# The Influence of Metacognitive Strategies on the Performance of Primary Students in Solving Mathematical Problems

Dorina SĂLĂVĂSTRU, Manuela VLASIE[1]

***Abstract*:** This paper starts from the premise that metacognition is a factor which influences the primary cycle students' results at math. Within this context, we set as our goal to create a program of metacognitive intervention and to apply it on a group of 9-10 years' old students (third grade). The main objective was to evaluate the impact from the metacognitive treatment upon school performance at math of the students from the experimental group. This impact was measured within two groups of students, distinguished according to the independent variable „intelligence level". The experimental plan was a test - retest type. The results achieved from the retest indicate a significant increase of the school performance at solving math problems for both groups of students.

***Keywords***: metacognition, self-regulation, intelligence level, solving problems, metacognitive intervention program

## Introduction

From the perspective of cognitive psychology, many of the students' difficulties at math originate within metacognitive deficits. More precisely, we can notice that many students know the theorems and formulas, but they don't know when and how to use them. Or, they know how to approach certain situations but fail at similar tasks whose characteristics have been slightly modified. We can say that the students do not know how to use the appropriate strategies to solve a problem or to fulfill a task.

The researchers state that most of the differences between experts and beginners, between those who learn with ease and those who encounter learning difficulties, between the students regarding failure and those who are successful in school, can be found at a metacognitive level. The successful students know his/her own cognitive capabilities. They can move away from themselves, can step in to improve their own knowledge or his/her learning activities.

The starting idea was that metacognition can contribute to students overcoming their learning difficulties. Access to metacognitive reasoning mostly depends on the manner in which the teacher designs the teaching - learning activities. These must help the student to acquire the needed instruments in order to regulate his/her intellectual activity.

Referring to mathematical activity, which consists mostly of solving problems, J. Focant (2003) considers that, in order for it to take place, at least 3 types of abilities are needed:

[1] Alexandru Ioan Cuza University of Iaşi

- efficient knowledge of the procedures (algorithms) needed for solving the problem;
- the ability to select and activate these procedures;
- motivational, volition and affective abilities to actively approach the task and persist until it is solved.

From analyzing all these abilities, we can see that metacognition is a determining factor for solving problems and learning math. The researchers in this field converge towards the idea that, during the teaching - learning process, the metacognitive activity must be brought to a conscious level, in order to be looked at, analyzed and accepted.

**Metacognition and self-regulation**

Metacognition is the process through which cognition considers itself as an object; it is cognition on cognition, referring by that to the knowledge which an individual possesses about his/her own cognitive processes and products. The individual can use this knowledge to exert a reversing influence, self-regulative, upon his/her own cognition. The research undertaken by Veenman & Van Hout Wolters (2006) points out the fact that 17% of the students' school performances are explained by the presence of metacognitive abilities, while the influence of intellectual aptitudes is only 10%. Together, the two parameters explain 20% of the academic performances. From this data, the authors conclude that metacognitive abilities could compensate possible weaknesses of the intellectual aptitudes.

The first works on metacognition emerged in the USA, during the eighth decade of the last century (Flavell, 1976, Brown & Campione, 1978, Brown, 1987) and they belong to the larger sphere of research within cognitive psychology. The pioneer of the research on metacognition is J.H. Flavell (1976, 1979), who reached this concept by undertaking research activities on metamemory. Metamemory represents the knowledge which an individual possesses about the memory process (for instance, the fact of knowing that certain kinds of information need more repetition, that the better organized material can be memorized more easily, etc) and about the strategies used during the memorizing process.

According to A.L. Brown (1987), the concept of metacognition has 2 dimensions: it designates both the knowledge which an individual has about his/her own cognitive functioning and the mechanisms for regulating and controlling the cognitive functioning. J. Delacour (2001, p. 35) emphasizes all these aspects of the metacognitions very well with the next definition: "Metacognition is the capacity to represent oneself their own cognitive activity, to evaluate their tools and results, to adjust it for all kinds of problems or situations by deliberately choosing strategies and rules and mainly to establish the value of truth for some representations".

As such, metacognition is a complex construct, which implies not only metaknowledge, but also self regulated and self monitored learning. Self regulated learning refers to the students' capacity to exercise an active, metacognitive, motivational and behavioural control of their own learning. Self regulation assumes abilities of independent designation of the learning goals, of cognitive preparation of the action (planning, strategy's selection), of performances' self evaluation and self strengthening of the available answers.

**Metacognition's components**

The analyses undertaken by J.H. Flavell (1976) and afterwards by A.L. Brown (1987), Gombert (1990), Pintrich, Schrauben (1992), Noël, Romainville, & Wolfs (1995), Louise Lafortune & Lise Saint-Pierre (1998) about the metacognition process emphasized 2 components:

1. the knowledge and beliefs which an individual possesses about his/her own cognitive processes, including both favorable factors and unfavorable factors for this process (knowledge of cognition).
2. active control, the regulation and the manipulation of these processes in order to reach a specific goal (regulation of cognition).

**Metacognitive knowledge** represents „the declarative aspect of the metacognition" and they include three categories: knowledge relating to persons, knowledge related to the task and knowledge related to the strategies.

- *Knowledge related to the persons is: intraindividual, interindividual and universal.* Those intraindividual include ideas and beliefs that the individual possesses related to his/her own self. As an example, He/She can believe that they have a better visual memory than an auditory memory or that they are more successful at verbal tasks rather than numerical or spatial tasks. Interindividual knowledge is the comparisons which we draw from others. For instance, a student compares himself/herself with their desk mate about mathematical success and believes they are better than the other in this field. Finally, universal knowledge is the information in which we possess about human thinking in general. For instance, we know, because of the discoveries made by cognitive psychology, that the processing level of information influences learning efficiency or that short term memory has a limited time span and volume or that, in order to understand a new subject, prior knowledge of the respective subject is extremely important.
- *Knowledge referring to the task* concern knowing the task's goals, its requirements, its difficulty level and the factors and conditions for fulfilling the respective task. For instance, the student has to know how to distinguish between the manner of approaching a historical text and a literary one or that in order to solve a math problem he/she will follow a different method than for a grammatical one.
- *Knowledge referring to strategies* is both general and specific knowledge about the learning strategies which we need to know where, when and how to use

them, for instance, to know how to make a summary, how to find the main idea or what to do in order to understand a text.

For math, the knowledge referring to persons include evaluating mathematical abilities, comparing between math performances and performances in other fields as well as the effects of affective variables (motivation, anxiety, self-confidence). Task related knowledge includes the subject's opinions about the effects of the content, context, structure and terminology upon the task difficulty. The strategy related knowledge includes knowledge of algorithmical and euristical strategies, knowledge of the strategies which allow the understanding of a task, the manner of depicting the information and problems' data, the way to fulfill the plan.

All this metacognitive knowledge is stored within the memory and it is automatically or, on the contrary, voluntarily activated according to the task's requirements. Metacognitive knowledge has a great influence on managing mental processes. For instance, a student who believes that in order to solve mathematical problems he/she needs special abilities, which they do not possess, will superficially approach the task, abandoning it at the first hurdle. At the same time, the fact of possessing metacognitive knowledge does not automatically lead to using them in order to manage the mental activity. For instance, the fact of knowing an efficient learning strategy does not represent any guarantee that it will be used when needed. In order for that strategy to be used at the appropriate moment, there is a need for abilities to control and regulate the cognitive activity.

**The control and regulation of the cognitive activity** (managing mental activity) define „the procedural aspect" of the metacognition and refers to the activities which we undertake in order to control and monitor our own thinking. This metacognition component was developed within the realm offered by the paradigm of self regulated learning. According to Brown (1987), the management of mental activity takes place through specific strategies and processes of planning, controlling/monitoring and regulating, closely tied to the situation at hand and the task.

- *Planning strategies* - consisted of anticipating and deciding upon the way in which the task was to be solved. For instance, when we find ourselves facing a problem which has to be solved, we act in the next manner: we first undertake an analysis of the task and the strategies with the greatest chance of success, then we divide the problem in sections and we set the goals which have to be reached; we set the stages to go through and the required time for each stage. Schöenfeld (1987) showed that the beginners in the field of the mathematics devote much less time than the experts for such planning activities when they have a problem to solve. This pushes them, many times, to take a wrong road, which are much more demanding in time and cognitive effort.
- *Strategies of control/monitoring* - they assume the supervising of the ingoing activity by checking the progress, the correctness of the results, identifying the errors and evaluating the efficiency of the chosen strategies. For instance,

while solving a task we make statements like „if I use this method, I will have a greater chance to make more mistakes", „within this problem, there are 3 formulas which I'm not aware of", „the result I attained makes no sense because it contradicts t theory". These reflections are the evidence for using control strategies.

- *Regulating strategies* refer to the interventions which we decide to undertake relying on what we ascertained through the control activities. The decision to repeatedly read difficult material, to change the strategy we used with another one which seems more certain. To increase the level of effort or the time dedicated to studying a subject are all examples of regulating strategies.

Garofalo & Lester (1985) think that an important condition for the mathematical activity of solving problems is the efficient management of mental processes. The students seem deficient particularly in regard to controlling and regulating the cognitive activity. The lack of self-regulation is a characteristic which sets the beginners apart during problem solving: the beginners seek just one solvable hypothesis and perform calculations without asking about their suitability.

A lot of teachers think, mistakenly, that these strategies are spontaneously acquired by the students, as an effect of repeatedly solving problems. This conclusion can be valid only for a small number of students. For the most of them though, there is a need for clear training regarding the creation of specific steps which will ensure the development of the students' metacognitive processes and their ability to monitor their own learning process. The teacher can teach, during some special parts of the lesson or even during some independent lessons, these metacognitive abilities by which the students are encouraged to think about the steps, to evaluate them, to compare them with others, to choose the most efficient ones and to undertake transfers.

Veenman & Van Hout - Wolters (2006) state that, in order to be successful, this training has to follow 3 principles:

1. to integrate metacognitive training within the teaching of each subject, in order to ensure a connection between strategies and content;
2. to inform the students about the utility of the strategies and the steps of control in order to convince them to make the necessary efforts to acquire and practice them;
3. to constantly undergo such metacognitive training with the purpose of guaranteeing the stability and the appropriate usage of metacognitive strategies and control.

Taking into consideration these suggestions implies restructuring the educational process both at the goal level (it is needed to explicitly set metacognitive goals) and at the level of teaching strategies. The pedagogical methods, traditional or modern, have to be rethought and applied in such a manner so they should solicit the students as much as possible to think about the activity as well as process and develop ties between their cognitive activity and task success.

**Research problem**

Based on observations made by metacognition theorists, concerning the necessity of integration of metacognitive instruction in each discipline in order to ensure the connection between strategies and content, we proposed a metacognitive intervention program for students from primary school mathematics classes. The main objective was to find out the relations between metacognitive intervention and school performance of students from the experimental group in mathematics.

**Research hypotheses**:

1. *The use of metacognitive strategies leads to increased school performance (in mathematics) to students in primary*
2. *School performances in mathematics increase with the increase of the level of intelligence*
3. *Students with above average intelligence, school performances are increasing more than to those with average intelligence, following the application of experimental treatment*
4. *Students with high intelligence have more metacognitive knowledge and strategies than those with average intelligence*
5. *Before the application of therapeutic treatment, subjects have metacognitive knowledge and strategies at a below average level.*
6. *Prior to the application experimental treatment, the teacher did not use metacognitive strategies and knowledge in teaching and learning*

**Research variables:**

*Independent Variables:*

1. Experimental treatment (implementation of metacognitive intervention program)
2. Level of intelligence

*Dependent variables:*

1. School performance in mathematics

*Parasite variables*:

1. Age (control method: *constance control*; nine and ten years olds were chosen, and samples were used in pairs)
2. Genre (control method: *constance control*; sample pairs were used)
3. The existence of additional educational interventions to increase the school performance (control method: *classroom teacher involvement in the intervention program and the inclusion in the experimental program of non-standard problems*, which normally does not resolve the class)
4. The existence of prior knowledge and metacognitive skills (control method: applying *fact sheets of criteria analysis*)

**Experimental Design**

Joint research plan type 2 * 2 (or research plan with repeated measurements)**:**

| VARIABLES | | *The Level of Intelligence* | |
|---|---|---|---|
| | | H(igh) | M(edium) |
| *Experimental Manipulation* | T(est) | G1 | G2 |
| | R(etest) | G’1 | G’2 |

According to the plan, the research and school performance of subjects were measured at the beginning of the experiment. Then we conducted an experimental manipulation, after which they measured the school performances again. At the same time, subjects were divided into two groups, according to the independent variable – intelligence level (high - a minimum IQ of 120, average - IQ between 97 and 110).

We chose an experimental design with repeated measurements because of its advantages. Thus, in experiments with pairs of groups as well as the same participants experiencing different treatment conditions. This leads to the fact that there is no need for a large number of subjects to conduct the study in a relevant way. There is a greater chance of detecting the effects of independent variables if we compare the behavior of the same subjects under different conditions. Thus, if differences in behavior in different experimental conditions are observed, we will know more precisely that behavioral changes are not due to different reactions of participants from experimental conditions. Research plans with pair groups are the perfect form of equivalence of the participants. The subjects related variables’ effects concerning the treatment conditions are controlled by the same subject participants in all treatment conditions. Using this type of design it increases the power of the experiment. If we have the same subjects in all treatment conditions, they will be more obvious to the behavioral differences caused by experimental intervention.

The only disadvantage identified was that of the possibility of installing the fatigue or the saturation due to the relatively large time that the subjects spent under experimental conditions. That disadvantage was controlled by conducting experimental treatment under natural conditions (during school hours) and within periods that lasted five weeks, on different days of week.

**Method**

In our experimental research the following instruments were used: docimologic tests, the Raven Standard Progressive Matrices, semi-structured interview, initial assessment criteria sheet and metacognitive intervention program.

**The Use of Tests in Docimologic Research**

In this research it was necessary to use docimologic tests to assess students from experimental group performances in mathematics (both before experimental treatment and after this treatment) due to the rigor of the experimental research (the applied samples must be objective, must include the same tasks for all subjects and to be in accordance with specific objectives and also must be accurate).

In an attempt to frame the two tests used in a particular type of tests, we can say that there are docimologic tests developed by the teacher, written, criterial and that there were used both in the initial phase as well as the final phase (before and after the experimental treatment). The items that made up the tests were items of problems solving (with open responses). This category of items were chosen because they are related with the upper levels of the taxonomy of cognitive objectives (less covered in class). Those allow the development of cognitive processes which enables a critical and self-critical analysis and offers the possibility of errors. Both in the testing and re-testing stages, the docimologic test had in its construction the same types of problems, at the same level of difficulty. Two similar tests were built, which meant that, even if not used with the same problems, the problems used had the same requirements and had assumed the same level of difficulty, the same way of scoring, to meet the needs for the equivalence of the applied samples (For example, an item from the initial test is the following problem: "The sum of two numbers is 420. Their difference is half as the lowest. What are the numbers?”. In the final test, the similar item is the problem: "The sum of two numbers is 216 and the quotient is 8. Determine the two numbers").

**Raven – Standard Progressive Matrices. The Use of Proof in Research**

The choice of application of the Standard form of the Raven Progressive Matrices was due to its power to discriminate (at 9-10 years old, the age of the subjects of our research) among individuals from all levels of intellectual ability (low, high, high). At the same time, the Progressive Matrices are described as one of the most effective ways to assess the factor “g” or general intellectual functioning. In the present research, the intelligence level is one of the independent variables and one of its objectives being the identification of correlations between the level of intelligence, metacognitive interventions and school performance in mathematics. In this aspect, using the matrix Standard Progressive was an appropriate and effective choice.

**Semi-Structured Interview – Its use in the research**

The Semi-structured interview was used to interview the teacher of the class (from our experimental group). It was followed primarily to identify the practices used in mathematics’ classes and of the significance given to these practices by the teacher. The interview consisted of eleven questions, formulated in an open manner, which enabled the construction of extensive answers. From their analysis one can draw conclusions about the strategies used in order to facilitate the results of performance by the school students that she coordinates and on how the school teacher views the performances of his/her students. Her views on the types of possible and necessary interventions were also highlighted in order to optimize school performances in mathematics. Analysis of responses also allowed for the control of the parasite variable "existence of earlier metacognitive knowledge”, due to earlier interventions, before the research. The analysis showed that such interventions have not taken place , and if some elements were used, this has been sporadically and unsystematic.

**Criteria Sheet – Its Use within The Research**

The criteria Sheet is an assessment tool / self assessment through self-reflection. It includes a set of questions related to specific criteria for achieving certain tasks. The criteria sheet is built to be used in our research aimed the knowledge and metacognitive skills of the subjects. The criteria used to build the question and of possible responses were extracted from the operationalization of the concept of metacognition. Namely: knowledge about itself (For example, item: "When you have failed to solve a mathematical problem you think that: a) the problem is too hard and you can not solve it, b) the problem is hard and exceed your classes, c) the problem is difficult, but if you think more you can solve it; that depends only on you), knowledge on the overall strategies of resolving problems (for example, the item: "When you have to solve a math problem: a) you think about the problem and without thinking about something else you are able to solve it, b) you read the problem and think about how to solve similar problems that the teacher or you have already solved and then you begin to solve it, c) think about the operations that have to do with the problem without thinking too much about it ), planning skills (For example, item: "When you get in math themes: a) before you do them, you search what problems are easier and what are more difficult and solve them in the order that is best suited for you, b) don’t think prior to their difficulty, and solve them in the order that they were received, c) just think how quickly you get results and move on to another activity), control skills (for example, the item: "When someone tells you that the result is wrong: a) you think you did everything correctly and you are not interested in his/her view, b) looking for help from someone around you or ask a for different viewpoint, c) search for mistakes, trying to solve the problem again) and adjustment skills (for example, the item: "When you have finished solving a math problem: a) you are glad you finished it and are ready to move on, b) check with others to verify that the results are correct, c) you can check whether the results are correct and change the way of solving it, if the result is wrong ").

The Criteria Sheet has sixteen items, four items for each criterion used. Each item requires three-choice questions of which only one is an operationalization of metacognition, the other two variants highlighting the lack of knowledge and metacognitive skills. The Criteria Sheet was constructed and used to identify metacognitive knowledge and skills of the students before metacognitive intervention. This aspect could become a parasite variable that was necessary to be controlled. The results of this analysis will be presented in the intervention program.

**The metacognition intervention program**

In the last years several studies have pointed out that the methods of teaching – learning have a forming effect on a child's thinking style. Studies by Péntek, Veress and Téglás (2002, as cited in Imre, 2005, p.72) showed that different kinds of schools promote different styles of thought, and the school performances are correlated with preference to certain styles of thinking, the correlation coefficients ranging from 0.40 to 0.58, values comparable with the predictive validity of aptitudinal tests.

In our education system, certain styles of thinking (Imre, 2005, p.72), such as evaluative, hierarchical and conservative styles are mainly promoted, while creative, heuristical, investigative styles, based on problem solving or, more recently, metacognitive approaches are placed in second place. Students with conservative thinking styles are more rigid in the construction of a problem's representation; they prefer mental representations and processes used previously in solving similar problems; also, they are unable to make an analysis of the problems based on their essential characteristics; in the categorization of problems they are using categories that are too broad (similar differences were observed between novices and experts in the case of solving problems from physics – (Chi & Feltovich & Glaser, 1981, as cited in Imre, 2005, p.72). Instead, children with good self-reflexive and autoevaluative skills, that are able to analyze the problems in depth and use heuristic strategies which they are adapting to their needs, those would prefer to use atypical representations of problems. They will categorize the problems with respect to more specific categories and will use different strategies to solve a multiple task. This approach is called a strategic or metacognitive approach.

Pintrich (as cited in Romero, 2004, p.11) considers that the study of these strategies, in isolation from their context of learning, can lead to the risk that the conclusions could not be transferred to other contexts. Therefore he proposed that the learning of metacognitive knowledge should be made during other courses / disciplines (mathematics, science, arts, and physical education). Thus, the learner creates a link between metacognitive strategies and different types of disciplines. So, in solving a problem during the class time, the teacher may add "a metacognitive layer" and while he/she is using and verbalizing these strategies, they may also use arguments in order to justify their choice, adapted to other situations.

As a result of our attachment to the vision proposed by the above theory, our intervention program aims to improve school performances by appealing to metacognitive teaching – learning strategies, these strategies being "attached" to mathematics' education classes.

In order to determine with greater accuracy the limits of our intervention program and to control the parasite variables that may arise in implementing the experimental treatment, we used the criteria analyzing sheet and the structured interview. Thus, using the criteria analyzing sheet we put into evidence if the subjects used metacognitive strategies before undergoing the experimental treatment, when they undertaking mathematical tasks. By analyzing the interview we determined the types of strategies used by teachers in the classroom, and whether he/she used strategic or metacognitive teaching.

The conclusions highlighted the following: the distribution of the subject's scores is one of a platicurtic type, the number of low scores is higher than the number of high scores resulting in a left tilt, with right asymmetry. In other words, our research hypothesis that confirmed the fact that before applying the therapeutic treatment the subjects own metacognition knowledge and strategies at an under average level had been confirmed, thus achieving control of the parasite variable. Regarding the next hypothesis work, according to which students with superior intelligence have higher metacognitive strategies and knowledge than the ones with average intelligence, we can claim that it has also been confirmed.

Thus, in the case of the subjects with a superior level of intelligence, the high scores outnumbered the lower ones, unlike in the case of the ones with a average level of intelligence where the number of low scores was higher than the higher ones. By analyzing the class teacher interview we can generally conclude that during the mathematics class she uses active methods by which she develop and strengthen mathematical skills of her students. The metacognitive strategies are not completely absent but they have a low weight in comparison with executive and expository strategies. We are dealing with a style that is focused on the teacher's activity of explanation, demonstration, performing scaffolding student's tasks (and here we are dealing with a metacognition strategy), evaluation and communication of the results. Metacognitive strategies are being reduced to provision and analysis of knowledge about tasks (categorizing problems) and strategies that can be used.

In other words, the hypothesis according to which before applying experimental treatment the teacher didn't used metacognitive strategies and knowledge during the teaching-learning process, has been confirmed, their use reaching a minimum level.

**Running metacognition intervention program**

The aim involved improvement of the school performances in mathematics by using metacognitive interventions to develop specific knowledge and skills (matacognitive).

The target group was comprised of 31 students aged 9 to 10, from the 3rd grade. The aims pursued were set such so at the end of the intervention program the participants were able to identify their strengths and weaknesses in relation to solving mathematical tasks, to identify specific characteristics of the received tasks, to reflect upon their cognitive processes and problem solving strategies, to asses their own skills and results and to self assessment resolution behaviors.

The duration of this program was composed of 10 sessions, 60 minutes each, held twice a week over a period of five weeks. The methods and techniques used were: self observation, personal reflection, mapping, criteria self-assessment, planning, problem categorization, thinking aloud protocol, metacognitive facilitation by asking questions, I know/ I want to know/ I have learned/ I want to change, analysis of critical incidents, exercise, heuristic conversation, problematization, objective personality assessment method – the Zapan method, creative techniques : "the story of the problem", "me and mathematics", peer review, scaffolding and guidance (coaching).

Among the used instruments may be listed as follows: criteria analyzing forms, self-portrait, self assessment question sheets, comparing performances with standardized assessment sheets, problem analyzing sheets and "complete the sentence" sheets.

In a brief presentation, the methods and instruments used for the metacognitive intervention were:

- ✓ *guidance* (coaching) which consists of a careful observation of the students/novices by the teacher/expert, while a task is being carried out independently, providing tracks for reflection, feedback, pattern task completing and solutions to guide them towards achieving a performance close to that of an expert. This can range from monitoring the learning process of the adult in order to prevent deviations from the gist of the tasks, to emphasizing the performance and comparison to others, to creating "learning moments" that provide clarifications, warnings and suggestions, emphasizing certain content (Wilson & Cole, 1996, as cited in Joita, 2002, p.129);
- ✓ *scaffolding* – a method first presented by Vygotsky – which provides support given by the teacher to the student in order to achieve a given task. Support is built and offered in steps so that it can be expertly controlled (this could be the teacher or students who have the necessary skills). This support may take the form of suggestions, visual patterns and expert-novice (total or partial) cooperation in completing the task. This scaffold, built around completing the task, represents, in fact, a materialization of processing information (the novice

being supported by an expert): charts, graphs, drawings, representations, cognitive maps, summaries, plans and others.

- ✓ *metacognitive facilitation by formulating questions* that represents the use of questions by the teacher to help the student in reaching the right processing and proposed performances. According to White and Frederiksen (1998, as cited in Joița, 2006, pp.189-190) there are three categories of questions that can be used to facilitate understanding and knowledge: questions about building knowledge activity (being able to meet the need of knowing how the scientific knowledge takes place): methods, steps, requirements; questions about controlling their own activity based on a criteria reflection (quality of assumptions made in its effort to complete the task, steps taken, organizing the actions, development methodology, conditions met, common errors); questions regarding general knowledge or questions in which students can make themselves according to their knowledge and skills acquired as well as their goal.
- ✓ *thinking aloud, protocol* is another metacognitive training process by which the student is asked to loudly recite the steps taken in solving a problem (Sălăvăstru, 2004, p.66). At the same time, the teacher may ask for explanations about the choices or to highlight the difficulties encountered. In other words, the student is forced to verbalize and judge the effectiveness of his/her own cognitive process.
- ✓ *I know/ I want to know/ I have learned/ I want to change* is a technique that combines introspection and self criticizing knowledge and skills of the subject with self regulated behavior. The student is forced to identify his/her knowledge and skills (which often lie in a half dark area) orally or in writing (by using a self-analysis sheet), to establish objectives regarding further knowledge (based on previous analysis), to complete the task, and then to set an agenda for changes, readjustments, adjustments of the activity depending on what the student has learned from their previous test along with the results. This technique can be applied in order to complete a specific task (for example a math problem) but also regarding a discipline, a field of knowledge or itself.

The development of the intervention involved a similar structure for all ten activities, each comprised of the following steps: organizational time (at this stage, capture the students' attention and present the objectives of the current activity being performed); presenting metacognitive knowledge and strategies (at this stage, depending on the objective of each session, a counselor present for the student's specific metacognitive knowledge and instruments that will be used in completing the metacognitive tasks), solving mathematical problems and metacognitive tasks (in this stage students receive non-standard math problems that require heuristic strategies, but, students already have all the knowledge related to calculation and work algorithms and, using the instruments presented in the previous stage, they have to solve the problem along with applying metacognitive strategies - developing an action plan, analyzing available resources, establishing a set of questions to be answered, referrals to expert models, self-reflection, verbalizing their own cognitive approach, self assessment and error correction, categorizing the problems); self assessments, conclusions, generalizations (in this last stage of the activity the students have to self asses their strategies, to identify the errors that prevented them from reaching their goal and to set ways of regulating the next activities in order to be able to achieve the intended.).

**Some observations and breakdowns regarding the development of the intervention programe**

The intervention program was developed by a team composed of the school counselor (who brought about the metacognitive interventions) and the class teacher (who had specific educational interventions regarding mathematics). Due to the level of cognitive development of the subjects (3rd grade students aged between 9 and 10), and at the concrete operations stage, all metacognitive strategies used benefited the pupils from concrete support (form, figure models, cognitive maps, representations, expert models, guidance lists with already asked questions), and benefited from scaffolding provided by the two specialists through the intervention. Since most methods, techniques and tools used, and all ways of development were new and required, an adjustment effort in the working style of the students, the same scenario was used for three sessions (sometimes consecutive, but not always). As a result, we had three major types of meetings, one of them is to be detailed below:

*ACTIVITY 2*

***Specific Objective:*** *Enhance school performances in mathematics by the formation of metacognitive knowledge and skills*

***Operational objectives:***

1. *Indentify specific characteristics of received mathematical tasks*
2. *Reflect on own knowledge, cognitive processes and strategies to solve problems*
3. *Self –regulate resolvent behavior*
4. *Indentify general knowledge and strategies needed to achieve overall performance*
5. *Reflect on characteristics, attitudes and own knowledge relating to achieving performance in mathematics*

**Methods and procedures:** “ice breaker” exercise, exposure, self observation, personal reflection, problems categorizing, oral thinking protocol, metacognitive facilitation through asking questions, guidance, self-assessment, problem solving, cognitive maps, creative techniques “Problem story”, “Me and mathematics”.

**Instruments:** *complete the sentence sheets (Problem story, Me and mathematics*)

**Proceedings**
**Organizational moments:**

The school counselor captures the students attention to the activity to be conducted by an ice-breaker exercise (For example, think of your name's initial and tell us one of your qualities that begins with that letter, completing a puzzle, "personal motto", "say one quality of your colleague", etc).

This step is intended guide the student's attention towards the following activity but also to create a positive working atmosphere that fosters emulation.

**Presentation of knowledge and metacognitive strategies**

School counselor presents the worksheet that students will use in problem solving (Problem Map or Problem Story) stating how to complete each item separately (for example, in the I know box they have to write the problem analytically, with an explanation if necessary, in the I Want To Know box they also have to write the requirements analytically, in the problem type they have to assign a category for the problem, at methods its necessary that they write strategies/methods indicating they know to solve the problem, for the resolution they will make operations using the chosen method, and for verification they will test it, and afterwards they will see if they have reached the result they wanted.) The teacher writes on the blackboard a problem that needs heuristic strategies, problem solving for which students have all the necessary knowledge.

**Solving mathematical problems and performing metacognitive tasks**

Students solve the problem individually by completing given sheets. During the individual problem solving process of the given problem, the teachers guide the students according to their needs. After the students have resolved the problem, one of them is invited to the blackboard to solve the problem with the same breakdown as in the sheet he/she has received, this time aloud.

The student is supported both by the school counselor and the teacher in his/her reflective approach upon the characteristics of the problem and its resolution (reporting to a type of issue, the strategies chosen, mental operations that need to be completed, the possible advantages and disadvantages will be highlighted).

The other students are also asked to answer a series of metacognitive facilitating questions asked by the two guides (what kind of problem it was, the steps we need to follow when we deal with such a problem, what are the behaviors that help us achieve our purpose, why is it important to understand such a scheme of the problem and others).

***Self-evaluation. Conclusions. Generalizations***

*Students are invited to complete the statement "Me and mathematics" (Mathematics is ... I believe that in order to be "good" in mathematics you have to ... To correctly solve a math problem I think about ... I find it very hard to ... I think about me that ... My colleagues think about me that ...." ). When they are finished, the counselor gathers the responses. At the next session each student will receive a summary and the individual files. They will have a discussion based on these responses trying to reach generalizations.*

**Results and discussion**

To perform the statistical analysis, the *ANOVA repeated measures* model was used, because one of the independent variables (experimental manipulation) involved pair samples or repeated measures.

At the same time, the analysis of the interaction of the two independent variables was pursued (experimental manipulation and intelligence level), one regarding independent samples (intelligence level) and the other one repeated measures (experimental manipulation). Using this model allowed us the measurement of both the influence of each independent variable on the dependent one (school performance in mathematics) – meaning the main effects – and the combined influence of the two independent variables on the dependent variable – the effect of the interaction.

The analyses have revealed the following results:

- The research hypothesis according to which the use of metacognitive (i.e. applying the experimental treatment) leads to an increase in school performance (the subject of mathematics) is confirmed. At the end of the metacognitive intervention, the level of the students' performances was significantly higher than their previous results. In other words, the use of metacognitive strategies a "package" to solve math problems, caused a significant increase in the performance of subjects ($3^{rd}$ grade students). [$F(1,29) = 44{,}53$, $p = 0 < 0{,}05$. Test average is 39,51 and the one of the retest is 70,80).

- The research hypothesis, according to which after the experimental treatment, to students with high intelligence school performances increased more than those with average intelligence was confirmed by emphasizing that school performance in mathematics for subjects with higher intelligence were significantly higher both before and after the experimental manipulation which led to the confirmation of the research hypothesis that school performances increase with higher levels of intelligence (whether or not the experimental treatment ). [$F(1,29) = 8{,}43$, $p = 0{,}007 < 0{,}05$]. It was highlighted as a main effect of variable levels of intelligence.

- At the same time a combined effect was not revealed from the two independent variables (level of intelligence and experimental manipulation). In other words, educational performance in mathematics is increasing at whatever level of intelligence from the subjects (superior or average ). [$F(1,29) = 1,22$, $p = 0,278 > 0,05$].

- According to the experimental design, we have two different groups (subjects with superior intelligence and with average intelligence) passing through two different situations (before and after the experiment). Average scores obtained by subjects in school performance in the four cases are presented bellow in a summarized table form.

| | Superior Intelligence | Average Intelligence |
|---|---|---|
| Performance (test) | **G 1**<br>55,93 | **G2**<br>22 |
| Performance (retest) | **G' 1**<br>82,18 | **G' 2**<br>58,66 |

- Comparing the groups G1 and G2, i.e. the educational performance before the experimental treatment from the first test we observed that students with higher intelligence achieved significantly higher performances than those with average intelligence [$t (29) = 3.08$, $p = 0.04 <0.05$]. The same result can be observed from the re-test evidenced by comparing the groups G 'and G 1' 2 [$t(29) = 2.15$, $p = 0.04 <0.05$].

- Comparing the groups G1 and G'1[$t (15) = - 3.91$, $p = 0.001<0.05$] and the groups G and G' 2 [$t (14) = - 5.54$, $p = 0 <0.05$)] revealed both subjects with higher intelligence and the average intelligence scores were significantly higher on retesting school performance in mathematics.

**Final conclusions**

Cognitive education is closely linked to metacognition. Metacognition allows students to receive training and it influences the use and maintenance of cognitive strategies. It is linked to introspection, self-evaluation, self-introspection, self-reflection and self-correction. All these elements can also be restated in terms of metacognitive skills as well as education methods. The necessary condition is that the teacher recognize them as such, to detail them procedurally ,to integrate them in the used method's system, to create applied tasks, to evaluate the student, taking into account these dimensions, and last but not least to provide specific feedback and design solutions in case of failure. Although most people that have at least normal intelligence, need metacognitive adjustments when faced with a difficult cognitive task, there are major differences between individuals regarding their activation, and those with grater metacognitive abilities tend to be more successful in their cognitive efforts (this fact is obvious when referring to experts and novices). There is, though, an important positive premise that can be exploited for educational practice: metacognition can be educated, individuals can learn and practice how to better self-regulate activities, and metacognitive and strategic learning can be the solutions for students in order for them to become aware of their own cognitive processes, learn how to learn effectively. We can say that the development of metacognitive intervention programs (teaching – learning metacognitive knowledge, located at both declarative and procedural as well as conditional level, and developing and strengthening metacognitive skills (planning, monitoring, control or adjustment) at a formal education level, mathematics leads to increased school performances regardless of their intelligence level.

The achievement of such programs has led to more effective learning and the promotion of the deep processing of information. „Packing/Wrapping "the already existing content in a metacognitive housing would maximize results with minimal costs (only a change of perspective and strategy for teachers). In terms of achieving the proposed metacognitive program in the teaching procedure, clarifications and detailing of methods and metacognitive instruments that are less used in educational practice in Romania (scaffolding, guidance, metacognitive facilitating questions, mapping, criteria analysis) have been made, or even instruments or adapted techniques have been created (criteria sheets, creative techniques „Problem's story, „Me and math" and others). They can potentially be retrieved, adapted, customized with minimal effort by practitioners in the education system.

**Reference List:**


Brown, A.L. (1987). Metacognition, executive control, self-regulation and other more mysterious mechanisms. In Weinert, F., Kluwe, R. (Eds.), *Metacognition, motivation, and understanding* (pp. 65-116). Hillsdale NJ: Lawrence Erlbaum Associates.

Brown, A. L., Campione, J. C. (1978). Memory strategies in learning: Training children to study strategically. In Picl, H.L., Leibowitz, H.W., Singer, J.E., Steinschneider, A., Stevenson, H.W. (Eds.), *Psychology from research to practice,* New York: Plenum Press.

Delacour, J. (2001). *Introducere în neuroştiinţele cognitive.* Iaşi: Editura Polirom.

Flavell, J. H. (1976). Metacognitive aspects of problem-solving. In Resnick, L.B.(Ed.), *The nature of intelligence* (pp. 231-235), Hillsdale, NJ: Lawrence Erlbaum Associates.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist* (34, p. 906-911).

Focant, J. (2003). Impact des capacités d'autorégulation en résolution de problèmes chez enfants de 10 ans. *Éducation et francophonie*. Revue scientifique virtuelle, Vol. XXV, Nr. 1. (45-65), Association Canadienne D'Éducation de Langue Francaise. http://www.acelf.ca/c/revue/pdf/XXXI_2_045.pdf

Garofalo, J., Lester, F. K. Jr. (1985). "Metacognition, cognitive monitoring and mathematical performance". *Journal for Research in Mathematics Education,* 16 (3), p. 163-176.

Gombert, J. L. (1990). *Le developpement métalinguistique.* Paris: PUF.

Imre, P. (2005). Dezvoltarea categorizării flexibile şi a adaptabilității strategice în rezolvarea de probleme la elevi. Raport de cercetare proiect cod CNCSIS: AT316., *Revista de Politica Ştiinței şi Sociometrie, Universitatea "Babeş-Bolyai"* (special issue), pp.1-27.

Joița, E. (2002). *Educația cognitivă. Fundamente. Metodologie*. Iaşi: Editura Polirom.

Joița, E. (2006). *Instruirea constructivistă – o alternativă. Fundamente. Strategii*. Bucureşti: Editura Aramis.

Lafortune, L., Saint-Pierre, L. (1998). *Affectivité et métacognition dans la classe,* Paris, Bruxelles, De Boeck & Larcier;

Noël, B., Romainville, M., Wolfs, J. L. (1995). La métacognition: facettes et pertinence du concept en éducation. In *Revue française de pédagogie*, Vol. 112, (47-56).

Pintrich, P. R., Schrauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom academic tasks. In D.H. Schunk & J.L. Meece (Eds.), *Student Perceptions in the Classroom,* Hillsdale, N.J.: Lawrence Erlbaum, (149-183).

Romero, M. (2004). *Metacognition dans les EIAH,* Laboratoire d'Informatique de l'Université du Maine *(*LIUM), Le Mans, accesat aprilie 2010, la adresa [http://www.margaridaromero.com/cursus/dea_chm_ie/content/romero_transversal.pdf]

Sălăvăstru, D. (2004). *Psihologia educației.* Iaşi: Editura Polirom

Schöenfeld, A. H. (1987), „What's all the fuss about metacognition?" in Schoenfeld, A.H. (eds.), *Cognitive science and mathematics education* (p. 291). Hillsdale, NJ: Lawrence Erlbaum Associates.

Veenman, M. V. J. & Van Hout-Wolters, B. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition and learning*, 1, (3-16).