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Assessment of Metacognition in Mathematics: Which One of Two Methods is a Better Predictor of Mathematics Achievement?

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ABSTRACT

In recent years metacognition was discussed as a significant concept in mathematics education. However, means of measuring metacognition efficiently is still a problem. This problem has been at the center of a scientific debate about which instruments are more suitable. In this study two off-line methods, student and teacher evaluations were used. The aim of this research is to investigate which one of the evaluation form (teacher form versus student form) is the predictor of mathematic achievement. For this aim two studies were carried out. In the first study mathematics achievements of students were measured by mathematic scores in their reports. In the second study it was measured by more standard test called Placement test (Seviye Belirleme Sınavı -SBS). In the first study 408 primary school students from a state school participated. Only sixth grade students who attended SBS exam of the first study were taken the second study. According to results of this study that aimed to investigate which one of the evaluation forms (teacher form versus student form) is the predictor of mathematics achievement, instead of the results of students evaluation form, the results of teacher evaluation form are the main predictor of the mathematics scores of students. Teacher evaluation form alone explains about 51 % of the variance in mathematics achievement.

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Keywords:
metacognition, mathematics, off-line measurement instruments, self-report, teacher evaluation

Introduction

Mathematics is conceptualized as the master and servant of most disciplines and thus, a source of explanation of the universe (Obe, 1996). At the same time at every level of education, mathematics lesson is known as a subject that students have to allocate most of their time to study. Although it doesn't draw attention in the first years of schooling, as the level of class increase, it is perceived as a lesson that is boring and difficult (Yenilmez & Duman, 2008). Therefore investigating factors that have positive effects on mathematics education are important research topics for mathematics education subject area. Metacognition is one of these study topics.

Currently metacognition is discussed as a significant concept in mathematics education. The concept of metacognition was first defined in the 70s. Flavel (1979), the pioneer of the research on metacognition defines metacognition as one's knowledge of ones' own cognition and control and monitor one's own cognition. Metacognition that was defined by Zimmerman (1989) as an important dimension of self-regulated learning is also defined as one's knowledge and beliefs about one's own cognitive process and one's resulting attempts to regulate those cognitive processes to maximize learning and memory (Ormrod,

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2006). Fundamentally metacognition is a high level thinking competence that enables students get successful and it effectively controls cognitive processes during learning period (Baltaş, 2004).

There are studies concerning the relationship between academic success and metacognition (Carr & Biddlecomb, 1994; Dunning, Johnson, Ehrlinger & Kruger, 2003; Kruger & Dunning, 1999). As well as the significant relationship between academic success and metacognition, there are studies that point out that students who have high metacognitive skills perform better in mathematics lessons (including problem solving) than student**s** who have low metacognitive skills (Boekaerts, 1997; Jaafar & Ayub, 2010; Özsoy, 2010). Moreover, some studies pointed out that metacognitive skills are significant predictor**s** of mathematics achievement (Cardella-Elawar, 1992; Cardella Elawar, 1995; Deseote & Roeyers, 2006; Hoek, Vanden & Terwel, 1999; King, 1990; Larson at al., 1985; Stillman & Mevarech, 2010; Van der Stel, Veenman, Deelen, Haenen, 2010; Zhao, Valcke, Desoete, & Verhaeghe, 2011).

In addition to correlational studies there are many experimental studies that were designed to increase metacognitive skills of students in math lessons. For that reason, for researchers, as well as teachers it is important to have an adequate instrument to measure students' metacognition in order to analyze the relationship between growth in metacognition and growth in achievement. However, means of measuring metacognition efficiently is still a problem. This problem has been at the center of a scientific debate about which instruments are more suitable (Schellings & Van Hout-Wolters, 2011).

Metacognitive skills can be measured off-line or on-line of the learning process. Online methodologies catch any activity that occurs during processing and interviews and think aloud protocols are good examples. On the other hand off-line methods catch any activity that happens either before or after processing (Azevedo et al., 2010).

It is known that while presenting certain features that a person possesses, if there isn't an important obstacle, self-report instruments are preferred**.** In self-report questionnaires those are one of the most frequently used off-line measures, students are asked to report on their own metacognition. Some examples of frequently used self-report questionnaires are the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich and De Groot, 1990), the Metacognitive Awareness Inventory (MAI; Schraw and Dennison, 1994) and Junior Metacognitive Awareness Inventory (Jr. MAI; Sperling, Howard, Miller & Murphy, 2002). These questionnaires are general and contain general statements about metacognitive monitoring or regulation for which the students are asked to rate the degree to which the statement applies. One notable practical advantage of using questionnaires is that they can easily be administered on a large scale (Schelling and Van Hout-Wolters, 2011).

In recent literature, while collecting data which is about students' metacognitive levels, it is thought that teacher evaluation forms those are one of another off-line method have an important contribution to measure students' metacognitive levels. In teacher evaluation form, teachers evaluate metacognitive skills of students. Also, it is indicated that complicated and time consuming measurement instruments such as interviews (Fitzpatrick, 2000) and think aloud protocols (Schraw 2010; Veenman, 2005) have high correlation with teacher evaluation forms (Desoete, 2007; Saraç & Karakale, 2012). Thus, it is suggested that instead of time consuming and complicated instruments, teacher evaluation forms can be used to measure students' metacognitive levels (Desoete, 2007; Saraç & Karakale, 2012).

With this respect, in this study two off-line methods, student and teacher evaluations were used. Since metacognition is a domain-specific construct (McNamara, 2011; Venman and Spaans, 2005), instead of general measurements which were used in literature mostly, domain specific instruments were selected and effectiveness of these two instruments were compared.

According to recent research studies, to measure effectiveness of a measurement instrument is measured by the power of the prediction of performance, achievement or mathematical problem solving (Deseote, 2007; Jacobse & Harskamp, 2012; Veenman, 2005). For that reason, the aim of this research is to investigate which one of the evaluation form (teacher form versus student form) is the predictor of mathematic achievement. For this aim two studies were carried out. In the first study mathematics achievements of students were measured by mathematic scores in their reports that were given two times in a year, and in the second study mathematics achievements of students were measured by mathematics

scores in a more standard test called Placement test (Seviye Belirleme Sınavı -SBS[2]) that was done ones a year by National Minister of Education.

Method

Participants

Data were collected through by convenient sampling. In the first study 408 primary school students from a state school participated. The participants consisted of 211 (51.7 %) female and 197 (48.3 %) male students. 183 students (44.9 %) were from fourth grade, 90 students (22.1 %) were from fifth grade and 135 students (33 %) were from sixth grade.

Only sixth grade students who attended SBS exam of the first study were taken the second study. Five students that did not attend the first study was added. So, one hundred – forty sixth grade students participated in the second phase of the study. The participants consisted of 73 (52.1 %) female and 67 (47.9 %) male students.

Measures

In this research "Young Pupils' Metacognitive Abilities in Mathematics", "Teacher Evaluation Form of Students' Metacognitive Abilities" and "Personal information form" were used.

Young Pupils' Metacognitive Abilities in Mathematics. The scale of ''Young Pupils' Metacognitive Abilities in Mathematics'' were developed in the light of Jr. MAI (Sperling, Howard, Miller & Murphy, 2002) by Panaoura and Philippou(2003) in order to measure metacognitive ability of young pupils in the domain of mathematics. Original scale consisted of 30 items and for each item pupils circle the answer that described their thoughts best while solving a problem they might encounter in math class (1 = never, 2 = seldom, 3 = sometimes, 4 = often, 5 = always). Examples of items are ''While I am solving a problem I wonder whether I answer its major question'', ''I know ways to remember knowledge I have learned in mathematics''. The inventory demonstrated high reliability (Cronbach alpha = 0.83). After confirmatory factor analysis, Panaoura and Philippou (2003) concluded that 15 items with two dimensions (metacognitive knowledge and metacognitive regulation) consist of an appropriate valid inventory for the measurement of young pupils' metacognitive abilities. The fit of final model was excellent and the values of the estimates were satisfactory in all cases (χ^2=119.128, χ^2/SD=1.547 GFI=0.94, AGFI=0.907, CFI=0.925, and RMSEA=0.047). Five items were indicators of the metacognitive knowledge, seven items were indicators of the metacognitive regulation and three items split at both the dimensions of metacognition. Translation and confirmatory factor analysis studies were carried by Özcan (2010). In the Turkish version, multidimentional form was not supported therefore only total score of the scale was used in this study. CFA's results show that the fit indices of the final model were satisfactory in all cases (χ^2=189.40 (N=417, SD=77, p=.000), χ^2/SD=2.45, GFI=0.94, AGFI=0.92, CFI=0.94, and RMSEA=0.059). Reliability coefficient of the scale was found 0.83 which is consistent with original form (Özcan, 2010). In this study this scale was called as "Metacognition – student form".

Teacher Evaluation Form of Students' Metacognitive Abilities in Mathematics. Teacher Evaluation Form of Students' Metacognitive Abilities in Mathematics which is also a mathematics domain specific measurement instrument was developed by Desoete (2007) and it was translated in the context of this study. It is a seven point Likert type scale (1 = never, 7 = always) consists of 20 items with four dimensions (prediction, planning, monitoring, evaluation). In the Turkish version multidimentional form was not supported therefore only total score of the scale was taken in this study. With one dimension the scale accounted 84 % of the total variance. Results from confirmatory factor analysis showed that the fit indices of the final model were satisfactory in all cases (χ2 = 189.40 (N = 417, sd = 77, p = .000), χ2/sd = 2.45 GFI = 0.94,

[2] SBS is a standard exam done by National Education Ministry to measure students' personal attainments related with their curricula. The year this research study conducted this exam is applied to 6th, 7th and 8th grade students. It is not a restricted exam. It is only done to select students to privileged high schools.

AGF I = 0.92, CFI = 0.94, and RMSEA = 0.059). The reliability coefficient of the scale was found to be .83, consistent with the original form. In this study this scale was called as "Metacognition – teacher form".

Personal Information Form. Teachers completed a personal information form about students' class level, final mathematics scores in their report and SBS mathematics scores were taken from administrator of the school.

Procedure

This study consisted of two parts. In the first part while investigating relationship between students' metacognitive scores (which consisted of students' self-evaluation and teacher evaluation) and mathematics achievements, students' mathematics scores in their report were taken as math achievement scores. Since it is thought that more standard test was suitable to measure students' mathematics achievement, in the second study, the same analyses were repeated with sixth grade students by using students' math scores from SBS that is more standard test were taken as math achievement score of students. In order to collect data, the permission was taken from the school administration. Metacogniton-teacher forms and personal information forms which are related with students were given to teachers. For the 4^{th} and 5^{th} graders classroom teachers and for the 6^{th} graders mathematics teachers completed forms. The teachers in this study recognize the students at least 8 monts. Metacognition – student forms were given students in one of their lessons with the help of school counselor. In order to search the relationship between metacognitive skills and mathematics achievement Pearson correlation coefficient and Multiple Linear Regression analyses were used for test statistics.

Findings

Data were initially analyzed by using correlation analysis, and independent variables (Metacognition-teacher form, Metacognition-student form) which have a significant correlation with math scores were taken multiple regression analysis. In multiple regression analysis, variables with smaller *t* values than 0.05 were identified as predictors of dependent variable.

Results of the First Study

Means, standard deviations and bivariate correlations of three measures (metacognition-teacher form; metacognition-student form, mathematics scores) are presented in Table 1.

Table 1. Means and bivariate correlation between the different instruments and mathematics achievement

Pearson Correlation	M (SD)	Math scores	Metacognition-Student form	Metacognition-Teacher form
Metacognition-Student form	58.31 (8.77)	0.42***	-	
Metacognition-Teacher form	94.95 (27.60)	0.78***	0.52***	-

* p < 0.05; ** p < 0.01; ***p < 0.001

As shown in Table 1, math scores were positively and significantly correlated with Metacognition-student form scores (r = 0.42, p < 0.001) and Metacognition-teacher form scores (r = 0.78, p < 0.001). There is a moderate correlation between Metacognition-student form and Metacognition-teacher form (r=0.52, p<0.001). Although Metacognition-student-form showed convergence with Metacognition-teacher form, instead of Metacognition-student form, Metacognition-teacher form highly correlated with mathematics scores.

To assess the amount of unique and shared explained variance of two measures (Metacognition-teacher form and Metacognition-student form) as predictors of scores on math scores multiple regression analysis was used.

Table 2. Results of Multiple Regression Analysis for variables of scores of metacognition- teacher form and scores of metacognition-student form that predicting mathematics achievement

Variable	β	t	p	Zero-order correlation	Partial correlation
Metacognition-teacher form	.76	21.02	.00	.78	.72
Metacognition-student form	.04	1.09	.28	.42	.05

[R = .78; R^2 = ,60; (F=306.31; p < 0.001)]

As shown in Table 2, the results of multiple regression analysis of predictive variables (scores of Metacognition-teacher form and scores of Metacognition-student form) showed that there is significant positive relationship between mathematics scores and Metacognition- students form scores (r=0.42). However when metacognition scores of teacher form controlled, (that are kept at fixed values) this relationship decrease seriously (r=0.05). However, the relationship between mathematics scores and Metacognition-teacher form scores were high (r=0.78) and this value remained unchanged on partial correlation when metacognition scores of student form controlled (r=0.72). When these two forms were analyzed together in the model, there is a significant positive relationship between these two forms (student form-teacher form) and mathematics scores of students [R =0.78; R^2 =0.60; (F=306,31; p < 0.001)]. An examination of R^2 values showed that these two variables accounted for 60 % of the total variance. When t values of the model that include**s** these two variables (Metacognition-teacher form and Metacognition-student form) were analyzed, it is observed that only the scores of Metacognition-teacher form was an important predictive variable of mathematics score.

Results of the Second Study

Means, standard deviations and bivariate correlations of three measures (Metacognition-teacher form, Metacognition-student form, SBS math scores) are presented in Table 1.

In order to assess the convergence between the two measures aimed at measuring students' metacognition and SBS math scores, means and bivariate correlations are presented in Table 3.

Table 3. Means and bivariate correlation between the different instruments and mathematics achievement

Pearson Correlation	M (SD)	SBS Math scores	Metacognition-Student form	Metacognition-Teacher form
Metacognition-Student form	59.13 (7.77)	0.26**	-	
Metacognition-Teacher form	97(24.52)	0.54***	0.29**	-

* p < 0.05; ** p < 0.01; ***p < 0.001

As shown in Table 3, SBS math scores were positively and significantly correlated with Metacognition-teacher form scores (r = 0.54, p < 0.001) and Metacognition-student form scores (r = 0.26, p < 0.01).There is a

low correlation between Metacognition-student form and Metacognition-teacher form (r=0.29, p<0.01). Although Metacognition-student form showed convergence with Metacognition-teacher form, instead of scores of Metacognition-student form, scores of Metacognition-teacher form is highly correlated with mathematic scores.

Table 4. Results of Multiple Regression Analysis for variables of scores Metacognition-teacher form and scores of metacognition-student form that predicting SBS mathematics scores

Variables	β	t	p	Zero-order correlation	Partial correlation
Metacognition-teacher form	.52	6,86	.000	.54	.51
Metacognition-student form	.07	.97	.33	.26	.08

$R = .54$; $R^2 = .29$; $F=28.31$; $p < 0.001$

As shown in Table 4, the results of multiple regression analysis of predictive variables (scores of Metacognition-teacher form and scores of Metacognition-student form) showed that there is a significant positive relationship between SBS mathematics scores and Metacognition-student form scores (r=0.26). However when metacognitive scores of teacher form were controlled (that are kept at fixed values) this relationship decline more radically (r=0.08). Yet, the relationship between SBS math scores and metacognition teacher form scores were positive and significant (r=0.54). At the beginning this value remained nearly unchanged (r=0.51) on partial correlation when metacognition scores of student form were controlled. When these two models (metacognition teacher form and metacognition student form) were analyzed together in the model, there is a significant relationship between these two forms and SBS math scores [$R = .54$; $R^2 = .29$; ($F=28.31$; $p < 0.001$)]. An examination of R^2 values showed that these two variables accounted for 29 % of the total variance. When t values of the model that includes two variables were analyzed, it is observed that only scores of Metacognition-teacher form was important predictive variable of mathematics score.

Discussion and Conclusion

According to results of this study that aimed to investigate which one of the evaluation form (teacher form versus student form) is the predictor of mathematics achievement, instead of the results of students evaluation form, the results of teacher evaluation form are the main predictor of the mathematics scores of students. Teacher evaluation form alone explains about 51 % of the variance in mathematics achievement. In both Deseote and Royers (2006) and Deseote (2007)'s studies pointed out that real metacognitive skills of the students can be evaluated by teacher form in that teachers evaluate students metacognitive skills. On the other hand as Veenman et al., (2006) stated time consuming on-line measurements of metacognition process explains 37 % of the total variance in learning. In Deseote (2007)'s study it is also reported that teacher evaluation results accounted for 22.2 % of the mathematics achievement. In the recent studies because of the economic usage, teacher evaluation forms used to assess students' real metacognitive skills (Deseote, 2007; Deseote & Roeyers, 2006).

Since both of mathematics report scores and teacher evaluation forms are evaluated by teachers, a significant relationship between them are highly expected result. On the other hand the presence of significant relationship between SBS math scores which is a standardized test and the results of teacher evaluation forms are very remarkable. Although there is a relation between metacognition student form and math scores, it was observed that metacognition student form did not predict variable on math scores. Similarly in Quinto and Weener's (1983) studies teachers self-report about students' math performance were positively correlated with knowledge-based metacognitive behaviors.

In the model of this study, elementary school students' self-report metacognitive skills were not predictor of their math scores. This finding can be explained by many of factors. The age of students maybe

was not enough to self-evaluate their metacognitive skills. This can be explanation of this finding. This is a parallel finding with Van der Walt, Maree and Ellis's (2008) studies which was indicated that there is no significant relationship between the students' views about their usage of cognitive strategies and math performance.

Applying on-line measurement instruments like think aloud protocols or interviews are very difficult to measure metacognitive level of students in crowded classrooms which is common in Turkey. This research study shows us that teacher evaluation form that is an off-line method is a good alternative to measure metacognition.

Although metacognition is a domain-specific construct (Venman and Spaans, 2005), in literature mostly while comparing that skills of students and mathematics achievement, general measurement instruments were used in order to measure students' metacognitive abilities. Designing math-specific instruments is the responsibility of mathematics educators. Using domain specific (math) instruments in this study is important with regard to generalization of the results. In addition, cultural adaptation of Metacognition-teacher form makes a contribution to math related studies. Comparative studies that use on-line and off-line mathematics domain specific measurement instruments (including teacher forms) should be carried out in the following researches.

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