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Development of a Metacognition Scale in Learning Mathematics for Senior High School Students

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ABSTRACT

The purpose of the study was to develop a scale of metacognition in mathematics for senior high school students using a confirmatory approach. There were 250 participants of tenth grade students from two senior high schools in Jakarta, Indonesia. The sample of the study was selected through simple random sampling technique. Data analysis was done by using the Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). The study revealed that (1) 52 scale items were validated by a panel of experts with reliability coefficient among panellists that amounted to 0.830; (2) after piloting the metacognition scale with 250 students, 46 items were found with the validity range (0.197 to 0.804) and the reliability coefficient of 0.938; (3) Next, by using EFA analysis revealed three factors were found which were tested by CFA and yielded: constructs'reliability of the self-regulation skills of 0.990, the type of knowledge to 0.980, and the executive control skills of 0.982. The final measurement model comprised 46 items and three factor were more appropriate as a scale for measuring the students' metacognition in mathematics on senior high school level.

Keywords: Confirmatory factor analysis, construct validity, metacognition, reliability

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INTRODUCTION

Metacognition plays an important role in raising awareness of learning and in the development of students' mathematical thinking skills. In particular, the mathematical habit enables students to develop both mathematical thinking and disposition. According to NCTM (2000), students' mathematical disposition are manifested in the confidence in using mathematics, high expectations for one's self, paying attention in class, persistence in problem solving, a high level curiosity, the desire and ability to communicate one's opinion with others and metacognition.

In relation to the instruction, there are some studies show that there is significant relationship between academic success and metacognition. Students who have high metacognitive skill perform better in mathematics lessons than students who have low metacognitive skill (Boekaerts, 1997; Jaafar & Ayub, 2010; Özsoy, 2010).

Furthermore, students' metacogntion on a mathematics assignment refers to they start thinking what they know and how they are applying it before they start the assignment itself. Metacognitively speaking, a myriad of knowledge or abilities alone is not enough without having the ability to make appropriate decisions, organize, control, and use them in problem solving. Therefore, the ability of metacognition can be classified as involving executive skills, managerial skills, and self-control skills with regard to the learning of mathematics.

There are widely differing views of 'metacognition'. However, generally, it emphasizes the importance of the two components which consist of knowledge about cognition and the regulation of cognition (Boekaerts, 1997; Fernandez-Duque et al., 2000; Flavell, 1976; Sperling et al., 2004). The concept of metacognition refers to the level of the learners' knowledge about their own memories, cognitive monitoring, and regulation of cognition. Moreover, the regulation of cognition refers to how well the students could regulate their own learning system (i.e., matching to goal setting, carrying-out strategies, and awareness of their problem faced). Schoenfeld (1992) argued that organizational skills and control and monitoring was of paramount importance in the process of resolving the problem. Since they are so important within the realm of the metacognitive, these processes should be emphasized by teachers in teaching and learning activities which use the problem-solving approach. The term self-regulation, monitoring, and control are covered within the definition of metacognition.

By developing metacognition skills, students know how to recognize the weaknesses and shortcomings in the process of thinking, revealing what people think, restoring the efforts that they have made, and deciding which element is understandable and not understandable. The more complete concept relating to metacognition is made clear by Marzano et al. (1988) who elucidated that metacognition was a skill that could be organized into multiple domains, namely: (1) self-organization (self-regulation skills), including a commitment to academic tasks, positive attitude of students toward academic work, and controlling attention to the needs of academic work, (2) the use of the kinds of knowledge (types of knowledge) which include; declarative knowledge, procedural, and conditional knowledge, and (3) control of the implementation (executive control skills), which include: skills to evaluate, plan and monitor the process skills.

Furthermore, Nitko (2001), using a 5-point scale to assess metacognition, argued that the use of sub categories of metacognition skills, could be realized by writing a statement that described the process of thinking, belief, or awareness of the types of special events. Assessment consists of two parts, covering the task itself and the criteria for assessing the student performance known as a rubric.

There were some previous studies which focusses on developed scale for measuring metacognitive was so called Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994; Sperling et al., 2002, 2004). The MAI was used as the basis to developing instrument which was self-report to measure metacognitive ability of students in mathematics lessons (Desoete, 2007; Özcan, 2010; Panaoura & Philippou, 2003). The studies above developed only two dimensions of metacognition on the primary school level, namely knowledge of cognition and regulation of cognition.

However, the current study develops metacognition scale with three dimensions in learning mathematics on the senior high school level. This metacognition scale is a prominent thing to be understood and it plays a significant role in instead of on supporting the students' performance in learning mathematics. Therefore, the aim of this study is to examine the construct validity of metacognition scale which comprises of three dimensions, namely self-regulation skill, type of knowledge, and executive control skill based on theory of Marzano et al. (1988) using confirmatory factor analysis.

METHODS

Participants

There were 250 students (female=152, male=98) at the tenth grades of two senior high schools in Jakarta who participated in the study. Conformity of the items with dimensions and indicators, were assessed by the 13 (thirteen) expert panelists. The expert panelists consisted of three high school Math teachers who have experience teaching mathematics for more than 10 years and have been teaching high school at the tenth grades, three psychology professors, five lecturers in mathematics, as well as each 1 expert in linguistics and the researcher who participated as an expert to judge contruct validity of the metacognition scale (e.g., blue print, face, content, dan items).

Measures

Construct validity assessment was done by using the "Quantification of Content Validity" developed by Gregory (2004, p. 99). The scale used, 5-point Likert scale ranging from 1 (very inappropriate), 2 (inappropriate), 3 (less appropriate), 4 (appropriate), and 5 (very appropriate). Thus, the higher scores were given by the panelists indicated the more appropriate items measure the indicator of metacognition on mathematical tasks.

Determination of construct validity based on an assessment of panelists using content validity index formula accuracy/constructs, are as follows:

$$V = \frac{\sum n_i |i - l_0|}{N(c-1)} \quad \text{(Aiken, 1996, p. 91)}$$

Where
V = content validity index
n = count of point scale rater assessment results
i = point scale to-i (i = 1, 2, 3, 4, 5)
l_0 = lowest scale point
N = number of rater (expert)
c = number of points scale

Based on the results of assessment by the expert panellists using the index validity (V), it was revealed that of the 60 item metacognition scale, 52 were considered as valid (as appropriate), and 8 as invalid (dropped), i.e., the item numbers: 9, 16, 22, 29, 36, 45, 51, and 58. V index values from 52 valid items which were recommended by the expert panelists as the approporiate items to measure the three factors of metacognition which ranging (0,65 – 0,90) with the reliability of inter-panellist at .830. Furthermore, the scale weight value was determined empirically using 250 high school students of the tenth grades in Jakarta as the respondents. The method used was Method of Successive Interval (MSI). It was a method to converse the items on ordinal scale to interval scale. Results of the study revealed that of the 52 items measuring metacognition obtained 49 item instrument that can be weighted in the continuum scale 1, 2, 3, 4, and 5. Each item was measured on a 5-point Likert scale ranging from 1=never, 2=very seldom, 3=seldom, 4 = often and 5=very often. Examples of items are ‘‘Before deciding to use one of Math formulas, argument, or definition in finishing Math task, I asked to myself, which idea supports to finishing the test,’’ and ‘‘In solving Math task, I double check what part has been well mastered or has not yet, and on what part I should pay more attention or concentration.’’ Thus, the higher scores of participants indicate the higher metacognition on mathematical tasks.

Furthermore, using product moment correlation, on the 49-item scale metacognition, there were 46 valid items had a validity range (0.197 to 0.804), as well as Cronbach’s Alpha coefficient of 0.938. The second order path diagram of metacognition on mathematical task comprises of 46 items and three factors, namely self regulation skill (SRS), type of cognitive (TK), and executive control skill (ECS). Self regulation skill contained 16 items, type of cognitive consisted of 12 items, and executive control comprised 18 items.

Procedure

Procedure of development of the item using the stages according Djaali and Mulyono (2008) as follows: (1) the construct was based on the theory of variable metacognition, (2) developing the dimensions and indicators of variables, (3) making a blue print, (4) establishing the range parameter, (5) writing items, whether positive and negative, (6) validation through examination of experts, (7) revisions based on expert advice, (8) limited replication for testing purposes, (9) the process of empirical validation, through piloting items, (10) the analysis of items with EFA and CFA, (11) calculation of the reliability coefficient, and (12) compiling the accepted items for the final instrument.

Generally, the procedure of the development of metacognition scale in this study consists of three stages, namely define, design, and develop. The design of the development of metacognition scale can be presented in Figure 1 below.

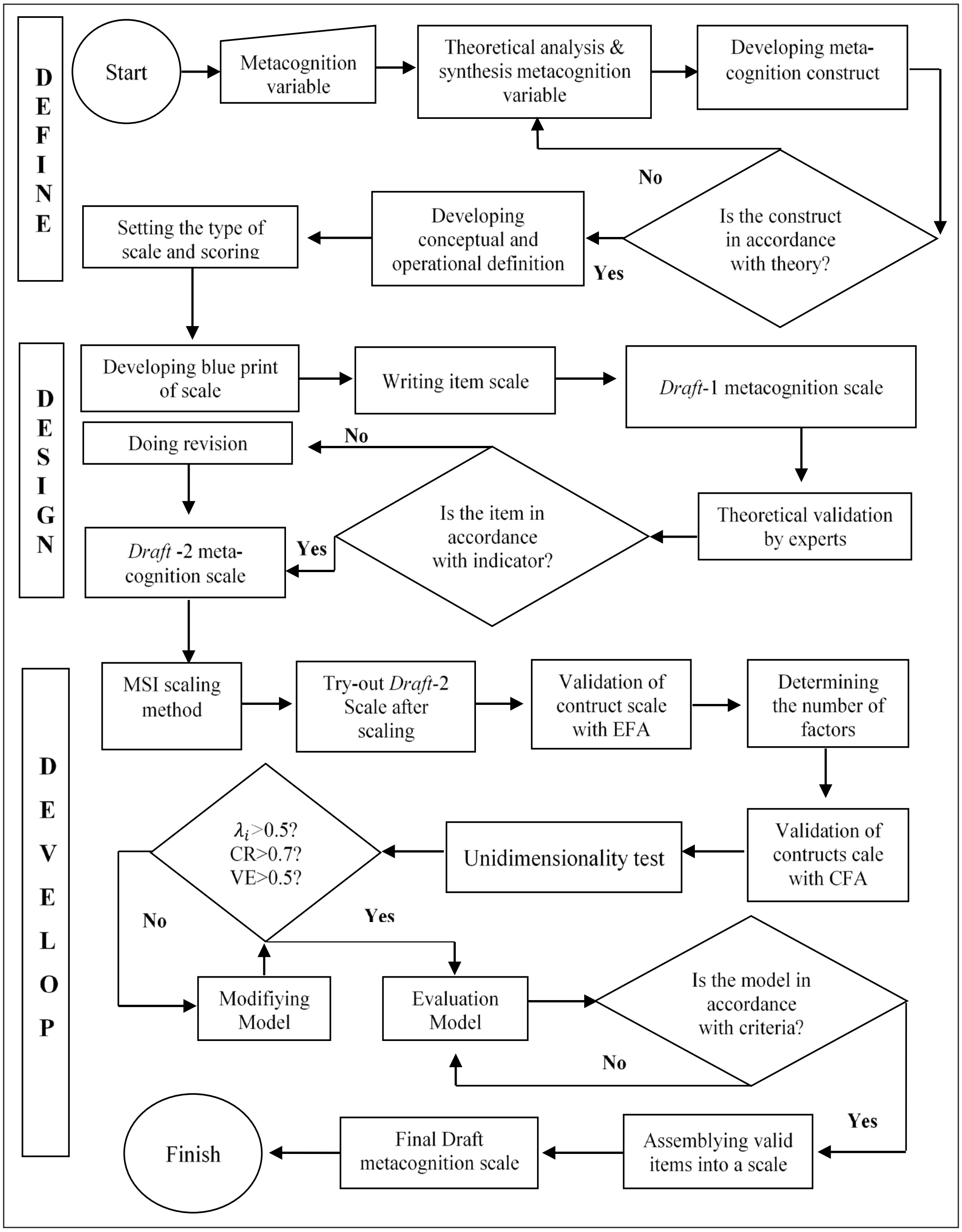

Figure 1. The developmental design of metacognition scale

Based on the design procedure as seen in Figure 1, it was described as follow: *The define stage* started from analyzing and synthesizing various thoeries to formulate construct, dimension, and indicator of the metacognition variable. For example, the metacognition dimension, namely self-regulation skills, types of knowledge, and executive control skills. Furthermore as the example from the indicators of metacognition dimension as mentioned above, they are commitment to an academic task, positve attitude toward an academic task, controlling attention to the requirements of an academic task, declarative knowledge, procedural knowledge, conditional knowledge, evaluation skill, planning skill, and regulation process skill. Once the construct has been appropriate with the theory, then the conceptual definitions of metacognition variables are developed. The conceptual definition of metacognition that is used in this research is: "an awareness of the student's ability about their own thought processes, and the cognitive monitoring mechanisms during the completion of math tasks." The next step is to choose the type of scale, i.e., Likert scale with score range (1-5).

The design stage began with developing the blue print of metacognition, and then followed by writing the item scale to get the scale draft-1. The draft-1 is then validated by expert panelists using a method proposed by Aiken (1996). Expert panelists were required to assess the accuracy of items in measuring the indicators by applying the rating scale: 1 (very inappropriate), 2 (inappropriate), 3 (less appropriate), 4 (appropriate), and 5 (very appropriate). In addition, the panelists also provided corrective records to each item. Then, the items were revised according to the panelists' inputs to get the scale draft-2.

The develop stage started with the development of scale using *Method of Successive Interval* (MSI) based on the *draft*-2 to convert the ordinal scale into a continuum scale with involving participants of 250 tenth-grade students of senior high school. For example, an item "I do not do my math tasks which given by teacher, if I follow another activity at school" with 5 scales, namely: never=5; very seldom=4; seldom=3; often=2; and very often=1, are converted using the MSI into never=4.72; very seldom=3.52; seldom=2.51; often=1.69; and very often =1.00. Furthermore, the draft-2 in which has been converted then analyzed by using EFA approach to determine the number of the factors, and obtained three factors. The next step was a unidimensional test to assess the accuracy of the item in measuring the construct or factor using CFA approach and obtained contruct reliability. The next step was evaluating the fit model to decribe whether the items which measuring the construct had fit with data. This evaluation was to ensure that the construct measuring item was correct or in accordance with the data. All valid items were assembled into the final metacognition scale instrument.

Data Analysis

To determine the number of construct of metacognition variable, exploratory factor analysis (EFA) was used. Furthermore, to determine the validity of each construct of confirmatory factor analysis (CFA) was used. The both EFA and CFA analysis technique were subsequently used to determine the factors that make up the construct of the metacognition scale. Item factors obtained from EFA by using SPSS 23 then were tested with CFA by using Lisrel 88.00. Data were entered and screened using SPSS 23. Data were checked for missing data, outliers and multivariate normality prior to the CFA. In the present data analysis, the multivariate skewedness and a kurtosis test were used to test the assumption of multivariate normality.

CFA is considered done empirically with a valid indicator to measure the construct if the estimated standardized loading factor (λ) > 0.5 or have a statistical value of the t-test with p-value <0.05. An indicator is said to be dominant as forming constructs if it has $\lambda^2 \geq 0.70$. Determination of Composite Reliability is based on internal consistency composite indicators measuring the construct. In general a construct, unidimensional, precise, and consistent can be measured by indicators /items, if Estimated coefficient *CR* ≥ 0.70 and *VE* ≥ 0.50 (Hair et al., 2010). Calculations Construct Reliability (*CR*) and Variance Extracted (*VE*) were determined by using the formula:

$$CR_i = \frac{\left(\sum_{i=1}^{k} \lambda_i\right)^2}{\left(\sum_{i=1}^{k} \lambda_i\right)^2 + \left(\sum_{i=1}^{k} \theta_i\right)}$$

and

$$VE_i = \frac{\left(\sum_{i=1}^{k} \lambda_i^2\right)}{k}$$

Where:
λ_i = loading factor to indicator to-*i*, θ_i = error variance indicator to-*i*
k = number of indicator in the model

According to Hair et al. (2010), using 4—5 criteria *goodness of fit* were regarded adequately to assess the feasibility of a model. These criteria mensioned should represent in the *absolut fit indices*, *incremental fit indices*, and *parsimony fit indices*. Absolut fit indices, covers recommended fit values: Chi-Square (p) > 0.05, the root mean square error of approximation (RMSEA)< 0.08, and goodness of fit index (GFI)> 0.90. Incremental fit indices covers: adjusted goodness of fit (AGFI)> 0.90, normal fit index (NFI)> 0.95. comparative fit index (CFI)> 0.90, incremental fit index (IFI)> 0.90, relative fit index (RFI)> 0.90. Parsimony fit indices covers: expected cross validation index (ECVI)-default < ECVI saturated and ECVI independence, Akaike's information criterion (AIC) default < AIC saturated and AIC independence, Consistent Akaike's information criterion (CAIC) default< CAIC saturated and CAIC independence, and parsimonious goodness of fit index (PGFI)> 0.60.

RESULTS

Exploratory Factor Analysis (EFA)

Determining the number from 46-item scales using EFA. Test Result of adequate factors by EFA in Table 1.

Table 1
KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure (KMO) of Sampling Adequacy		0.934
Bartlett's Test of Sphericity	Approx. Chi-Square	5915.989
	df	1035
	Sig.	0.000

Based on analysis result as seen in Table 1, it shows that the feasibility test samples with obtained figures KMO of 0.934 which means very good , the figure was also above 0.5 and Bartlett's significance test χ^2 = 5915.989 the degree of freedom (df) = 1035 far below 0.05, then H_0 is rejected or an item that is already adequate for factor analysis.

The number of factors are formed from 46-item scale in Table 2.

Table 2
Factor variance explanation percentages of metacogntion scale

Factor	Initial Eigen-values		
	Total	% of Variance	Cumulative %
1	42.275	91.902	91.902
2	2.265	4.924	96.826
3	1.018	2.213	99.039

Based on analysis result as seen in Table 2, it shows that through EFA, there are three factors formed by Eigen value above 1.0. All three of these factors turned out to have total variance of 99.039% or greater than 65% as the criterion, thus empirically, is formed of three factors or dimensions that measure metacognition scale.

Confirmatory Factor Analysis (CFA)

CFA analysis techniques aim to re-estimate the accuracy of the items scale that measure factors that have been prepared based on a theoretical construct. CFA analysis technique used was Structural Equation Modeling (SEM) measurement model. Through analysis of the CFA, factors estimated were: (1) self-regulation skill, (2) types of knowledge, and (3) executive control skills. Summary results of the estimation, in Table 3.

The results of the analysis in Table 3, shows that all the standardized factor loadings are much larger than the recommended minimum criteria of 0.50. This means that every item of factors such as for self-regulation skills, types of knowledge and executive control skills has excellent validity and as the main factor in determing metacognition scale. Futhermore, it shows that the estimation of reliability metacognition scale gives a value of 0.984, or very good categorized and greater than the minimum criteria of 0.70.

Table 3
Standardized factor loading λ, construct reliability, and variance extracted

Factor and items	Standardized Factor Loading (λ)	Composite Reliability (CR)	Variance Extracted (VE)
Self regulation skill	**0,999**		
SRS1	0.983		
SRS2	0.994		
SRS3	0.994		
SRS4	0.997		
SRS5	0.991		
SRS6	0.997		
SRS7	0.999		
SRS8	0.997	0.990	0.989
SRS9	0.997		
SRS10	0.999		
SRS11	0.994		
SRS12	0.994		
SRS13	0.986		
SRS14	0.999		
SRS15	0.999		
SRS16	0.999		
Types of knowledge	**0.885**		
TK17	0.974		
TK18	0.992		
TK19	0.999		
TK20	0.988		
TK21	0.992		
TK22	0.984	0.980	0.979
TK23	0.992		
TK24	0.996		
TK25	0.999		
TK26	0.973		
TK27	0.996		
TK28	0.992		
Executive control skills	**0.932**		
ECS29	1.000		
ECS30	1.000		
ECS31	0.992		
ECS32	0.994		
ECS33	0.992		
ECS34	1.000		
ECS35	0.997		
ECS36	0.994		
ECS37	0.997	0.982	0.993
ECS38	0.997		
ECS39	0.997		
ECS40	1.000		
ECS41	0.997		
ECS42	0.997		
ECS43	0.997		
ECS44	1.000		
ECS45	0.997		
ECS46	0.989		
Total	-	0,984	0,988

Model Fit

Testing suitability models aimed at studying how precise the measurement model proposed could fit the research data. The results of the analysis relating to the size of the model fit are in Table 4.

The analysis in Table 4, shows that except GFI and AGFI, all indicators for Goodness of Fit were fulfilled. This means that the test results scale conceptual model of metacognition in mathematics learning of the proposed turned out to fit or match the data.

Table 4
Summary of fit model indices

Goodness of Fit	Fit Indicators	Result	Judge
Chi-Square (χ^2)	p > 0.05	p = 0.999	fulfilled
RMSEA	< 0.05	0.000	Fulfilled
GFI	> 0.90	0.872	Unfulfilled
AGFI	> 0.90	0.860	Unfulfilled
NFI	> 0.90	0.995	Fulfilled
CFI	> 0.90	1.000	Fulfilled
IFI	> 0.90	1.000	Fulfilled
RFI	> 0.90	0.995	Fulfilled
ECVI (a)		4.719	
ECVI for Saturated Model (b)	(a) < (b)<(c)	8.683	fulfilled
ECVI for Independence Model(c)		872.305	
Model AIC (d)		1030.487	
Saturated AIC (e)	(d) < (e) < (f)	2162.000	fulfilled
Independence AIC (f)		217204.006	
Model CAIC (g)		1455.504	
Saturated CAIC (h)	(g) < (h) < (i)	7049.699	fulfilled
Independence CAIC (i)		217411.993	
PGFI	> 0.6	0.796	fulfilled

DISCUSSION

Using self-report instruments, think aloud protokols, interview, and teacher questionnaires to measured metacognition have many limitations and difficulties in application and not the actual performance (Desoete, 2007; Sperling et al., 2002). This study was aimed at testing the construct validity of metacognition scale. Through the results from EFA and CFA, this study shows there are three factors formed, namely self-regulation skills, types of knowledge, and executive control skills. Furthermore, this study suggests that the three factors have very good internal consistency, amounting to 0.990; 0.980; 0.982 respectively. The achievement of an internal consistency through student engagement is in compliance with expert assessment results that also establish three factors of construct metacognition, in which the reliability of the inter-expert-panelist is in a good category. Thus, all items to measure the construct metacognition recommended by the expert-panelists, are empirically valid through the engagement of participant students.

Self-regulation Skills

The metacognition scale items in the self-regulation skill dimension consist of student awareness to control the commitment, attitude, and attention to the task of Math subjects. The item scale of the *commitment to an academic task* contains the decision-making by students to complete the task, whether the task is pleasant or unpleasant. An example of the item is "Although a math assignment given by the teacher is not fun, I still try to do it my best." The *positive attitude toward an academic task* contains the views related to the independence in completing the tasks. The essence of this view is that the successful completion of the task lies in the hard work of each, not on the luck, talent, or the help of others. Example of the item is "I am pleased to solve the mathematics tests that are given by the teacher in different ways." Furthermore, the scale item of the *controlling of attention to the requirements of an academic task* is the awareness of the students to adjust their focus and attention to the objectives of the task completion. Example of the item is "When I am reading a mathematics book, I just focus on the important parts that are related to the mathematics tasks."

Types of Knowledge

Metacognition scale items in the dimensions of types of knowledge consist of three types of knowledge that students use to respond to the mathematics tasks, namely declarative, procedural, and conditional knowledge. The *declarative knowledge* scale item is the knowledge that students use to accomplish the mathematics tasks, eg factual information needed, understand what must be done, and what will be doing. Example of the item is "I firstly solve the easier questions in doing the mathematics tests." The items of the *procedural knowledge* scale related to the use of appropriate strategies to accomplish the task. Example of the item is "In order to be easier to understand the story type of the mathematics test, I start with posing questions: what is known? What is asked? and what data must be fulfilled?" Furthermore, the *conditional knowledge* scale item related to student awareness to find the reasons why certain procedures, strategies, or conditions are more appropriate to use. Example of an unfavorable item is "I confuse choosing formula/method to be used in solving the mathematics tests."

Executive Control Skills

The metacognition scale items on the dimensions of executive control skills include the skills of evaluating skill, planning, and regulation processes skill. Item *evaluation skill* is the students' assessment of the knowledge, identification of materials needed, and assessing the purpose of the tasks. Example of the item is “After finishing mathematics tasks, I asked to myself what I have learnt from the tasks.” *Planning skills* are used when students deliberately choose the procedures and strategies before and during the task. Example of the item is “In finishing the mathematics tests, I made some ways, then choosing the best one.” Furthermore, item *regulation processes skills* scale is the students’ skill in monitoring the progress of the tasks’ completion. Example of the item is “In finishing the mathematics tasks, I observe the successful part, failure part, and the part that is carefully revised.”

The findings above are slighly different from Schraw and Dennison (1994) who found two factor supporting awareness metacognition, i.e., knowledge of cognition and regulation of cognition. Internal consistency of these two factors are very well, ranging from 0.88 to 0.93. The finding also different from Özcan (2010) who founded that there was one factor and 14 items as construct validtiy of the scale of young pupils’ metacognitive abilities in mathematics scale in Turkish culture and the reliability was high (0.88).

The findings above are in line with Flavell (1976) theory that metacognition is knowledge or awareness of a person regarding the cognitive, for example, know the rules are relevant to the information and controlled consequently to the process which is associated to with cognitive objects in the problem solving process. Furthermore, the implications of measuring metacognition in the learning of mathematics requires metacognition strategies to facilitate students control weaknesses in learning and then fix this, the students can determine the best way of learning according to their own abilities, can solve mathematical problems, problems related to the learning process, and students can understand the extent of the success he has achieved in the study. This synergizing of metacognition in the learning process is appropriate to Du Toit and Du Toit (2013), at the eleventh grade students who found that the behavior of metacognitive corresponded to the first three stages of Polya (1956), i.e., understanding the problem, divising a plan, carrying out the plan, but did not correspond with stage-four, namely looking back. This respect resembles to Özsoy (2010), that there is significant and positive correlation between metacognition and mathematics achievement in the fifth-grade students. Furthermore, research results showed that 42% of total variance of mathematics achievement could be explained with metacognitive knowledge and skills.

The finding of this study asserts that the theory and the concept of metacognition as expressed by Marzano et al. (1988), that it is a skill that can be organized into: self-regulation skills, the use of types of knowledge, and executive control skills. This finding implies that metacognitive skills can help to identify weaknesses and deficiencies in the process of thinking mathematically, reveal what people think clearly, restore the efforts that have been made, and decide which element is understandable and not understood unidimensional, right and consistently be explained by three factors and 46 items, as conceptualized by the theory of metacognition.

CONCLUSION

The conclusions of this study are three factors that must be included in the development of a metacognation scale for mathematics high school students: (1) self regulation skill as measured by commitment to the task, positive attitude toward the task, and control of attention to the task. (2) Types of knowledge consisting of declarative knowledge, procedural, and conditional. (3) Executive control skills are measured by the skills of evaluating, planning, and regulating processes. The three factors are the main factors which determining the students' metacognition on the mathematical tasks.

Development of scale to measure metacognition in mathematics learning needs to be expanded in scope both populations, a branch of mathematics, material characteristics, approaches and strategies as well as education levels. This investigation is an important issue for future research, it might be possible to elaborate and use a different, such as combining aspects of the disposition and skill of metacognition. Moreover, the findings of this study have a number of important implications for future practice, especially in developing instrument metacognition for assessing mathematics learning. It is suggested that training in metacognitive learning and assessment models for teacher in secondary education can be taken into consideration. It may be important to promote the importance of metacognition for supporting student learning.

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