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**Educating Mathematics Pre-Service Teachers in Metacognitive Skills**

Nimer Baya'a, Wajeeh Daher, Otman Jaber and Ahlam Anabousy

Athens Institute for Education and Research

8 Valaoritou Street, Kolonaki, 10683 Athens, Greece

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Nimer Baya'a, Senior Lecturer A, Head of the Information Communication Technology Center, Al-Qasemi Academic College of Education, Israel  
Wajeeh Daher, Professor, An-Najah National University, Palestine & Head of M.Teach Program in Graduate Studies, Al-Qasemi Academic College of Education, Israel

Otman Jaber, Lecturer and Pedagogic Supervisor, Department of Mathematics, Al-Qasemi Academic College of Education, Israel

Ahlam Anabousy, PhD Student, Tel Aviv University & Research Assistant, Department of Mathematics, Al-Qasemi Academic College of Education, Israel

**Educating Mathematics Pre-service Teachers in Metacognitive Skills**

**ABSTRACT**

In the present research, we educated mathematics pre-service teachers in using metacognition as learners and teachers of mathematics. This education was performed in one-year and was part of the participants' practical training in the training schools and in the frame of a reflection-based course related to the practical training. We studied the development of pre-service teachers' use and perceptions of using metacognitive skills in problem solving as part of mathematics learning. In addition, we verified whether the pre-service teachers' achievement in the different sets of B.Ed. courses has significant correlations with their metacognitive skills. Twenty pre-service teachers participated in the preparation. They were in their third academic year majoring in teaching mathematics and computer science in middle schools. The research results indicated that the educating program resulted in significant improvement in the pre-service teachers' scores in metacognitive skills, except in selecting solving strategies. In addition, the research results indicated that the achievement of the pre-service teachers in computer science courses, TPACK (Technology Pedagogy and Content Knowledge) courses and pedagogic training courses had significant correlation with the evaluating metacognitive skill. The other correlations between the achievement in the different sets of B.Ed. courses and the pre-service teachers' metacognitive skills were insignificant.

Keywords: Metacognitive skills, pre-service teachers, educating program, practical training, mathematics education.

## **Introduction**

Researchers are interested in the metacognitive aspect because of its relationship with other aspects as the cognitive aspect (Gavelek & Raphael, 1985) and the social and affective aspects (Daher, Anabousy & Jabarin, 2018). Belet and Guven (2011) claim that metacognition makes students aware of their learning. This awareness supports the internalization of what one learns and makes him/her consider carefully how to solve problems posed in the classroom. These advantages of metacognition for students' learning make it necessary that teacher education colleges attempt to prepare pre-service teachers, so that they develop their knowledge of metacognition for teaching. This development is expected to develop also their use of metacognitive skills and perceptions of using metacognition in teaching and learning. In the professional development program that the present study accompanies, we intended to develop the metacognitive skills of mathematics pre-service teachers as learners and teachers of mathematics.

## **Research Goals and Rationale**

The present research had two goals. The first is to find out whether a preparation program in metacognition would result in significant improvement in the scores of the metacognitive skills that mathematics pre-service teachers use in problem solving. The second is to find whether achievement in the different sets of courses in the B.Ed. studies has significant correlation with the metacognitive skills scores.

## **Research Questions**

1. Would the educating program in metacognitive skills result in significant differences in the scores of the various components of metacognitive skills in favor of the scores after the experiment?
2. Are the metacognitive skills scores correlated with pre-service teachers' achievement in the different sets of courses in the B.Ed. studies?

## **Literature Review**

Researchers looked at metacognition as cognition about cognition or knowledge about knowledge (Flavell, 1976; Panaoura, Philippou & Christou, 2003). Flavell (1976) was the first to use the term 'metacognition' to refer to the individual's awareness, consideration and control of his or her own cognitive processes and strategies. Since then, a variety of definitions has been given to the term of metacognition. Du Toit and Kotze (2009) argue that the various definitions of metacognitive processes in the literature, including that of

Schoenfeld (1992), emphasize the monitoring and regulation of cognitive processes. Moreover, Gavelek and Raphael (1985) argue that metacognition involves promoting effective understanding through adjusting the cognitive processes involved in the activity. Furthermore, Panaoura et al. (2003) say that it coordinates cognition, affecting it and, as a result, affecting students' academic success. Researchers pointed out, that metacognition is comprised of two different components connected to each other. Veenman et al. (2006) argue that the most common distinction in metacognition distinguishes between metacognitive knowledge and metacognitive skills. On the one hand, Flavell (1999) defines metacognitive knowledge as the knowledge or beliefs about the factors that act and interact to affect the course and outcome of cognitive enterprises: person, the task and the strategy. On the other hand, metacognitive skills involve planning, monitoring, evaluating and regulating the processes leading to achieving goals. Davidson and Steinberg (1998) described a theoretical framework that includes the following metacognitive skills: encoding, representation, decomposition, planning, selecting strategy, monitoring, evaluating and suggesting other strategies. In the present study, we focused on metacognitive skills and utilized the previous framework to introduce metacognition to our pre-service teachers. In addition, researchers suggested ways to encourage students to use metacognitive processes (e.g., Spiller & Ferguson, 2011). Schoenfeld (1992) describes ways for students to practice monitoring and evaluating their performance on math problems. For example, pause frequently during problem solving to ask themselves questions such as “What am I doing right now?” Spiller and Ferguson (2011) say that if we want students to use metacognitive processes, we need to encourage them to consider the nature and sequence of their own thinking processes. Chauhan and Singh (2014) say that as students become more skilled at using metacognitive strategies, they become confident and more independent as learners. In the present research, we wanted to educate mathematics pre-service teachers for using metacognitive processes, as learners and as teachers, through utilizing mobile technologies and collaborative learning.

## **Methodology**

### *Research Context and Participants*

The preparation was held for a full academic year 2017-2018. Twenty pre-service teachers participated in the preparation. They were in their third academic year majoring in teaching mathematics and computer science in middle schools. Two of the authors, who were the pedagogical supervisors of these pre-service teachers, accompanied them in two middle schools in the frame of the practical training. Our preparation of the pre-service teachers in metacognitive skills was based on the work of Davidson and Steinberg (1998) with special emphasis on using mobile technologies for solution strategies. In

addition, special attention was given for collaborative learning among the pre-service teachers' groups.

The preparation of the pre-service teachers went through the following phases (Daher, Baya'a, Jaber & Anabousy, 2018): (1) Theoretical preparation of metacognitive thinking, (2) designing activities that encourage metacognitive thinking, (3) implementing the metacognitive activities as learners and as teachers, (4) reflection and evaluation of the whole preparation process.

### *Data Collection Tools*

The data collection tools were the mathematical problems that the pre-service teachers were requested to solve. The data was the solution texts that the pre-service teachers provided for solving the problems using metacognitive processes.

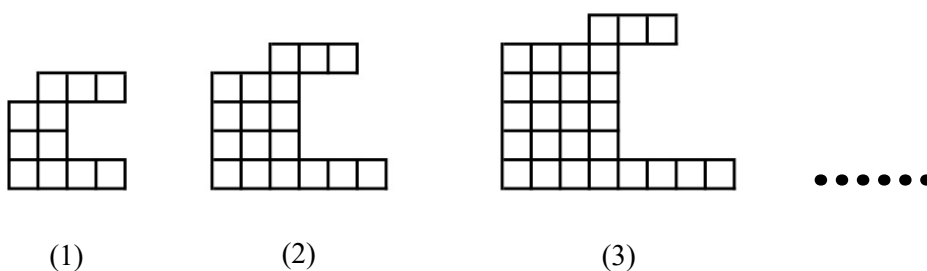
The pre-service teachers were requested to solve two mathematical problems at the beginning of the experiment, and another two problems of the same type at the end of the experiment. All the problems were constructed by the authors to promote the use of metacognitive skills.

### The Assignment

Below, we present the two problems given to the pre-service teachers before the experiment.

First problem before the experiment: In the figure below, you are requested to discover the pattern in the sequence of shapes below.

- A. Express the number of squares in the n term.
- B. Find the location of the shape that has 486 squares.
- C. Find the perimeter of the shape in the n term.
- D. Is there a shape in the sequence with perimeter equals to  $6^{2017}$ ? Explain your answer.



Second problem before the experiment: Find the sum of the following numerical series.

$$1^2 - 2^2 + 3^2 - 4^2 + 5^2 - 6^2 + \dots + 99^2 - 100^2$$

In every one of the previous assignment items, write down all the thoughts that came up to your mind and the questions that you asked yourself before, during and after solving the assignment.

### *Data Analysis Tools*

To analyze the data, we used deductive qualitative content analysis. Content analysis is a process designed to condense raw data into categories or themes based on valid inference and interpretation that use inductive and deductive reasoning. Deductive reasoning is used to generate concepts or variables from theory (Patton, 2002). In the present research we used only the deductive reasoning based on the theoretical framework of the metacognitive processes (Davidson & Steinberg, 1998) in order to categorize the pre-service teachers' metacognitive skills in solving mathematical problems. The metacognitive skills categories were: Encoding of the givens, representation of the givens, decomposition of the problem, planning, selecting and implementing strategy, monitoring of the plan, evaluating the solutions, and suggesting other strategies for solving the mathematical problem.

After categorizing the pre-service teachers' metacognitive skills in their solutions of the mathematical problems before and after the experiment, we counted the occurrences of each skill for each pre-service teacher. This count was considered the score of the pre-service teacher in the specific metacognitive skill.

### **Findings**

At the beginning, we report the participating pre-service teachers' metacognitive activity when solving authentic mathematical problems during the one-year preparation and the influence of the preparation on the pre-service teachers' scores in the various components of metacognitive skills.

In the first activity, when the pre-service teachers were requested to solve the authentic problem of measuring the height of a tree, they did not mention any technological tools that would help them in measuring the tree height. They suggested using a stick, but could not elaborate on the process of the solution. On the other hand, in the following activities, for example, when given an authentic problem about a computer engineer from a village in the suburbs who was hired to work for a Hi-tech company in the city. The participating pre-service teachers were requested to help the engineer find the most efficient way to get to work. They suggested a plan that demonstrated their awareness of the metacognitive processes needed for such plan. Following are their suggestion in which they used the terms of the metacognitive processes.

Encoding of the givens – We can use Google Maps to identify the locations of the village and the city, and to measure the distance between them.

Representation of the givens – After presenting the locations on Google Maps, we prepare a table of the various measurements of the variables that could contribute to the efficiency of each road or type of transportation.

Decomposition of the problem – Depending on Google Maps representations, we can identify various roads or types of transportation.

Planning – After finding data about each road or type of transportation, we give weight for each variable to determine the efficiency of each road or type of transportation, and finally decide on the most efficient one.

Selecting and implementing strategy – We will suggest to the engineer to choose several roads or types of transportation using Google Maps and/or the Mobile application "Waze" in order to collect data.

Monitoring of the plan – We advise the engineer to travel using more than one suggested road or type of transportation. Doing that, the engineer needs to keep collecting data, using a mobile application like "Waze", to keep calculating the efficiency.

Evaluating the solutions – To look after the measurements and compare between the transportation types and the different roads, the engineer could use a Mobile spreadsheet. This application facilitates the evaluation of the transportation roads or types efficiencies.

Suggesting other strategies or mobile applications - Finally, we advise the engineer to keep tracking of new strategies/applications that could improve the accuracy of the measurements in order to get better assessment of the efficiency of the transportation roads and types.

#### *The Influence of the Preparation on the Pre-service Teachers' Scores in the Various Components of Metacognitive Skills*

To answer the first research question, we computed means and standard deviations of the scores of the various components of metacognitive skills. In addition, to verify whether the differences in the scores are significant, we ran paired-sample t-test. The results are shown in Table 1.

**Table 1.** Means and Standard Deviations for the Pre-service Teachers' Metacognitive Scores before and after the Experiment, and Paired t-test for the Differences of the Scores (N=20)

Metacognitive skills	BE M (SD)	AE M (SD)	95% CI for Mean Difference	t value
Encoding	1.55 (1.00)	2.85 (1.95)	-2.25, -0.35	-2.87*
Representing	1.50 (1.36)	2.60 (1.73)	-1.84, -0.36	-3.10**
Decomposing	0.00 (0.00)	0.45 (0.69)	-0.77, -0.13	-2.93**
Planning	0.15 (0.37)	1.05 (1.15)	-1.45, -0.35	-3.45**
Selecting strategy	1.65 (1.31)	2.30 (1.98)	-1.44, 0.14	-1.72
Monitoring	0.20 (0.52)	1.70 (1.63)	-2.22, -0.78	-4.36***
Evaluating	0.10 (0.45)	1.80 (1.40)	-2.35, -1.05	-5.51***
Suggesting	0.00 (0.00)	0.20 (0.70)	-0.53, 0.13	-1.29
Total	5.15 (2.43)	12.95 (5.35)	-9.28, -6.32	-11.00***

\* p< 0.05, \*\* p<0.01, \*\*\* p<0.001, BE=Before Experiment, AE=After Experiment.

Table 1 shows that the differences in the pre-service teachers' scores in the various metacognitive skills are all significant except in selecting strategies and suggesting other strategies.

To find whether the metacognitive skills scores are correlated with the pre-service teachers' achievement in the sets of courses in the three college years, we first computed means and standard deviations of the achievement in the different sets of courses. Table 2 describes the results of these computations.

**Table 2.** Means and Standard Deviations of the Participants' Achievement in the Different Sets of Courses (N=20)

Courses type	M	SD
Education	84.85	3.32
Mathematics	83.68	5.38
Computer Science	88.80	5.65
TPACK	91.94	6.19
Practical Training	91.56	3.17
General	87.58	3.16

We see that generally the pre-service teachers' grades are good (More than 80 out of 100) to excellent (More than 90 out of 100).

To find the significance of the correlations between the achievement in the different sets of courses and the metacognitive skills scores, we ran Pearson's correlations. These correlations are exhibited in Table 3.



**Table 3.** *Pearson's Correlations between the Achievement in the Different Sets of Courses and the Metacognitive Skills Scores (N=20)*

	<b>Edu</b>	<b>Math</b>	<b>Comp</b>	<b>TPACK</b>	<b>Pract</b>	<b>Gen</b>
<b>Encoding</b>	0.273	-0.430	0.14	-0.01	-0.04	-0.21
<b>Representing</b>	-0.050	-0.32	-0.29	-0.357	0.01	-0.16
<b>Decomposing</b>	-0.065	-0.305	-0.07	-0.279	0.012	-0.25
<b>Planning</b>	-0.179	0.06	0.11	0.00	-0.343	0.11
<b>Strategy</b>	-0.20	-0.06	0.17	0.23	0.43	0.16
<b>Monitoring</b>	0.09	-0.22	-0.05	-0.08	-0.14	-0.22
<b>Evaluating</b>	0.37	0.19	0.50*	0.54*	0.63**	0.58**
<b>Suggesting</b>	0.30	-0.32	-0.30	-0.21	-0.02	-0.12
<b>Total</b>	0.13	-0.36	0.11	0.02	0.20	-0.01

\* p< 0.05, \*\* p<0.01, Edu= Education, Math=Mathematics, Comp=Computer Science, Pract =Practical Training, Gen=General Average.

Table 2 shows that the achievement in the different sets of courses is correlated with just one metacognitive skill which is evaluating.

### Discussion and Conclusions

The present research had two goals. The first is to find out whether a preparation program in metacognition would result in significant improvement in the scores of the metacognitive skills that mathematics pre-service teachers use in problem solving. The second is to find whether achievement in the different sets of courses in the B.Ed. studies has significant correlation with the metacognitive skills. Regarding the first goal, the results indicated that the pre-service teachers' scores in the various metacognition skills improved significantly after the education program, except in selecting strategies and suggesting other strategies. It seems that the pre-service teachers developed their planning of the problem solution, but this planning did not include looking for different strategies and selecting one of them. This indicates the need to attract the students' attention to the importance of considering different solution strategies before they go forward to solve the problem and after they solve it. This could be done through giving the students mathematical problems that could be solved in different strategies, when the immediate strategy is not the most effective one. Discussing the solution of the problem with the students would show them that more effective strategies would have made their solutions sounder.

In addition to the above, the research results indicate that teacher education program affect positively teachers' practices as learners and as teachers. Valli, Perkkilä and Valli (2014) report about a pre-service teachers' experience in developing 21st century skills through collaboration in order to use technology, critical thinking and creativity in problem solving. Valli et al. (2014) found that

the pre-service teachers took into account the 21st century skills in planning learning environments, but less so regarding how to apply 21st century skills in classroom. Moreover, Baya'a and Daher (2015) examined the effect of educating college instructors in using ICT skills in education on their technological pedagogical content knowledge. Baya'a and Daher (2015) found that the educating program was successful in making the participating instructors improve their use of ICT in teaching their pre-service teachers who are the future teachers.

Regarding the second research goal, the results indicated that achievement in the different sets of courses is correlated with just one metacognitive skill which is evaluating. This could be explained by the achievement of the pre-service teachers being good or more.

Thus the educating program affected them all almost in the same extent. As to the correlation between the achievement in the different sets of courses and the evaluation metacognitive skill, being significant, there are two issues here. The first issue is that the education courses and the math courses did not correlate significantly with the evaluation metacognitive skill. This insignificance is represented also in the means of the two sets of courses being the smallest between the other scores, as they are near the good scores more than the excellent scores. This makes the scores of the education and math courses not influencing evaluation metacognitive skill, which is a skill at the end of the metacognitive measurement scale. This results in the expectation that it will be influenced only by high levels of knowledge, which is the case in the computer science, TPACK and Pedagogic training courses. The second issue here is that the evaluation means increased, as a result of the experiment, by 1.70 which is the biggest increase in the scores of the metacognitive skills. This means that the educating program affected the evaluation skill more than any other skill, which is expected because generally this skill is low among students and teachers. Yusoff and Seman (2018) examined teachers' questioning skills, where this examination revealed that teachers were familiar with questioning based on Bloom's Taxonomy, but only half of the teachers practiced asking high order thinking questions based on Bloom's Taxonomy.

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