HOW DO CHILDREN ADD: A WALK THROUGH THE REASONING, METACOGNITION AND CREATIVITY PROCESSES

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ABSTRACT

This investigation encompasses the inner workings of meta-cognition, reasoning and creativity when second graders are figuring out and solving mathematical problems which involve three types of additive structures related to addition, all this set in a constructivist epistemology. To achieve this goal, the Peva (Thinking out loud) strategy was applied to thirty four boys and girls, cursing the second grade, from three schools in Bogotá. It was discovered that deduction was the most commonly employed method of reasoning since the children set out from the general information supplied to fulfill their requirements. Although there were a few signs of creativity, no new or suitable products were found. Meta-cognition was evidenced throughout as the children used their skills to solve the proposed situations, thus showing the constant relationship between the processes studied.

Key words*: Meta-cognition, reasoning, creativity, additive structures, Peva, figuring out and solving problems.*

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INTRODUCTION

Day to day, we face diverse social, cultural, legal and educational situations that, due to their complexity, need to be tackled by psychology, since man becomes the main actor in each of the stories that intertwine here. In childhood, school life is fundamental: there exist diverse actors that according to the circumstances and their traditions, live, learn and teach, situation that concerns us and that we want to discover with children in the second grade, having as pretext the formulation and resolution of mathematical problems and their relationship with reasoning, metacognition and creativity processes.

This article presents the main aspects of a research effort that intended to describe and understand, through the research strategy of thinking out loud (Peva), how such processes operate in second grade children when they formulate and solve mathematical problems related to additive structures relative to addition.

We start with the concept of educational mathematics, the field of this research, that we define as a discipline with diverse and varied practices that allow us to understand how learning and mathematical construction are developed in and out of the classroom, with the aid of other disciplines like psychology, anthropology and pedagogy, among others; and a discipline that is also interested in proposing tools that help understand the process of a child's approach to mathematical thinking (ability to formulate and solve problems from the discipline's basic grammar).

Educational mathematics makes a distinction between state-of-the-art and school mathematics. Rodríguez (1996), quoted in the National System of Education Evaluation

(SNEE)[1] Monitoring Plan (1992-2005), describes the former as "…a set of dynamic knowledge that expands continually and that is in charge of the study and development of mathematical objects." On the other hand, according to the National Ministry of Education (1998), school mathematics "must promote the development of mathematical thinking, that is, a thinking that allows the student to describe, organize, interpret and relate with certain situations through mathematics."

In this sense, it is necessary to clarify the difference between exercise and problem, since this is maybe one of the hurdles that both teachers and students have for achieving good performance in mathematics. According to Rodríguez (1998), quoted by Bernal (2001) an exercise requires the application or execution of some algorithm or mechanized procedure, while the problem situation requires more complex processes and suggests the consideration of specific contexts that involve elements additional to the exercise; therefore, it has other demands. The problem situation is novel and requires the individual to approach a construction process where it is possible to assemble strategies and execute actions in order to find an answer that is not immediate or easy to reach, something that encompasses the idea of problem solving individual and context.

This research assumes that problems in mathematics facilitate the development of cognitive processes; therefore, this work was centered on three processes, considered fundamental in educational mathematics.

Reasoning Process

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[1] *Sistema Nacional de Evaluación de la Educación.*

Based on authors like Carretero (1984) and Santamaría (1997), we built a definition of reasoning that provided conceptual elements in order to conduct the analysis of the results. The definition proposes reasoning as a process of knowledge construction that stems from a problem situation that is presented to us, situation that is not isolated from the context that surrounds us. Besides, reasoning implies associating knowledge that we bring from the past in order to infer and draw conclusions in the same manner. For this research we acknowledged three types of reasoning by authors like Mario Carretero (1984), Juan A. García (1984) and Pierce (1978) (quoted by Santamaría, 1997), who gave us the opportunity to precise, delimit and establish certain differences. According to these authors the types of reasoning that can be found are:

- *Deductive.* When the child starts from a general piece of information pretending to arrive to a particular conclusion, that is, he/she identifies what the problem situation requires (rule), then he/she takes into account what such situation presents to him/her (case) in order to draw a conclusion (result).
- *Inductive.* When the child starts from a particular piece of information and extracts conclusions that are probable within a generality. That is, he/she takes into account the statement of the problem situation (case), draws a conclusion (result), and this way he/she extracts the requirement (rule).
- *Abductive.* When the child makes hypotheses in order to achieve interpretative or inductive reasoning; that is, he/she starts from what the problem situation demands of him (rule), guesses reaching a conclusion (result), in order to infer what the situation is about (case).

Creativity Process

In order to better understand the creativity process and some of its implications, we reviewed definitions proposed by authors like Romo (1997), Castro (1991) and González (2001), among others, and from there we developed a particular concept: creativity is the set of abilities and dispositions of cognitive and affective nature that allow a person to frequently produce creative products; the ways of representation and symbolization and the problem-solving capacity take part in this process, as the results that let humans reaffirm and structure themselves, generate culture and transform its surroundings.

González (2001) proposes three simultaneous conditions without which the product ceases to be creative: originality, pertinence and relevance. On their part, Nickerson, et al. (1988, quoted by Bernal, 2001) have identified at least four components in creativity: the creative capacities, the cognitive style, attitudes and strategies.

Metacognition Process

Authors like Chadwick (1999), González (2001) and Nickerson (1988, quoted by Bernal, 2001) understand metacognition as the capacity or ability that people have to recognize and handle their own cognitive resources, which implies a knowledge of the strengths and weaknesses of their intellectual functioning, that allows them to organize, plan, regulate and evaluate their performance when they solve a problem. According to these authors, metacognition is used when there is supervision, regulation, control and knowledge of knowledge, which constitute evidence of metacognitive functioning, and which are clear indicators of the process that operates in children when they solve mathematical problems.

Additive Structures

As the main referent for the development of additive structures, we quote Vergnaud (1995), who defines the additive structure as “the capacity that a person has to identify, understand and tackle situations where addition and subtraction operations are applicable.”

Vergnaud distinguishes between six structures relative to addition and subtraction, from which we take those that are relative to addition, which vary according to the events that intervene in a certain situation and that transform the final state. Thus, we take the following structures: 1) fixed state + fixed state = fixed state; 2) fixed state + transformation = fixed state; and 3) transformation + transformation = transformation.

METHOD

The study was conducted under qualitative research guidelines, where the fundamental interest is to understand phenomena based on a construction given by the communication and interaction of the participating actors, as well as the study of daily life and natural factors where the phenomenon in question takes place, as stated by Pourtois (1992).

Subjects

Thirty-four children of three schools in Bogotá (Gimnasio Pascal, Unidad Básica Gabriel García Márquez and Ciudad Montreal) who were in second grade in 2001 participated in this study. In order to select the participating schools, we took into account heterogeneity and accessibility; the criteria for selecting the children were outstanding performance in mathematics and facility with language. The teachers also participated as a source of information on the processes that intervene at the schools.

CHART 1. CHARACTERISTICS OF THE SCHOOLS THAT PARTICIPATED IN THIS PHASE OF THE RESEARCH

SCHOOL	TYPE	SOCIOECONOMIC STRATA	OWNERSHIP	NUMBER OF CHILDREN SELECTED
Unidad Básica Gabriel García Márquez	Academic	0, 1, 2[2]	Public	14
Ciudad Montreal	Academic	0, 1, 2	Public	10
Gimnasio Pascal	Academic	3, 4, 5[3]	Public	10

Research Strategies

In order to access reasoning, metacognition and creativity processes used to solve mathematical problems, and having the certainty that they are not tangible, we drew on two strategies that allowed us, somehow, to gain access to such information.

As the main instrument, we found the Peva, defined as *thinking out loud*. This method allows giving account of the way a subject accesses knowledge and the mechanisms that he/she uses in order to construct solutions in problem situations. Also, we designed two semi-structured interviews: one for the children, which we used to study in a fundamental manner the process followed by the children in problem solving situations that were presented to them; the other interview was applied to the teachers, in order to complement the information given by the children.

[2] Schools that tend to lower class populations.
[3] Schools that tend to middle class and upper middle class populations.

Procedure

The research team created a database with problems based on selected additive structures, which would allow us to access the greatest possible amount of information about the reasoning, metacognition and creativity processes, and their relationship with the structures.

To begin with, the child was introduced to the researchers and to the objective of the research; afterwards, he/she was given the instructions, and one of these was to verbalize all the things or ideas that came to his/her mind when solving the problem; finally, he/she was asked whether he/she had any doubts about the task.

The child was given the first problem and he/she started to solve it, making emphasis, always, on verbalization; when he/she finished, we conducted the semi-structured interview in order to complement the information. This same procedure was followed with the additional problems and with all the children who took part in this research. The last step was the interview with the teacher.

In order to collect and analyze the information we conducted a categorial analysis, that is, we created categories and indicators that allowed us to organize the information in a clear and precise manner, through a code tree, which is a graphic map that is used to help the reader recognize key elements of the research and their ramifications, and a code book that defines the elements that make up the tree. Such elements became the basis for structuring the matrices where the information was analyzed.

The proposed matrices correspond to two levels: type 1 gave account of children's textual verbalizations according to the corresponding category; and type 2 was used to analyze the information of the type 1 matrix, which allowed us to specify the results, analyze them, and establish crosses and relationships between the processes and the additive structures.

RESULTS

As we stated before, in the process we took into account three types of reasoning, according to Santamaria's ideas (1997). Thus, in deductive reasoning the children identified the problem's elements, identified the rule, organized the information and executed the action plan. One example of this is Juan, who said during the interview: "I added 28 plus 45 and I got 73; as Pablo said he had 28 Pokemon cards in his backpack and 45 on the table, then I thought that I had to add."

The deductive process was evident in children, since the data and the information in itself became the pretext to solve the problem situation, and we considered that it was assumed as correct and true, given that it is immersed in, and it is part of, their day-to-day life. Moreover, the problem situation is involved in events that are important and pleasant for the children, in this case, a cartoon as an element in school play. We also observed that the rule was detected thanks to key words that are associated to the mathematical operation and, in this sense, they promote the familiarity with the context.

Regarding inductive reasoning, we found that in order to solve the problem the children took certain information as a point of reference that allowed them to detect the problem's requirements. Such information stood out for not being part of the main statement, but of the question, key words or particular data.

Concerning abductive reasoning, we observed that it was not evidenced, which led us to propose three possible explanations for this. The first one is the possible difficulty that children have to make conjectures and, to that extent, to establish hypotheses; the second one refers to posing the problem situations, since their structure makes the case explicit and, in this sense, reduces the possibility that the abduction will take place; the third one involves the medium: when it is necessary to deal with day-to-day problem situations with quick and functional answers, this type of reasoning is restricted to specific moments that do not entail complications or time limits.

Based on the results, we were able to determine that creativity is a process that is somehow limited, since the children's actions not always generated the right products, a requisite for fulfilling most of the indicators of this process. "Creative products are usually defined as original and adequate products" (Jackson & Messick, 1973, quoted by Bernal, 2001) or, as proposed by González (2001), creative products are characterized by their originality, pertinence and relevance.

Thus, in this process only a few indicators were evidenced. The children did not generate any creative product; most of them (80%) generated products that were pertinent but that were not original in any way, they repeated the outline that their teacher had taught them. However, we cannot ignore other indicator, like remote associations, which are part of the abilities category, which, according to Nickerson (1988), quoted by Bernal (2001) are constituted by ideational fluency, remote associations and intuition. In children that took part in this research we found remote associations as repetitive indicators.

According to Mednick (1962), quoted by Bernal (2001) remote associations are defined as the ability to recover information associated to the problem; that is, it would be easier for creative people than for conventional people to recover remote information. But like ideational fluency, these researches have yielded different results. This indicator was observed frequently in children, because in order to solve the problems that were presented to them, they constantly drew on information from similar experiences: “My teacher taught me like this” or “I know one like this but with cars.”

Regarding metacogition, we found the supervision indicator, which consists, according to authors like Kagan and Lang (1978), quoted by González (2001), of the possibility to reflect about the cognitive actions that are being performed. The children showed this indicator when they recognized the mistakes they had made, mostly when responding to the semi-structured interview. For example, to the question “How did you solve the problem?” Linaida responded: “It was when I thought and I had a hunch that I had to add 25 and 45 and I added and I got 72.” As we can see, the product is not correct, which is not a priority in this process; what is important is that, through this verbalization, she became aware of her mistake and she corrected it later.

According to the same authors, other indicator that gives account of the metacognition process is relating information, which is part of the knowledge of knowledge category, and it makes reference to the possibility of retaking previous information, and organizing it in a coherent way in order to respond to the problem question, as expressed by Andrés: “First I read it out loud in a low voice like this and then I read it all, it is what my mom has told me. I already knew it when they were teaching us, I knew it since 0 grade, my mom taught them to me.” This is how we see that Andrés, by organizing previously known information, facilitates the resolution of the stated problem.

Lastly, the regulation and control category, proposed by Kagan and Lang (1978) quoted by González (2001) includes the identification of what is stated by the problem as known, and the planning of actions in order to solve it, as the problem detection indicator. In most of the children the detection was evidenced when they read the statement, recognized the elements and, to that degree, generated strategies for its resolution.

CONCLUSIONS

We were able to establish that reasoning, metacognition and creativity processes have indicators that, depending on the problem solving situation and the action that must be performed, are connected and evidenced in a simultaneous manner. Proof of this is how the remote association indicators (creativity) and relating information indicators (metacognition) are presented in relation to recovering information, organizing it and applying it to the problem situation.

In the same way, we see how certain indicators of the same process are also transposed; for example, in the metacognition process we could observe that the indicators of detection of the problem, design and execution of strategies, and coherence, were seen frequently in the same action and verbalization reported by the child. These indicators describe the procedure that takes place since the child identifies what is stated by the problem (detection of the problem), followed by the devising of the action (design of execution strategies) and the coherent execution (coherence).

Lastly, as psychologists we consider that from reasoning, creativity and metacognition, we drive the work of mathematical education concerned with so-called addition problems; at the same time, we acknowledge the importance of studying and contributing to the dynamic that grows from the interaction of the teacher, the student and mathematics as a formal discipline, as proposed by Broody (1997, quoted by Bernal, 2001). In this sense, we suggest that when constructing mathematical problems, the teacher should keep in mind the importance of innovating when it comes to the contexts that are involved in the problem; this will make the problem more attractive and meaningful for the children. That means that in problem situations the teacher should use current and day-to-day elements that have an important influence in the child's representations; at the same time, the structure, wording and language of the formulation of the problem should not continue fomenting the repetition and mechanization of concepts that we see today, but it should allow the child to assimilate, internalize and understand the actions that take place when he/she solves a particular problem situation.

REFERENCES

BERNAL, T. (2001). *Más allá de las cuentas: procesos cognitivos y estructuras auditivas*. Proyecto Institucional, Facultad de Psicología. Universidad Santo Tomás, Bogotá.

CARRETERO, M. (1984). *Lecturas de psicología y pensamiento, razonamiento, resolución de problemas y desarrollo cognitivo.* Madrid: Alianza Editorial.

CHADWICK, C. (1999). La psicología del aprendizaje desde el enfoque constructivista. The Chadwick School. *Revista Latinoamericana de Psicología*, *3,* (3), 463-475.

GONZÁLEZ, F. (2001). *Acerca de la metacognición.* [Online] en 10 de agosto de 2001. Available in fgonzalez@dino.coniat.ve [2001, August 12]

MINISTERIO DE EDUCACIÓN NACIONAL. (1997). *Evaluación de logros en matemáticas*. Serie Publicaciones para Maestro. Bogotá: Ministerio de Educación Nacional.

MINISTERIO DE EDUCACIÓN NACIONAL. (1997). *Análisis y resultados de las pruebas de matemáticas TIMSS*. Serie Publicaciones para maestros. Bogotá: Ministerio de Educación Nacional.

MINISTERIO DE EDUCACIÓN NACIONAL. (1998). *Lineamientos curriculares en matemáticas*. Dirección de Investigación y Desarrollo Pedagógico. Bogotá: Ministerio de Educación Nacional.

POURTOIS, J. (1992). *Epistemología e instrumentación en ciencias humanas*. Barcelona: Herder.

ROMO, M. (1997). *Psicología de la creatividad*. Barcelona: Paidós.

SANTAMARÍA, C. (1997). *Razonamiento y racionalidad*. Barcelona: Paidós.

SANTOS, L. (1996). Investigación en educación matemática. *Revista Latinoamericana de Psicología, 28*, (28).

VERGANAUD, G. (1995). *El niño, las matemáticas y la realidad*. México: Trillas.