are developed among grade four pupils while executive skills like planning and monitoring are still developing. As a cognitive process, planning does not increase with other components indicating that this executive and regulation skill is still limited among children.

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Appendix A
Items of the MPA

Read the problem solving without solving it:

Mario has 2 jobs in a day. He is earning a minimum wage of P 275.00 as an ordinary factory worker during daytime. At night he works as a waiter and earns P 250.00 a night. How much does he earn in a month with 31 days?

(1) How difficult is the problem for you in a scale of 1 to 10? *(declarative)*

Easy ←---→ Difficult
10 9 8 7 6 5 4 3 2 1

(2) Why did you give that rating for the difficulty? (conditional)

____
____
____

(3) What are the steps that you will do to solve the problem? Enumerate below (procedural)

(4) Can you solve the problem correctly? *(check one)*(prediction)

__ I am absolutely sure I can solve the problem correctly
__ I am sure I can solve the exercise correctly
__ I am sure I cannot solve the problem correctly
__ I am absolutely sure I cannot solve the problem correctly

(5) How will you proceed to solve this problem? Put the number (1 – 3) of the correct order in the sentences. (planning)

___ Choose the appropriate strategy
___ I read the assignments well
___ I extract the information necessary for the solution

What is the answer?

(6) Are you sure that your answer is the correct answer? *(Check one)(evaluation)*

__ I am absolutely sure I have solved the problem correctly.
__ I am sure I have solved the problem correctly.
__ I am sure I have not solved the problem correctly.
__ I am absolutely sure I have not solved the exercise correctly

(7) What do you think are the kind of mistakes do students make in such problem solving? (monitoring)

____
____
____

(8) What do you think is the most important to succeed in Problem solving using the following scale? (monitoring)

4 – the most important reason
3
2
1 – not important at all

___ To solve the needed answers first
___ To know the multiplication table
___ To pay attention to what is asked
___ To finish as soon as possible

Appendix B

Single Sample Fit Index

	Value
Joreskog GFI	0.922
Joreskog AGFI	0.843
Akaike Information Criterion	0.385
Schwarz's Bayesian Criterion	0.568
Browne-Cudeck Cross Validation Index	0.388
Independence Model Chi-Square	340.443
Independence Model df	21.000
Bentler-Bonett Normed Fit Index	0.767
Bentler-Bonett Non-Normed Fit Index	0.692
Bentler Comparative Fit Index	0.795
James-Mulaik-Brett Parsimonious Fit Index	0.511
Bollen's Rho	0.650
Bollen's Delta	0.799