AN INTERVENTION TO THE METACOGNITIVE PERFORMANCE: SELF-REGULATION IN MATHEMATICS AND MATHEMATICAL MODELING

ARETI PANAOURA, ATHANASIOS GAGATSIS, ANDREAS DEMETRIOU

Abstract. The present study investigates the improvement of students’ self-representation about their self-regulatory performance on mathematics by developing an intervention program depended on the mathematical model proposed by Verschaffel, Greer and De Corte (2000). Three tools were constructed for pre and post-test. There were administered to 255 students (11 years old). The mathematical model was presented to students as a useful tool for problem solving through a constructed web page. Results confirmed that providing students with the opportunity to self-monitor their learning behavior when they encounter obstacles in problem solving, through the use of modelling, is one possible way to enhance students’ self-regulation and consequently their mathematical performance.


Riassunto. Il presente studio si propone di discutere l’impatto, che consegue all’uso del modello matematico proposto da Verschaffel, Greer e De Corte (2000), sullo sviluppo dell’autorappresentazione degli studenti del loro comportamento autoregolatorio in matematica. Sono stati sviluppati tre materiali utilizzati in pre e post test somministrati a 255 studenti di 11 anni ai quali il modello è stato presentato tramite una pagina web. I risultati confermano che dare la possibilità agli studenti di auto monitorare, attraverso la modellizzazione, il loro apprendimento quando incontrano ostacoli nella risoluzione dei problemi è una possibile via per migliorare l’autoregolazione degli studenti e di conseguenza le loro performance matematica.


Key words: self-regulation, mathematical modelling, metacognition

1 INTRODUCTION

Due to a multitude of empirical evidence, there is now a consensus on the effectiveness of self-regulated learning on academic achievement (Dignath, Buettner & Langfeldt, 2008). Self-regulation is a dimension of metacognitive performance and due to the differences on the use of concepts such as metacognition, self-representation, self-regulation etc, we explain at this introductory phase briefly the terms, which are used at the present study.

In the last decades, children’s early understanding of their own as well as others mental states has been intensively investigated, reflecting growing interest for this construct (Bartsch & Estes, 1996). In psychological literature, the term metacognition refers to two distinct areas of research: knowledge about cognition and regulation of cognition (Boekaerts, 1997; Fernandez – Duque, Baird & Posner, 2000). Metacognition has its basis on information processing and general intelligence theories and as a consequence, it is defined in many ways (Alexander, Carr and Schwanejflugel, 1995). Even from the time Flavell (1979) used the term “metacognition”, this concept has two main and distinct components: metacognitive knowledge and self-regulation. In the present paper we understand “metacognition” as meaning awareness and monitoring of one’s own cognitive system and its functioning. We adopt the view that awareness of cognition or self-representation and self-regulation constitute the two main dimensions of metacognition.
With regard to the first dimension, Boekaerts (1997) argues that “metacognitive knowledge has come to refer to aspects of student’s theory of mind, theory of self, theory of learning and learning environments” (p.165). Metacognitive knowledge allows students to better comprehend, monitor or assess conceptual and procedural knowledge related to a domain. Self-regulation refers to the processes that coordinate cognition. It reflects the ability to use metacognitive knowledge strategically to achieve cognitive goals, especially in cases where someone has to overcome cognitive obstacles. It has become clear that one of the most important issues in self-regulated learning is the student’s ability to select, combine and coordinate strategies in an effective way (Boekaerts, 1999).

Many researchers have argued that the development of metacognitive awareness, the accurate self-representation and the development of self-regulatory strategies are key factors to successful learning. Those characteristics guide the quality of interactions children have with the intellectual and social activities they encounter (Davis & Carr, 2002). According to the self-regulated learning approach, students are self-regulating when they are aware of their capabilities of the strategies and resources required for effectively performing a task, as well as when they plan, monitor and regulate actions towards their learning goals (Paris & Paris, 2001, Zimmerman, 1999). For effective self-regulation, however, positive beliefs about one’s own abilities are also needed (Schunk & Zimmerman, 2006).

As regards the relationship between academic self-concept and academic achievement, extant literature supports both direct and indirect relationships between them; however, the range of correlations reported is a function of several factors (Guay, Marsh & Boivin, 2003). Age is a factor that affects this relationship (Dermitzaki, Leonardi, & Goudas, 2008). In young students, academic self-concept is usually very positive and not highly correlated with external indicators, such as skills and achievement (Cuay et al., 2003). Veenman and Spaans (2005) assumed that metacognitive skills initially develop on separate islands of tasks and domains. Beyond the age of 12, these skills will gradually merge into a more general repertoire that is applicable and transferable across tasks and domains. Among 12 year olds a phase of transition is characterized by applying recently acquired general metacognitive skills, along with remainder of domain-specific metacognitive skills. The present work is concentrated on the development of metacognitive performance on the domain of mathematics.

Whereas in the beginning of research on metacognition almost all the investigations were confined to metamemory today metacognition is studied in a broader context. Metacognitive functions are now investigated in different domains, like text comprehension, mathematics, and problem solving (Dignath, et al., 2008). Research in mathematics education has recently focused on metacognition and its effect on student’s learning behavior, mathematical performance, and especially problem solving (Lerch, 2004). Learning mathematics, as an active
and constructive process, implies that the learner assumes control and agency over his/her own learning and problem solving activities (De Corte, Verschaffel & Op’t Eynde, 2000). Knowing when and how to use cognitive strategies is an important determinant to successful word problem solving (Teong, 2002). Metacognitive knowledge can be applied in every stage of the problem solving activity. For example before starting solving a particular problem, students can ask themselves questions like what prior knowledge can help them develop a solution plan for the particular task; during the application of the solution plan the students monitor their cognitive activities and compare progress against expected goals. Finally, after reaching a solution, the students may need to look back, to check for the reasonableness of outcomes and integrate newly acquired knowledge to existing. The metacognitive aspect of problem solving needs to be expanded in order to include the problem solver’s self-representation, as a mathematical being (Lerch, 2004). Lack of confidence and previous lack of success combined to prompt swift decisions to stop working. Self-efficacy theory predicts that students work harder on a learning task when they judge themselves as capable (Mayer, 1998).

2 PROBLEM SOLVING PROCEDURE AND THE USE OF MATHEMATICAL MODELING

Problem solving transfer occurs when a student is able to use what s/he has learned in order to solve problems that are different from those presented during instruction (Kapa, 2007). Studies on solving mathematical word problems refer to various conditions that cause transfer to occur, for example, providing solved examples (e.g. Bassok & Holyoak, 1989), having a scheme (Nesher & Hershkovitz, 1994), and providing feedback (Hoch & Loewenstein, 1992; Morrison, Ross, Gopalakrishnan & Casey, 1995).

Especially in problem solving tasks a balance between cognitive and metacognitive processes is necessary. As Gourgey (1998) puts it “whereas cognitive strategies enable one to make progress to build new knowledge, metacognitive strategies enable him/her to monitor and improve one’s progress – to evaluate understanding and apply knowledge to new situations” (p.82). According to Davidson and Sternberg (1998) the first step in solving a problem is to encode the given elements. Encoding involves identifying the most informative features of a problem, storing them in working memory and retrieving from long-term memory the information that is relevant to these features. Incomplete or inaccurate metacognitive knowledge about problems often leads to inaccurate encoding and could generate learning obstacles.

A specific strategy frequently taught in math classes in order to enhance problem solving ability, is to use analogy in order to create a mental model of
similar problems. In this regard, the students are expected to extract the relevant facts from the statement of the problem, compare it to their knowledge base, relevant to the problem domain, and recognize similarities between the new problem and problems they have previously encountered, and abstract the proper entities and principles. Empirical findings show that students fail to see the underlying principles unless they are explicitly pointed out (Panaoura & Philippou, 2005). Even after being exposed to multiple examples, they focus upon the procedural similarities of the problems. In order to successfully use analogy to create a mental model, students must be able to extract the relevant facts from the problem, compare it to prior knowledge base in the problem domain, and recognize relevant similarities between the current problem and previous ones that they had encountered.

The solution and modeling of open-ended problems have been of interest to mathematics educators for decades. Mathematical modeling of problem solving is a complicated procedure which is divided into different stages (Mason, 2001). When a mathematical modeling task is offered in a school the goal generally is not that students learn to tackle only that particular task. Rather, students are expected to recognize classes of situations that can be modeled by means of a certain mathematical concept, relation or formula, and to develop some degree of routine and fluency in mapping problem data to the underlying mathematical model and in working through this model to obtain a solution (Van Dooren, Verschaffel, Greer & De Bock, 2006).

A characteristic is that the modeling process is not a straightforwardly sequential activity consisting of several clearly distinguishable phases. Modelers do not move sequentially through the different phases of the modeling process, but rather run through several modeling cycles wherein they gradually refine, revise or even reject the original model. The present study discusses the impact of the use of the mathematical model proposed by Verschaffel, et al. (2000) on the development of students’ self-representation about their self-regulatory behavior in mathematics. The main stages of the model are:

- Understanding the phenomenon under investigation, leading to a model of the relevant elements, relations and conditions that re embedded in the situation (situation model).
- Constructing a mathematical model of the relevant elements, relations and conditions available in the situation model.
- Working through the mathematical model using disciplinary methods in order to derive some mathematical results.
- Interpreting the outcome of the computational work to arrive at a solution to the real – word problem situation that gave rise to the mathematical model.
- Evaluating the model by checking if the interpreted mathematical outcome is appropriate and reasonable for the original problem situation.
- Communicating the solution of the original real – word problem.
At the first phase of the problem solving procedure by the use of the mathematical model students have to consider and decide what elements are essential and what elements are less important to include in the situation model. In the next phase, the situation model needs to be mathematised i.e. translated into mathematical form by expressing mathematical equations involving the key quantities and relations. For this, students need to rely on another part of their knowledge base, namely mathematical concepts, formulas, techniques and heuristics. After the mathematical model is constructed and results are obtained by manipulating the model, numerical result needs to be interpreted in relation to the situation model. At this point, the results also need to be evaluated against the situation model to check for reasonableness. As a final step, the interpreted and validated result needs to be communicated in a way that is consistent with the goal or the circumstances in which the problem arose. In typical school word problems, task requirements do not go beyond reporting the outcome of the calculation work.

Generally mathematics learning is no longer seen as merely the acquisition of knowledge but also as learning to participate in the discourse of the mathematical community (De Corte, 2000). By participating in social activity (e.g. cooperate problem solving) students have an opportunity not only to learn mathematical skills and procedures, but also to explain and justify their own thinking, to discuss their observations and observe models of how to use mathematics effectively in different problem solving situations (Hurme & Jarvela, 2005).

Nowadays problem-solving skills have become a prominent instructional objective, but teachers often experience difficulties in teaching students how to approach problems and how to make use of proper mathematical tools. Many teachers of mathematics teach students to solve mathematical problems by having them copy standard solution methods. It comes as no surprise, therefore, that many students find it difficult to solve new problems, especially problems within a context (Harskamp & Suhre, 2006). Attempts to improve problem solving should focus on episodes students neglect when solving problems. The aim of the present study was to develop students’ (5th grade) problem solving ability and to enhance their ability to self-regulate their cognitive performance in order to overcome cognitive obstacles when they encounter difficulties while trying to solve mathematical problems. One of the main emphases was to oblige students rethink their cognitive processes while trying to solve the problems and encounter difficulties in order to monitor their performance and self-regulate their behavior. We hypothesized that the development of self-representation in order to be more precise regarding the students’ strengths and limitations would improve their self-regulatory behavior in mathematics. Especially for the problem solving procedure we hypothesized that the better distinction of problems and the clustering of those problems according to their similarities and differences would
have as a consequence the better transfer of knowledge and strategies from the one domain to the others and from general situation to the specific ones.

The positive impact of self-regulation on learning is undoubted and it has led to the great research interest in promoting self-regulated strategies. We believe that the construction of learning strategies, especially in mathematics, can be guided in order to acquire self-regulated learning strategies. Most of the research on self-regulated learning in school settings has been conducted with older students. Studies on the development of metacognitive knowledge and self-regulated learning reported a major shift between kindergarten age and grade six (Dignath et al., 2008). The present study concentrated on the upper stages of primary education.

3 Methodology

At the present section we present in details the procedure for the development of the program for the use of the proposed mathematical model, the participants and the statistical analyses that were used.

3.1 Participants

Data were collected from 255 children (107 experimental group and 148 control group), in Grade 5 (11 years old) from five different urban elementary schools. The mean age of the sample was 10.8 years. The participation at the program were voluntary because we had used the extra time students stayed at school for the program of the Ministry of Education, called “day-long school”. This program was developed during a pilot phase at few schools and students voluntary stayed at school for three more hours, where they were working on their homework, on athletics, music, computer and so on. We had used the time for the computer-lesson or the time for homework (when they had finished their homework) in order to work individually at the web page we had constructed.

3.2 Procedure

The main emphasis was on the development of the program for the use of the proposed mathematical model, the training of students on the model and the evaluation of its results.

At the first phase of the study three tools were constructed for pre and post test. The first one was about students’ self-representation, the second for mathematical performance and the third one for their behavior while trying to solve mathematical problems. The first one comprised of 40 Likert type items of five points (1 = never, 2 = seldom, 3 = sometimes, 4 = often, 5 = always), reflecting students’ self-representation about mathematical learning. The responses to the questionnaire
provide insight into students’ self-representation which refers to how they perceive themselves in regard to a given mathematical problem. The reliability of the whole questionnaire was very high. Specifically, the Cronbach’s $\alpha$ was .87.

The second tool, a test, was comprised of 20 mathematical tasks on counting, geometry, statistics and problem solving. In order to be sure about the suitability of the tasks we asked primary education teachers to assess their relation to the teaching content. All items in the mathematical performance questionnaire were scored on a pass-fail basis (0 and 1). The reliability of the mathematical tasks was high (Cronbach’s $\alpha$ was 0.85).

The third questionnaire comprised of ten couples of sentences and students had to choose which one expressed better their cognitive behavior while they are encountering a difficulty in problem solving. All the questionnaires were first used at a pilot study in order to examine their construct validity. All the tasks were presented in paper and pencil form and were individually administered.

Then an intervention program was developed in order to propose the use of the mathematical model (Figure 1) for problem solving, proposed by Verschaffel et al. (2000). The emphasis was on the understanding that different stages of problem solving would have as a consequence the use of different cognitive procedures and that the cognitive obstacles could be encountered by realizing the cognitive interruptions at one or more of those stages and mainly by self-regulating the cognitive performance. For example a self-regulatory strategy is the ability to recognize the “inner” mathematical similarities and differences of mathematical problems in order to transfer cognitive and metacognitive strategies among different domains. For this reason we had constructed a web page which was visited individually by each student of the experimental group (107 students) during 20 “meetings” where they had been introduced to the use of the proposed mathematical model. One of the main emphases was to oblige students rethink their cognitive processes while trying to solve the problems and encounter difficulties in order to monitor their performance.

![Figure 1. The mathematical model proposed by Verschaffel et al. (2000).](image-url)
We had organized twenty “individual meetings” of the students with the webpage in order to work with the model (almost 20 minutes each meeting). Each “meeting” had specific objectives. The first four “meetings” were for the familiarization with the environment of the computer and for understanding the whole idea of the webpage for the problem solving procedure. The ten following “meetings” concentrated on different stages of the proposed mathematical model. For example at the stage of “understanding the problem” students had to solve problems with not enough data, or with more than the necessary data, they had to answer specific questions about the data of the problem, they had to explain in their own words the problem, to summarize it etc. At the stage of “modeling” they had to work on the classification of mathematical problems by explaining the criteria they used in order to classify the problems. There were problems with the same situational characteristics or the same context in order to oblige students to be concentrated on the structural mathematical characteristics. At the last six “meetings” students should solve mathematical problems by using all the stages of the mathematical model. In each stage the “cartoon” who was the hero of the webpage asked questions such as “How did you get that?, This isn’t a better solution?, Do you have any better solution?”, in order to force students to self-regulate their cognitive performance. We wanted to have a reflection at all the stages of their work. The students’ responses were recorded automatically at a data base with details such as when they had worked on the specific task, and for how long.

3.3 Statistical Analysis

At the present paper we concentrate our attention on the descriptive analysis for the improvement of students’ self-representation, mathematical performance and self-regulation by comparing the experimental group with the control group and on the qualitative analysis of two students’ behavior.

4 Results

The data about self-representation (1st questionnaire) were first subjected to exploratory factor analysis in order to examine whether the presupposed factors that guided the construction of the items of the first questionnaire were presented in the participants’ responses. This analysis resulted in 6 factors with eigenvalues greater than 1, explaining 65.56 % of the total variance. After the content analysis, according to the results of the exploratory factor analysis items were classified in the following factors:
F1. general self-image about mathematics
F2. self-representation about problem solving abilities
F3. self-representation about the strategies used in order to self-regulate the cognitive performance
F4. self-representation about students’ spatial abilities in mathematics
F5. self-representation about the degree of concentration on problem solving procedure.
F6. the preference for different types of representations

We concentrated on the three factors which were related with self representation in respect to problem solving and self-regulation (F1, F2 and F3). The comparison of the means of the three factors between the pre and post tests for the experimental and the control group were statistically significant in all cases (p<0.001). Nevertheless the improvement was highest for the experimental group in the case of the second and the third factors (Table 1). It is obvious the increase of the control group as well as a consequence of the age development and the impact of teaching and learning (those were factors that could not be controlled). However the improvement was in all cases higher in the case of the experimental group.

Table 1. The means of the experimental and the control group for the three factors at the pre and post test.

<table>
<thead>
<tr>
<th></th>
<th>Pre-test experimental</th>
<th>Pre-test control</th>
<th>Post-test experimental</th>
<th>Post-test control</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>3.92</td>
<td>4.00</td>
<td>4.00</td>
<td>4.07</td>
</tr>
<tr>
<td>F2</td>
<td>3.22</td>
<td>3.25</td>
<td>3.69</td>
<td>3.57</td>
</tr>
<tr>
<td>F3</td>
<td>2.76</td>
<td>2.78</td>
<td>3.35</td>
<td>3.20</td>
</tr>
</tbody>
</table>

F1: self-image about mathematics
F2: self-representation about problem solving abilities
F3: self-representation about self-regulation

At the same time for the experimental group the improvement was highest in the case of the general mathematical performance (X̄_1exp=0.27, X̄_2exp=0.63, X̄_1control=0.27, X̄_2control=0.52) and the problem solving performance (X̄_1exp=0.20, X̄_2exp=0.47, X̄_1control=0.20, X̄_2control=0.39). Specifically the highest differences were found in the domain of geometry (X̄_1exp=0.28, X̄_2exp=0.47, X̄_1control=0.29, X̄_2control=0.44) and statistics (X̄_1exp=0.38, X̄_2exp=0.69, X̄_1control=0.38, X̄_2control=0.64). This result reveals the positive impact of the use of the specific mathematical model on the mathematical performance.

The most important in the case of self-representation is the accuracy of this feature in relation to the real mathematical performance. We have clustered the participants according to their general self-image about their mathematical performance into three groups. The first group was consisted of 42 students with low self-image (X̄=2.55), the second one of 82 students with medium
self-image ($\bar{X} = 3.26$) and the third one of 99 students with high self image ($\bar{X} = 3.94$). There were statistically significant differences between the first and the third group at the initial phase (pre-test) in respect to their real mathematical performance ($F=4.716$, $df=2$, $p=0.01$, $\bar{X}_1=0.466$, $\bar{X}_2=0.543$, $\bar{X}_3=0.605$). After the program the difference of the groups regarding their general self-image in relation to their mathematical performance (post test) was significant only in the case of the experimental group ($F=4.447$, $df=2$, $p=0.01$, $\bar{X}_1=0.557$, $\bar{X}_2=0.6059$, $\bar{X}_3=0.699$). Those results indicated that most students had accurate self-image in respect to their real mathematical performance and they did not seem to overestimate their abilities.

At the same time students’ means at the classification of similar mathematical problems according to the mathematical structure of the problems were highest at the post test. The development was statistically higher in the case of the experimental group ($\bar{X}_1=0.29$, $\bar{X}_2=0.49$, $t=12.79$, $p<0.001$) than the control group ($\bar{X}_1=0.29$, $\bar{X}_2=0.41$, $t=11.69$, $p<0.001$). The difference between the two groups was statistically significant ($t=3.32$, $df=228$, $p<0.01$).

A part of the couples of sentences at the third questionnaire were about the self-regulatory strategies they use in order to encounter difficulties and cognitive obstacles at the problem solving procedure. For example we supposed that the claim “I use to read again the problem and try to understand all the words” express a self-regulatory strategy rather than the claim that “I am asking of the help of my teacher”. For the self-regulatory strategies the difference of the means between the two measurements were statistically significant ($t=2.93$, $df=98$, $p<0.01$, $\bar{X}_1=0.65$, $\bar{X}_2=0.69$) only in the case of the experimental group. That means that students tended to develop more self-regulatory strategies or they tended to believe that they had to develop those strategies. Even the second learning situation is an important step for the change of cognitive and metacognitive behavior, as well.

Students of the experimental group were clustered according to their self-representation about problem solving ability and their general mathematical ability into three groups (low self-representation: 24 students, medium: 36 students, and high self-representation: 34 students). Analysis of variance (ANOVA) indicated that there was a statistically significant difference concerning their self-representation about the use self-regulatory strategies in mathematics ($F_{2,93} = 6.094$, $p=0.003$). As it was expected the mean of the group with the high self-representation was higher (0.80) than the other two groups (medium: 0.63 and low: 0.58). The most interesting result was that the mathematical performance of the students with medium and low performance was increased after the program (low: $\bar{X}_1=0.83$, $\bar{X}_2=0.87$, medium: $\bar{X}_1=0.90$, $\bar{X}_2=0.94$, high: $\bar{X}_1=0.94$, $\bar{X}_2=0.94$). In the case of the improvement on the self-representation about the use of self-regulatory strategies for the three groups the changes were similar (low self-representation: $\bar{X}_1=0.50$, $\bar{X}_2=0.53$, medium self-representation:}
4.1 QUALITATIVE RESULTS

After the results of the analysis of the first questionnaire (about self-representation) at the phase of the pre-test we had chosen the student with the lowest self-image about mathematical performance and the student with the highest self-image. We had observed those two students at all the stages of their work with the model and we had organized semi-structured interviews in order to analyze qualitatively their cognitive and metacognitive behavior. At this section we present indicative reactions they had while working at the program and answering questions at the researchers at a context of a semi-structured interview.

At the fourth “meeting” at the webpage the first student expressed her happiness because she would not have to “solve problems”. She had to work on the similarity of mathematical problems and the classification of the problems at groups of similar problems. She mentioned that two problems were similar because both of them were talking about oranges. The following discussion is indicative:

− Which is the similarity of the 3rd and the 4th problem? Why did you characterize them as similar?
  
  (3rd problem: The difference at the quantity of oranges between the box A and the box B is 12. The quantity of oranges at the box B is not bigger than 30 and it is a number which is a multiplier of 11. Which is the quantity of oranges at each box?
  
  4th problem: I have bought 2 kg of oranges for 1 euro and 50 cents and 3 kg of oranges for 76 cents. How much did a pay?)
  
  − Both of them include the word oranges.
  
  − All the problems with the word oranges are solving with the same way?
  
  − Maybe. There are similar. You have to put them in boxes so you have to multiply numbers.
  
  − At those problems you will multiply the numbers?
  
  − No because I do not know how much is 12X30.
  
  − Then?
  
  − But I do not have to solve them.
  
  − If you had to solve them what would you do?
  
  − I would multiply the numbers. I would write a possible answer because the teacher does not like to have empty boxes for the answers.
It is obvious that the specific girl used to solve routine problems by following specific procedures which are useful for “similar problems”. It is interesting that at the first “meetings” she tended to stop working after she encountered difficulties. At the end of the program, twice she decided to ask one of her classmates for assistance.

The second child, the girl with the most positive self-image about her mathematical performance, tried to solve all problems even in the cases that the program asked her to evaluate a proposed solution or to classify the problems. She mentioned that she liked to behave like a teacher and pose mathematical problems. At the 9th meeting she had to pose a similar mathematical problem with the following: “How can the number 3650043 be converted into 3620343” (a calculation was always present at the webpage). She posed the problem “How can the number 15803 be converted into 13800”.

− Good. Is your problem difficult?
− No because they (her classmates) have to use only subtraction. I did not want it to be difficult.
− They (her classmates) would not be able to solve it if there was addition as well?
− Not all of them. I am the best in mathematics. I will go at the Olympics competition in few days (There is a competition in mathematics for the students of primary education every year)...Last year I had done 3 mistakes but this year I feel that I will be better.
− What are you doing when you face difficulties in problem solving?
− I try to understand it. I do not like to say that I cannot solve it. I feel confused and I do mistakes at other problems as well. This happened last year at the competition.
− Do you always understand all the problems?
− Yes.
− Are you able to solve all the problems proposed by Alpinos (the cartoon of the webpage of the program)?
− Yes. For few of them I spend more time but most of them I solve them immediately. Only yesterday I did not solve a problem.
− Is it important to solve them immediately?
− I always do that in my class and then I try to explain them to my friends.
− Yesterday, when you did not solve it, what did you decide?
− It was difficult. It was wrong to pose such a difficult problem for children at the 5th grade. It was impossible to solve it.

We have to mention that we had observed the girl while working in cases that the problems were difficult and she seemed to feel very nervous with the idea that she could not solve them. Her anxiety seemed to prevent her from self-regulating her behavior because she was unable to concentrate on her work. At the same time, at the first “meetings” she did not spend time to rethink the
problems or to reflect on her solutions. At the next “meetings” she tried to answer questions about her reflections on the solutions only when the “webpage asked” for something like that. Further research could indicate whether these types of programs could have as a consequence the positive impact on the development of those strategies or procedures especially in cases where a student is not asked to do that, or whether there could be stability at the acceptance of this type of behavior.

In the case of the first student it is obvious that we had a child with negative self-image who did not have any motivation to continue working on mathematical problems. In the second case it is obvious that we had a child with positive self-image who did not realize that in problem solving procedure the encountering of difficulties is a normal situation and she has to regulate her performance in order to overcome cognitive obstacles. She did not actually seem to have metacognitive experiences in self-regulating her behavior.

5 DISCUSSION

Results confirmed that providing students with the opportunity to self-monitor their learning behavior in the case of encountering obstacles in problem solving through the use of modeling is one possible way to enhance students’ self-representation about the self-regulatory strategies they use in mathematics and consequently their mathematical performance. It seems that the program with the use of the model created a powerful learning environment in which students were inspired in their own experiences. Nevertheless it is obvious that students with high self-representation about their mathematical abilities in the initial phase were at the same time students with the most self-regulatory strategies after the impact of the intervention program, as well. That means that although the program improved the metacognitive performance and the mathematical performance of the experimental group, further research is needed in order to find ways to change the initial differences among students.

In respect to the use of the mathematical model, it is intuitively appealing to accept the view that people think by analogy, comparing problems with similar structures, but not necessarily with the same features or story line. A key obstacle to this process is the failure of subjects to abstract the relevant principles from the problem at hand. In order to successfully use analogy to create a mental model, students must be able to abstract out the relevant entities and principles of the problems. The results of the present study underline the difficulties that it is possible to be appeared if the teaching of problem solving is focused only on the use of strategies according to the similarity of the mathematical problems in order to enhance mathematical performance and metacognitive ability. Instruction should mainly lead students to self-questioning as a systematic strategy in helping them
control their own learning and organize by themselves the different occasions they may encounter.

The human mind is much more complex than simply cognitive abilities and processes and their presentations. Self-representation and self-regulation are constrained by processing potentials of the mind. For the development of a more accurate self-representation about mathematical performance and self-regulation in problem solving teachers must create a powerful learning environment, in which children are allowed and inspired to, their own learning experiences. According to the self-regulated learning approach students are self-regulating when they are aware of their capabilities of the strategies and resources required for effectively performing a task (Paris & Paris, 2001). Learners, who decide to ask a more competent person for assistance when faced with a task, indicate that they realize their difficulties and try to find out ways to overcome them. The accurate self-representation about the strengths and limitations is a presupposition for the development of self-regulation. The qualitative results are the first indications that researchers and school practitioners should be looking into students’ bias towards overconfidence in the first years of elementary school (Desoete & Roeyers, 2006). At the same time, it seems that strong problem solvers are flexible in their approach and usually monitor their solution process. Novices on the other hand spend much time carrying out procedure without questioning the adequacy of their solution plan (Harskamp & Suhre, 2007).

The present study has highlighted the need to expand the metacognitive aspects of problem solving, to include the solver’s self-image as a mathematical being (Lerch, 2004). Successful academic performance depends on cognitive as well as metacognitive abilities. In the area of mathematics, a number of important questions about metacognition remain unanswered. Much more research is needed to study the different aspects of metacognition in a more systematic and detailed way. We suggest specifically that further research could focus on interactive computer programs which may be designed to provide feedback and hints to assist students in becoming more aware of their cognitive and metacognitive processes. It would be optimistic and naïve to claim that such types of intervention programs would develop the self-regulatory strategies of all students. Possibly different models and programs are suitable for different groups of students. Providing students with the opportunity of self-regulate their behaviour by encountering cognitive obstacles and proposing them ways to handle them (such as the concentration of similarities among problems) is one possible way to enhance students’ self-representation about the self-regulatory strategies they use. Those types of strategies can be adapted in a stable way and transferred to other domains maybe above the age of 12 years old (Veenman & Spaans, 2005). Cognitive and metacognitive strategies are much more complex and further analysis is needed for the indicated duration of intervention in order to have the expected positive results which will have the expected stability.
ACKNOWLEDGMENTS

This paper draws from the Research Project ALPAS which was funded by the Cyprus Research Foundation and it was developed with the contribution of Erik De Corte (University of Leuven), Wim Van Dooren (University of Leuven), Andreas Demetriou (University of Cyprus), Athanasios Gagatsis (University of Cyprus) and Areti Panaoura (Frederick University)

REFERENCES


AN INTERVENTION TO THE METACOGNITIVE PERFORMANCE


ARETI PANAOURA, Department of Education, Frederick University, Yiagkou Michaelide 34A, 1048, Nicosia, Cyprus
E-mail: pre.pm@fit.ac.cy

ATHANASIOS Gagatsis, Department of Education, University of Cyprus, Nicosia, Cyprus
E-mail: gagatsis@ucy.ac.cy

ANDREAS DEMETRIOU, Minister of Education, Department of Psychology, University of Cyprus
E-mail: ademetriou@ucy.ac.cy