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La Matemática en el desarrollo cognitivo y metacognitivo del escolar primario
Mathematics in the cognitive and metacognitive development of school children

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Resumen: La formación de un escolar que transite hacia niveles superiores de reflexión al aprender es un reto actual en la enseñanza primaria. Desde la Matemática es posible alcanzar esa meta. El presente artículo tiene como objetivo valorar la incidencia del proceso docente educativo (PDE) de la Matemática en el desarrollo cognitivo y metacognitivo del escolar. Se analizan aspectos importantes en el tratamiento de la metacognición desde esta asignatura con el empleo de métodos teóricos como análisis y síntesis, inducción- deducción, histórico lógico.

Palabras clave: Proceso docente educativo; Enseñanza de la Matemática; Desarrollo cognitivo y metacognitivo; Escolar primario

Abstract: Training children to achieve high levels of pondering while learning is a challenge for primary educators nowadays. Using the subject Mathematics makes it easier to reach that goal. This paper aims at evaluating the incidence of the educational process (PDE, in Spanish) of mathematics in the cognitive and metacognitive development of the school children. Important aspects in the treatment of metacognition from this subject are analyzed with the use of theoretical methods such as analysis and synthesis, induction-deduction, and logical history.

Keywords: Educational teaching process; Teaching of Mathematics; Cognitive and metacognitive development; Primary school

Introduction

In their transit through primary education children come across a variety of important disciplines in their integral development, among them, Mathematics. From the educational process (PDE in Spanish) of Mathematics, teachers can enhance the cognitive and metacognitive processes in the school.

According to Sastre (2011):

> Metacognition is closely related to executive functions as a high level cognitive process usually related to the control and regulation of our cognitive functioning applied to learning and problem solving. Metacognition is a multidimensional construct that, according to most current researchers, include three basic elements: metacognitive knowledge, cognitive monitoring, and the regulation of problem solving strategies (p.12).

Different authors refer to the relationship between executive functions (EF) and mathematical learning, including Bull and Scerif (2001); Anderson (2010); López, Ávila and Camargo (2013); Durán, Álvarez, Fernández and González (2015).

Processes such as attention, memory and thought can be stimulated from the Mathematics classes in primary education, as well as metacognitive executive functions: planning, working memory, mental flexibility, among others. It is possible to establish a bidirectional relationship between metacognitive executive functions and the learning of mathematics. However, it is recognized that the number of studies related to the development of EF from the teaching process of Mathematics is limited.

At school, performance difficulties can be manifested in the planning of the activity and in the process of control. Zilberstein (1999) reports that in the students' behavior there is a limited search for procedures to learn and plan their actions.

Suárez (2003) refers, among other things, to limitations in the exploration of different ways of solution, and the tendency to focus attention on the result obtained and not on the process that was developed to obtain this result as manifestations of difficulties of the primary school students in solving problems. Companioni (2005) points out the importance of creating real questions in which children need to look for unconventional strategies and reflexive procedures to solve problems.

In a diagnostic study where executive functions were evaluated in a sample of 15 third graders, there were some difficulties in planning actions for success, especially when it was necessary to break stereotypes of work, which indicated the implication of mental flexibility.

In the analysis, the relationships between executive functions and mathematical learning converge, as well as the need to enhance the intellectual development at school; the difficulties that arise in activities involving metacognitive executive functions, allowed us to assess the incidence of the educational process of Mathematics in the cognitive and metacognitive

development of the school children. In order to theoretically support future interventions in this area this paper was written.

Development

Some characteristics of the educational process in primary school. Current Challenges

According to Leyva and Proenza (2005):

> The main objective of the primary school is to contribute to the integral training of the school personality, fostering from the first grades the internalization of knowledge and values orientation that are gradually reflected in their feelings, ways of thinking and behavior according to the value system and ideals of the Cuban Revolution.

To understand the processes related to the integral development of the personality at the primary school, it is important to analyze the peculiarities of the educational process. According to Álvarez de Zayas (1999), the educational process "is the school training process that in the most systemic way is directed to the social training of new generations and thanks to which the student is educated, transformed and aided" (p.11).

The educational process in primary education should be conducted in such a way as to enhance the active character of the school in the act of learning. Leyva and Proenza (2005) point out that: "The Projective Model of primary school includes among its components, psycho-pedagogical demands of a learning developer that constitute for the teacher premises to organize and direct the process of teaching learning". These authors highlight, among others, the organization and direction of the teaching-learning process from reflective positions of the student that provoke the development of their thinking and their cognitive independence, as well as the stimulation of the formation of concepts, the development of the logical processes of thought, and the reach of the theoretical level, as the appropriation of procedures occurs and the capacity to solve problems is increased.

It requires an increasingly reflexive student, involved in the learning process, progressively incorporating complex control actions and results assessment, asking about the process of developing their activity from the demand to the solution, depending on evaluation, that is capable of assessing in a flexible way the alternatives of solution to the demands of an activity.

The continuous improvement of the education system is aimed at finding solutions to learning problems through scientific research, so it is possible to find literature aimed at the analysis of didactic proposals and the development of the teaching process. These proposals, aimed at reaching, from the classroom, the reflective thinking of the student and their involvement in the act of learning, are important in primary education. At this level the results in the learning activity acquire repercussion in the integral development of the personality from the development of the self-assessment.

The intention to perfecting the work of educational professionals leads to the analysis of the interdisciplinary links between pedagogy and psychology in order to understand the child development. The particularities of primary education are intimately related to the characteristics of psychological development. The school curriculum and the organization of the teaching process goes through the analysis of the functions, abilities, skills to be developed at this stage, according to the particularities that from the cognitive, affective and axiological perspectives the school exhibits. The work of the teacher of the Mathematics discipline must pay attention to these characteristics, and reflect an empowering vision, that is demonstrated in the methods and procedures incorporated in the teaching process.

Cognitive processes, metacognition and metacognitive executive functions in the primary school. The teaching process of Mathematics in its development

The Social Development Situation (SDS) in the school stage has particularities that identify it.

According to Vygotski (1983) cited by Fariñas, 2005 "(...) at the beginning of each age period it is established a unique and unrepeatable relationship, specific for that stage of life, between the child and his environment, above all social. This relationship is called the social situation of development "(p. 57).

In SDS at school age the entrance to the school is transcendent. Relationships and social interactions become complex, the communication system is extended to the child's relationships with the teacher. The school is faced with new demands, the study appears in the activity system, which has planning and defined objectives to which it must respond. The system of activities is diversified, it involves the study, the rules, impact on the development of the moral sphere, and the role play that becomes complex, in relation to previous stages.

As important aspects in the cognitive development of the school it can be mentioned the emergence of the conceptual thought, and the conscious and voluntary character of the psychic processes.

Rico *et al* (2000) agree that in the first grades of the primary school (an analysis to the second grade), it is necessary to draw attention to an important quality of thought, such as reflection, achieved at later ages as it includes the possibility of the individual to hypothesize and self-regulate their own activity, it is important that the teacher creates conditions in the learning process from these first grades, fundamentally from the second, for a reflexive analysis by the students of the exercises to be solved. These authors point out that in the moments of development of third to fourth grades the achievements to be obtained demand to continue with the forms of organization and direction of a reflective learning activity.

The importance given to mathematics in the development of student thinking has been referred to by several authors, Companioni (2005); Proenza and Leyva (2008); Campistrous and Rizo (2014).

In the incidence of the teaching process of Mathematics in the cognitive and metacognitive development of the school we can mention contributions, while recognizing all the previous work of the scientific development that is exhibited.

We highlight the studies developed by Campistrous and Rizo, in the Techniques for Stimulation of Intellectual Development Project (TEDI in Spanish). Campistrous and Rizo (1996) provide a special place for modeling, analytical reading and reformulation techniques, determination of auxiliary problems, intelligent scoring and verification technique, as well as analyzing the importance of motivation in problem solving and developing function of the same.

In addition, studies such as those of Capote (2003), Suárez (2003), González (2001) (2005), Companioni (2005), Bernabeu (2005), Proenza and Leyva (2008) review the primary education from different contents, in order to contribute to the improvement and quality of the teaching process. As for solving problems, we highlight, among others, the research of González (2001) that deals with the formulation of mathematical problems; Capote (2003) that delves into the orientation stage for solving arithmetic problems with text; Companioni (2005) who brings to the

school practice a didactic alternative for the treatment of non-routine problems in the fourth grade.

It is argued that through problem solving, oral and written expression is contributed to the development of mental operations such as: analysis, synthesis, generalization, abstraction, development of heuristic thinking, flexible and creative (González, 2005).

However, as has been mentioned, schoolchildren show difficulties in working with problems. Labarrere (1995) states: "... many schoolchildren, immediately after the problem has been raised, begin operations, reflecting insufficiently on the ways to carry the analysis and a marked absence of activity planning ..." (p. 4).

Sometimes the student, in a hurried way, executes a series of organized steps to which he gives priority, obviating what is essential for success in the activity: a process of active, conscious pondering about the problem and the possibilities for its resolution. When asking a scholar: what do you have to do to solve a problem? he generally responds without hesitation: I read, then rereading I seek the way of solution ... and, in this way, list actions, however, it is important to ask about the meaning that for him has rereading or seeking the solution. Are these steps actively incorporated by the school? Or do they simply reflect a sequential order with which to comply? These considerations should accompany the teacher in the treatment of mathematical problems.

In the development of the teaching process of Mathematics teachers have been moving towards more protagonist forms of learning and towards more developing methods. Nevertheless, teachers still have to deepen in the treatment of the metacognitive processes.

A more dynamic vision is necessary, on the part of the school, of the sequencing of steps in the resolution of problems and to deepen in the connotation of the control and self-monitoring of the activity. It is important to develop procedures that are based on a favorable link between cognition and affection in the learning of mathematics, which will affect metacognitive regulation.

The cognitive-evaluative-experiential orientation towards the learning of Mathematics is one of the components that must be contemplated in the development of the metacognitive EF.

The complexity of mathematical knowledge, how to teach mathematics in primary school, is a fascinating world. The scope of this subject in the development of the intellect is really vast, its transcendence for life makes it relevant. To contemplate in a flexible way different strategies of solution to a problem, to self-evaluate the performance, to give a special place not only to what is learned, but to how it is learned, to reflect before responding, are learnings that transcend the classroom and are incorporated to life and to the future.

In Mathematics lessons it is possible to perform exercises that involve the transfer of known calculation procedures to new situations. As well as developing problem-solving activities that foster school reflection, it is necessary the interrelation of cognitive processes such as voluntary attention, thought, memory, language, but also the expression of metacognitive EF. Rico (2004) points out that the possibility of teaching students from the first grades to create problems and re-elaborate relationships between data is an essential element for their development.

In this sense, the conduct of the teacher and the effectiveness of his methodological procedure is to adequately conceive the problems and take into account the actions that the student must take in the stages of orientation, execution and control of the activity.

In his hypothesis about the planned formation of mental actions, Galperin starts from the thesis that psychic activity is the result of the passage of material actions external to the area of reflection, and that this process of transfer occurs through a series of steps (cited in Martínez, 2006). With the conduction of the mathematics teacher and depending on the demands of the learning activity, it is possible to develop internal mental actions and skills, say, for example, those of planning.

It is considered that from this subject it is possible the development of EF such as planning, self-monitoring, mental flexibility or inhibitory control.

According to Ardila and Ostrosky (2012):

EF are those that allow an individual to organize, integrate and manipulate the information acquired. In this way, as these functions are particularly developed in humans, they give the latter the ability to create, anticipate, plan, and abstract, among others (...) (p. 151).

Within the concept of EF, skills related to the ability of organizing and planning a task, selecting the objectives appropriately, initiating a plan and holding it in the mind while running, inhibit distractions, change strategies with flexibly if the case so requires, self-regulating and controlling the course of action will ensure that the proposed goal is in the process of being achieved (Soprano, 2003).

When it comes to the term metacognition, the concept refers to two dimensions: one, linked to knowledge about one's own learning, relating to a subject that learns, a task to be fulfilled and certain strategies to use to obtain the best performance; other, linked to the regulation and supervision over the own cognition, that is to say, the planning of resources, the control of the execution and the evaluation of the results (Mateos, 2002, cited in de la Barrera & Donolo, 2009). Metacognition is closely related to EF (Sastre, 2011).

Authors refer to "metacognitive" and "emotional" EF (Ardila and Ostrosky, 2008).

In relation to the above, Guerra (2012) states:

As components of EF, we can mention skills related directly to cognitive or metacognitive processes, such as: initiative, inhibition of responses or inhibitory control, planning and organization(...) sequencing, working memory, attentional control or change, flexibility, cognitive and behavioral self-regulation and behavior control, among others. Reference is also made to social skills more related to affective processes (...) (p. 35)

Can the meta-cognitive functions be enhanced in the school from the teaching process of Mathematics?

It is considered that the child can be stimulated in the very dynamics that arise in the interaction between the non- personal and personal components of the teaching process, from the unit between activity and communication that is generated in the classroom, within the framework of a teaching activity. The external actions can be incorporated to the internal side, in this way the genetic law of cultural development is welcomed (Vigotsky, 1987); besides, we can take into account the stages proposed by Galperin through which the training of mental action occurs:

1. The education of the motivational basis of action

2. The education of the schema of the guiding principle of action

3. The education of action in the material or materialized plane of its execution

4. The education of the action on the plane of the external language

5. Education of the action in the plane of the external language for itself

6. The education of the action in the plane of the internal language (in Martínez, 2006).

The contents of Mathematics, adequate in function of the development of the school, must be conceived so that through the methods implemented by the educator, it moves towards the education of mental action. In this way it would be possible to strengthen, for example, planning and mental flexibility in mathematical tasks.

The criteria for planning (Lezak, 1995; Soprano, 2003 in Injoquey Burin, 2011) and cognitive flexibility (Rojas, 2011) allow us to understand the importance they have for successful performance within the framework of the activity.

In general, the contents of the Mathematics subject are propitious for the development of the EF, which in the framework of cognitive activity are concretized in internal mental actions such as planning, organization, setting goals that grant with their expression quality to school performance, in this case, mental flexibility, inhibitory control.

They can be enhanced through diversity of contents and their treatment, with the inclusion of forms of heuristic work, the work with problems. The exercises incorporated should be aimed at stimulating higher levels of development, which implies that school activities are directed to the child deploying own actions at a potential level. From his possibilities of understanding, he must establish more complex actions in relation with the object of activity.

In this sense, Suárez (2005) states:

(...) the initial situation that seems explicit in the proposed exercise (what is given) must correspond to the student's current level of development, but the process required to solve the exercise (what is sought, what is unknown to the student) is in correspondence with the potential development so that development is generated(...) (p. 84).

The teaching process of Mathematics stands as a propitious context to gradually achieve a look at the course of its activity, to control it, to plan it and to take decisions among alternatives valued in

a flexible way. The development of cognitive processes and metacognitive EF has a gradual course throughout the school stage and continues into later stages of development.

Regardless of the advances that the teaching process exhibits in primary education and research on the subject, it is necessary to deepen the development of metacognition, according to the levels in which it can be expressed in the stage. One of the main shortcomings during learning is related to the child's supervision of the results of his / her performance, not only in terms of the final result compared to the demand, but also in the course of previous actions.

Taking a look at the metacognitive processes, from a retrospective view, with the help of the teacher, it is feasible to motivate the protagonist attitude in what is learned, in addition to stimulating, with the awareness of the error, a prospective vision based on the next performances. Learning would be (in addition to categories, mathematical concepts, skills) aimed at forming a strategic representational, dynamic notion, which is demonstrated in the behavior at school when facing, for example, a mathematical problem. It implies a pondering attitude that reflects the apprehension of the meaning of the actions to be performed.

It would be feasible to systematically stimulate a look at the execution process through questions such as: what was wrong with me? What was the hardest thing to do? And why? Did I succeed in doing all the relevant steps in the solution of the exercise? Have I evaluated my performance? Other questions directed to future executions could be: What should I do in the next few exercises? What to do in similar exercises? How to avoid the mistakes made in future tasks? These questions would allow the scholar to work on the transfer of work strategies to specific cases that require it.

In teaching practice, activities such as the writing of small paragraphs that illustrate the reflections of the scholar about the solution procedure would allow the analysis of the planning process, while stimulating working memory, all of this based on the relationship between thought and language. The answers of the schoolchildren can be very specific in the first years of primary education and will become progressively more complex. To achieve the knowledge and skills apprehension that propitiate the efficient performance of the school, the work of the teacher must follow the vigotskian path that asserts that development lags behind the teaching and is routed on the assessment of the potential of each school.

From all the study carried out and the implementation of theoretical methods of analysis-synthesis and induction-deduction, are specified aspects to be valued for the development of metacognitive EF such as planning and metal flexibility in solving mathematical problems.

Planning. Manifestations in the activity of solving mathematical problems

1st step. Determination of the objective of the activity. That connotes the projection towards the solution of the problem. According to Leontiev (1975): "(...) activity is regularly performed through a certain set of actions subordinated to partial objectives, which can be subtracted from the general objective (...)" (p. 85).

2nd step. Determination of actions leading to the goal:

• Determination of what was given and what was sought in the resolution of the problem.

• Establishment of the links between the information given and of this with the sought goal.

3rd step. Execution of actions corresponding to the achievement of goals or to consecutive sub-goals in the activity as organizational samples in the resolution of the task.

Actions that can be implemented by the teacher to promote it

Develop actions aimed at the orientation of the school tasks, and the construction of the representation of the problematizing demand:

• Guide students towards the interpretation of information from mathematical knowledge.

• Orientation towards the technique of analytical reading and reformulation, and the technique of modeling. (Campistrous and Rizo, 1996). Those that are considered of great importance for understanding and representing the problem on the part of the scholar.

The active participation of the school should be stimulated in determining the goal to be reached in the problem and how it can be reached, so that a plan for its resolution is expressed.

Actions for the breakdown and resolution of partial problems within the problem

Orientation of the scholar towards the use of antecedent information, reached in the resolution of partial problems, as new data in other subsequent problems, derived from the initial information, aimed at cognitive economy.

In order to enhance the notion of order and sequencing, exercises can be implemented in a way that involves indicating the order of the mathematical operations to be performed, the organization by the school of the text of a problem that appears disorderly, and the request to write small paragraphs directed to explain how they solved the problem.

Mental flexibility. Some of its manifestations in the activity of solving mathematical problems

1. Assessment of more feasible ways of solving several possibilities implicit in the formulation of the problem itself.

2. Possibility of avoiding erroneous answers with repeated character

Management of the error: evaluation of the congruence between what was sought and what was obtained in order to rethink the path. Search for new relationships between data.

Actions that can be implemented by the teacher to promote it

1. Work with the possible relationships established between the data to determine more feasible ways of solution.
2. Guide the school to the search for alternative solutions, to emphasize those that show a higher level of expression of logic.
3. Conduct the student towards the evaluation of solution pathways from the achievement of the pathway, and during the course of the activity, not only after the problem has been realized.
4. To devote time to the understanding of the problematizing demand and to listen to the reasoning of the child in relation to the ways to use and carry out the solution, from its real level of development, towards the incorporation of other posible, more feasible ways.
5. To orient the school to the self-evaluation of its performance during the course and also after the conclusion of the activity. Do the results obtained provide the solution to the problem?
6. Guide the student to the analysis of the errors made, so that he will be able to review the steps followed to solve the problem, and look for new relationships between the data.

7. Progressively develop self-criticism and recognition of error with an educative connotation, highlighting its detection as the first step in the search for new solution alternatives.

It is possible that in the course of the problem solving activity, procedures that are used to treat one of the EF also stimulate the development of others, according to their interrelation in the framework of the activity.

Conclusions

In the development of Mathematics in Cuba important contributions can be mentioned, including those that address the solution of mathematical problems as an activity that fosters the development of thought and metacognition.

From the educative process of Mathematics, the development of actions aimed at stimulating the active participation of the school in determining the goal to be reached and how it can be reached, enhance the notion of order and sequencing through mathematical exercises designed for that purpose. To formulate mathematical problems that allow to guide the school to different ways of solution, listening to the students´ criteria in relation to the procedure and leading, if necessary, to more feasible ways stimulate the self-evaluation of the individual performance and recommends treatment to the recognition of error, in a way that positively affects the cognitive and metacognitive development of the primary school.

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