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The purpose of the present study was to investigate whether teaching self-regulation strategies via "Solve it" to students with learning disabilities could affect their problem-solving performance in mathematics. The mathematical problems involved four mathematical operations with natural and decimal numbers. Also, the present study investigated the effect of "Solve it" instruction on students' self-efficacy and value related to mathematics. It was a single-subject design with a pre-test, four repeated post-tests and a maintenance test. The results indicated that the students' problem-solving performance was improved and their self-efficacy and value attributed to mathematics were increased.

Keywords: Self-regulation strategies, mathematical problem solving, LD, self-efficacy, value.

Introduction

Learning how to solve mathematical problems plays the most important role in the promotion of mathematical thinking. Mathematical problem solving process is especially complex as it requires the use of cognitive and metacognitive strategies as well as emotional management in case of a failure (Freeman-Green, O'Brien, Wood & Hitt, 2015; Rosenzweig, Krawec & Montague, 2011). Some researchers argue that many students with LDs face difficulties in solving mathematical problems due to their deficits in metacognitive processes, such as prediction and evaluation as well as difficulties in using metacognitive strategies in order to monitor and control their learning (Babakhani, 2011; Rosenzweig et al., 2011). A recent learning approach that combines the selection and use of cognitive and metacognitive strategies, motivation for learning and successful control of emotions is called *self-regulated learning* (Wirth & Leutner, 2008).

This paper is part of a larger study which was conducted for the requirements of a Master's Degree and explores whether teaching self-regulation strategies with the program "Solve it" can influence problem-solving performance of students with LDs. This program includes the use of seven cognitive strategies and three metacognitive strategies. In this paper, it was investigated if the use of seven cognitive strategies and three metacognitive strategies in combination with self-assessment which plays the role of motivation to students can improve problem-solving performance of two students with LDs in order to reach the mastery criterion of the program. In addition, it was explored if teaching problem solving process with these strategies can affect these students' self-efficacy and value attributed to mathematics. Also, the study tried to shed further light on the metacognitive and self-regulated learning processes and their interplay with motivation in students with LDs in mathematics.

Theorεtical framework and research questions

It is accepted that learning how to solve mathematical problems plays the most important role in the promotion of mathematical thinking. According to van Garderen & Montague (2003, p. 246)

> mathematical problems are challenging problems set in realistic contexts that require understanding, analysis, and interpretation. They are not simply computational tasks embedded in words; instead, they require appropriate selection of strategies and decisions that lead to logical solutions.

Over the last 20 years, a new approach called self-regulated learning has been developed aiming among others at improving problem solving skills. This approach has been successfully implemented in developing problem solving skills as it examines metacognitive, motivational and affective aspects of problem solving activity. A lot of researchers have tried to define the composite construct of self-regulated learning (Wirth & Leutner, 2008). Self-regulated learning is defined as

> a learner's competence to autonomously plan, execute and evaluate learning processes, which involves continuous decisions on cognitive, motivational, and behavioural aspects of the cyclic process of learning. (Wirth & Leutner, 2008, p. 103)

Research reveals that many students and especially students with LDs in both primary and secondary education face difficulties in solving mathematical word problems (Rosenzweig et al., 2011). Before proceeding to the description of these difficulties, a definition of the term "learning disabilities" should be provided. Under the Individuals with Disabilities Education Act of 2004 (IDEA), the federal law that protects students with disabilities, a specific learning disability is defined as

> a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include learning problems that are primarily the result of visual, hearing, or motor disabilities, of mental retardation, of emotional disturbance, or of environmental, cultural, or economic disadvantage. (34 C.F.R.300.7[c][10])

These students have difficulties in using metacognitive strategies in order to monitor and control their learning (Babakhani, 2011; Rosenzweig et al., 2011).

International contemporary research has shown that teaching self-regulated learning strategies is associated with the improvement of problem solving performance of students with LDs (Babakhani, 2011; Freeman-Green et al., 2015). A self-regulation program that has been successfully implemented in interventions in order to improve problem solving performance of students with LDs is called "Solve it" (Montague, 1992). This program was introduced by Montague (1992) and it combines the use of three self-regulation strategies: self-instruction, self-questioning and self-monitoring with the following four major instructional techniques: problem solving assessment, explicit instruction of problem solving strategies, process modeling and performance feedback. The program includes the following seven cognitive strategies which correspond to seven instruction phases (Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute and Check). Each of these strategies, **including** three self-regulation strategies: self-instruction, self-questioning and self-monitoring are taught. These strategies rely heavily on metacognitive processes. "Self-instruction implies telling oneself what to do before and while performing actions" (Montague, Warger & Morgan, 2000, p.111). "Self-questioning means asking oneself questions while engaged in an activity to stay on task, regulate performance and verify accuracy" (Montague et al., 2000, p.111). "Self-monitoring requires the problem-solver to make certain that everything is done correctly throughout the problem-solving process" (Montague et al., 2000, p.111).

The "Solve it" program includes seven instruction phases and it is separated into eight lessons (Montague et al., 2000). Lesson one includes an overview of "Solve it" and a description of the cognitive strategies. In lesson two students are tested for the mastery of seven cognitive strategies. Lessons three, four and five include metacognitive strategy instruction and students solve one mathematical problem in each lesson. For example, for the cognitive strategy "Reading" there were three self-regulation strategies that had to be implemented (SAY, ASK, CHECK). The students said to themselves "Read the problem. If I don't understand, read it again.", asked themselves "Have I read and understood the problem?" and checked by saying "Check for understanding as I solve the problem". The criteria for moving to lesson six are three: remembering cognitive strategies, remembering metacognitive strategies (SAY, ASK, CHECK) and solving problems with relevant confidence. In lesson six, students solve ten mathematical problems and they can consult the diagram with the strategies which had been given to them in lesson one and think aloud. Each problem-solving process is modeled by the students or by the teacher after it has been solved. Lesson seven requires the students to solve all 10 problems before modeling the correct solutions for the problems. Lesson eight is the first Progress Check (test of ten problems). Students plot their "grade" on their performance graph and then model the solutions. From then on there will be more tests and students will plot their performance. Student progress graphs show whether students can make constant progress and move toward mastery. It is important to engage students in assessing their own progress by having them chart their performance in diagrams which motivate them to continue trying (motivation) (Montague et al., 2000). The mastery criterion of the program, which is the ultimate goal, is solving 7 out of 10 problems correct on four consecutive tests (Montague et al., 2000).

It should be noted that this program is more frequently used in secondary education (students with and without LDs) with great success (Montague, 1992; Montague, Krawec, Enders & Dietz, 2014) for solving one-, two- and three-step problems with natural and decimal numbers but as Montague (1992) states, this program can be used with younger students provided that adaptations should be made in processes and materials. In the studies where the program was implemented with younger students, they did not manage the mastery criterion as there were no adaptations. As the participants of this study were sixth grade students of an elementary school, some adaptations regarding "Solve it" were required in order to manage the mastery criterion of "Solve it". In addition, acronyms were used for the description of the strategies in order to be remembered by the students. The acronyms came from the first letter of each strategy in Greek language. Furthermore, it should be noted that there is no clear exploration of the effects of teaching self-regulation strategies via "Solve it" to LD students' self-efficacy sense and value attributed to mathematics so this is the novelty of this study.

Consequently, the purpose of this study was to investigate whether teaching self-regulation strategies with "Solve it" could affect students' with LD mathematical problem solving performance, their mathematics self-efficacy and value. Therefore, the following 4 research questions were stated as follows: 1) Will sixth grade students with LDs improve their mathematical problem solving performance in problems with four mathematical operations with natural and decimal numbers after the implementation of "Solve it"? 2) Will students' self-efficacy related to mathematics and problem solving activity change after the implementation of the intervention? 3) Will students' value attributed to mathematics and problem solving activity change after the implementation of the intervention? 4) Will students with LDs maintain their improved performance one month after the intervention with "Solve it"?

Method

The present study was a single-subject design as two students with LDs participated in the study. In addition, an experimental design with one experimental group (two students with LDs) was implemented. A pre-test and four repeated post-tests took place. One month after the last post-test, a maintenance test was implemented. In this experimental design, the independent variable was the intervention with the program "Solve it" and the dependent variables were the following three: mathematical problem solving performance, self-efficacy in relation to mathematics and the value which was attributed to this school subject.

Participants

Two students (a male and a female) with LDs took part in the present study. The students were identified as having learning disabilities based on psychoeducational evaluations from an outside state agency. Specifically, the boy encountered specific learning disabilities of dyslexic type and speech problems and the girl learning disabilities in reading, writing and mathematics. Both students were studying in the 6th grade of an elementary school, in North-West Greece and they had difficulties in mathematical calculations and mathematical problem-solving. Moreover, they attended the subjects of Mathematics and Greek Language in a general education classroom and they additionally received resource room support on these subjects from a special education teacher. Parental consent was given for both participating students.

The students' teacher (first researcher) taught the self-regulation strategies. The teacher implemented "Solve it", designed the tests with the mathematical problems, administered and collected the questionnaires. The teacher was 25 years old female and she had met the children six months before the beginning of the intervention. She had completed her practicum with these children in the context of earning Master's Degree so she had already been acquainted with the students and that was the reason why they were selected to be the sample of the study.

Procedure

The intervention of the present study began in November 2015 and finished in December 2015.The maintenance test was implemented on 15th January 2016. The boy attended 18 sessions and the girl 23 sessions that lasted 35-40 minutes. One week before the beginning of the intervention, the pre-test was implemented. The pre-test included 10 one-, two- and three-step word problems (Montague et al., 2000). Also, the two students responded to the 2 questionnaires assessing mathematics self-efficacy and value attributed to mathematics. Afterwards, "Solve it" intervention began and included 8 lessons. The 8th lesson was the first progress check (post-test) and three additional posttests followed. In the last post-test, students responded again to the two questionnaires on mathematics self-efficacy and value. Additionally, as it was mentioned previously, an adaptation took place. Specifically, for the better interpretation of the strategies, the strategies were visualized. Specifically, each of the seven cognitive strategies was displayed with words and small pictures that showed the steps of action implied by the strategy. For example, the strategy "Read" was presented verbally, in a diagram and with this icon. 

Data collection

The mathematical problem solving performance was measured with tests which were designed by the researcher by following the suggestions offered by the creator of "Solve it". Each test included 10 mathematical one-, two- and three-step word problems which were based on the mathematical problems that students had been taught in their classroom (e.g. two-step word problem: 'Nick wants to buy three car-miniatures. Each of them costs 3.6€. He has already collected 8€. How much money does he need in order to buy them?').

Despite the small number of participants, quantitative methods for the data collection regarding self-efficacy and value were used, as the time for the completion of the intervention was limited and the school principal could not give extra teaching hours for an interview. However, some verbal questions were done for clarifications of some of the students' answers in the questionnaires. The data concerning self-efficacy regarding mathematics learning were collected with the use of a questionnaire. The questionnaire was developed by Dermitzaki and Efklides (2002) and assessed students' reported self-efficacy in mathematics with 5 items (e.g. 'I believe I will have a better mathematical problem-solving performance this year'). Answers were given on a five-point scale from 1-'Not at all true for me' to 5-'Totally true for me'. Because of the students' difficulties in reading comprehension, the questions were being read by the researcher and students were asked to circle the answer that was true for them. After the completion of the questionnaires, the students were verbally asked some questions in order to clarify some of their answers ("mini interview" for clarifications). These answers were written down by the teacher-researcher at the same time.

The data regarding value which was attributed to mathematics and mathematical problem solving were also collected with the use of a questionnaire which was made by the researcher based on Ames' scale (1983). This scale assessed students' value beliefs about mathematics as a school subject. The questionnaire included 3 items (e.g. 'Learning how to solve mathematical problems is…..') and the answers were given on a five-point scale from 1-'Not at all important' to 5-'Highly important'. Each question was asked verbally by the researcher and the students had to circle the answer that was true for them. After the completion of the questionnaire, the students were asked to clarify some of their answers ("mini interview" for clarifications) which were written down by the teacher-researcher at the same time.

Data analysis

The quantitative data that were collected from the tests were not statistically analyzed because of the small data number. However, a diagrammatical representation with Microsoft Office Excel 2010 was made. The quantitative data that were collected from the two questionnaires and mini-interviews were qualitatively analyzed. Because of the small number of questionnaires, a statistical analysis could not take place. The careful data reading and the description of the data had as a result two categories deriving from each questionnaire. Two categories were developed based on the first questionnaire. The first category included self-efficacy regarding mathematics and the second included self-efficacy regarding a problem solving activity. Similarly, two categories were derived from the second questionnaire. The first category included value attributed to mathematics and the second category included value attributed to a problem solving activity.

Results

Regarding to the first research question, the progress graph showed that both students' mathematical problem solving performance improved significantly. Specifically, the boy increased his performance from 2.6/10 on pre-test to 9.65/10 on the first post-test and the girl increased her performance from 0.5/10 on pre-test to 7.89/10 on the first post test. Additionally, both students achieved the criterion of solving at least 7 out of 10 word problems correct on four consecutive word problem tests which is the ultimate goal of "Solve it" according to Montague et al. (2000).

Concerning the second research question, the results showed that both students increased their self-efficacy regarding mathematics and mathematical problem solving activity. The boy reported that he was feeling a little efficacious in solving mathematical problems and towards mathematics before the beginning of the intervention. However, he reported that he felt very efficacious about solving mathematical problems and confident towards mathematics after the end of the intervention. The girl reported that she felt a little efficacious about mathematics and very efficacious about solving mathematical problems before the intervention. When the researcher asked her while she was completing the questionnaire "Why do you think that you will be more efficacious in solving mathematical problems?", she answered "I will read more, I will attend carefully the lessons and I will learn how to solve mathematical problems. " After the intervention, she reported that she felt very efficacious about mathematics and solving mathematical problems.

Additionally, both students attributed important value to mathematics and to the problem solving activity after the intervention with "Solve it". The boy reported that both mathematics as a school subject and problem-solving as a mathematical activity were of little importance for his life before the intervention. After the intervention, he thought that mathematics was highly important and problem solving was very important for his life. The girl attributed very important value to mathematics but she thought that solving mathematical problems was not an important activity for her life before the intervention. When the teacher asked her while she was completing the questionnaire "Why mathematics is very important for you?", she answered "Because learning the multiplication table is very important for our lives". After the intervention, she thought that both mathematics and problem solving activity were highly important for her life.

It should be underlined that both students expressed that they had developed more positive emotions such as happiness, when they solved mathematical problems after the intervention. That happened because according to them, they felt safety with the use of the strategies as the last ones had proved to be very helpful in order to solve a mathematical problem.

Finally, regarding the fourth research question, both students maintained their improved performance on the maintenance test one month after the intervention. The score for the boy was 9.6/10 and for the girl 9.05/10. It seems that the girl not only maintained her performance but also improved it more in relation to the last post-test. This finding has not been found in other studies.

Discussion

This study aimed to investigate whether teaching self-regulation strategies via "Solve it" affected students' with LDs mathematics problem-solving performance, their maths self-efficacy and reported value of maths. The results of the present study are very encouraging. In agreement with other studies (Babakhani, 2011; Montague, 1992; Montague et al., 2014) both students' mathematical problem solving performance was considerably improved. Also, they seemed to achieve the ultimate goal of "Solve it" (7 out of 10 problems correct on four consecutive tests). This was a surprisingly good result as there was not such a result in other studies which used "Solve it" with elementary school students. As Montague (1992) states, the sixth grade students have not easily reached the mastery criterion. However, in this study students appeared to maintain this performance on the maintenance test a short while after; maybe as the result of the visualization.

Furthermore, both students reported increased self-efficacy in relation to mathematics as a school subject and in relation to problem solving activity. Additionally, both students attributed higher value to mathematics as a school subject and to problem solving activity after the intervention. As Chatzistamatiou, Dermitzaki, Efklides & Leondari (2015) state, there is a positive relationship between the use of self-regulation strategies and self-efficacy and between the use of these strategies and value attributed to mathematics by typically developing students.

Although, the effect of teaching self-regulation strategies on students' emotions regarding problem-solving activity was not examined in this study, it is important to mention that both students reported they felt happier when they solved mathematical problems after the intervention with "Solve it". More particularly, the boy said "Now I do not feel so stressed when my teacher tells me to solve a mathematical problem and I feel happy when I do it, even if I cannot find the solution". A future research could examine in more depth whether and how self-regulation strategies could influence students' emotions during problem-solving activity.

In conclusion, this study showed that "Solve it" can improve problem-solving performance not only in older but also in younger students with LDs provided that some adaptations will take place. Furthermore, "Solve it" seemed to affect positively students' self-efficacy and value attributed to mathematics. However, there are some limitations such as the limited generalizability of the results (case study), the different characteristics of the two students, the short time in which the study was carried out and the absence of a control group. Future studies could use "Solve it" in other mathematical domains such as geometry which students with LDs find quite challenging and difficult. In addition, a future study could test how teaching self-regulation strategies would influence LD students' emotions in relation to mathematics. Such data would be actually illuminative for educational research and practice.

References

Ames, R. (1983). Teachers' attribution of their own teaching. In J. M. Levine & M. C. Wang (Eds.), *Teacher and student perceptions: Implications for learning* (pp. 105–124). Hillsdale, NJ: Erlbaum.

Babakhani, N. (2011). The effect of teaching cognitive and meta-cognitive strategies (self-instruction procedure) on verbal math problem-solving performance of primary school students with verbal problem-solving difficulties. *Procedia Social and Behavioral Sciences, 15*, 563–570. doi:10.1016/j.sbspro.2011.03.142

Chatzistamatiou, M., Dermitzaki, I., Efklides, A., & Leondari, A. (2015). Motivational and affective determinants of self-regulatory strategy use in elementary school mathematics. *Educational Psychology*, *35*(7), 835–850. doi:10.1080/01443410.2013.822960

Dermitzaki, I., & Efklides, A. (2002). The structure of cognitive and affective factors related to students' cognitive performance in language and maths [in Greek]. *Psychology: The Journal of Hellenic Psychological Society, 9,* 58–74.

Freeman-Green, S. M., O'Brien, C., Wood, C. L., & Hitt, S. B. (2015). Effects of the SOLVE strategy on the mathematical problem solving skills of secondary students with learning disabilities. *Learning Disabilities Research & Practice, 30*(2), 76-90. doi:10.1111/ldrp.12054

Montague, M. (1992). The effects of cognitive and metacognitive strategy instruction on mathematical problem solving of middle school students with learning disabilities. *Journal of Learning Disabilities, 25*(4), 230–248. doi:10.1177/002221949202500404

Montague, M., Krawec, J., Enders, C., & Dietz, S. (2014). The effects of cognitive strategy instruction on math problem solving of middle-school students of varying ability. *Journal of Educational Psychology, 106*(2), 469–481. doi:10.1037/a0035176

Montague, M., Warger, C., & Morgan, T. H. (2000). Solve it! Strategy instruction to improve mathematical problem solving. *Learning Disabilities Research & Practice, 15*(2), 110–116.

Rosenzweig, C., Krawec, J., & Montague, M. (2011). Metacognitive strategy use of eighth-grade students with and without learning disabilities during mathematical problem solving: A think-aloud analysis. *Journal of Learning Disabilities, 44*(6), 508–520. doi:10.1177/0022219410378445

van Garderen, D., & Montague, M. (2003). Visual-spatial representation, mathematical problem solving, and students of varying abilities. *Learning Disabilities Research & Practice, 18*(4), 246−254. doi:10.1111/1540-5826.00079

Wirth, J., & Leutner, D. (2008). Self-regulated learning as a competence: Implications of theoretical models for assessment methods. *Journal of Psychology, 216*(2), 102–110. doi:10.1027/0044-3409.216.2.102