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Original article

The logical-mathematical thinking of students. A didactic matter?

El pensamiento lógico-matemático del estudiantado. ¿Un asunto didáctico?

O pensamento lógico-matemático do corpo discente. Uma questão didática?

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ABSTRACT
The results obtained in Ecuador in the report of the International Student Assessment Program administered by the Organization for Economic Cooperation and Development in 2018, the Ser Bachelor test; and, recently, the Higher Education admission exam reveals a deep weakness in learning and developing problem-solving skills. The methodological heritage of teachers is not helping to solve this issue, which is why this article aims to analyze the creative didactic strategies and the logical-mathematical thinking of adolescents from a public school in Portoviejo canton. A descriptive and correlational quantitative study was carried out to determine findings that facilitate the explanation of this problematic situation. In the fieldwork, a bank of questions was applied to students and a survey was applied to math teachers. The results show that 85.7 % of adolescents have a score lower than 7, which means that they have not exceeded the required learning levels in problem-solving. For their part, teachers use creative didactic processes very frequently but with limited time for students to reflect on possible solutions to a problem. The teacher assumes a great responsibility in the mathematics learning process because he is the mediator of building that knowledge so that students can understand it.

Keywords: creative teaching strategies; teaching materials; creative thinking; mathematical logical thinking; didactic process.

RESUMEN
Los rendimientos obtenidos en Ecuador en el informe del Programa Internacional de Evaluación de Estudiantes administrado por la Organización para la Cooperación y Desarrollo Económicos en 2018, la prueba Ser Bachiller; y, recientemente, el Examen de Acceso a la Educación Superior, revelan una profunda debilidad en el aprendizaje y desarrollo de capacidades para la resolución

de problemas. El acervo metodológico del profesorado no está ayudando a solucionar esta cuestión, razón por la que el presente artículo tiene como objetivo analizar las estrategias didácticas creativas y el pensamiento lógico-matemático de los adolescentes de una institución educativa fiscal en el cantón Portoviejo. Se realizó un estudio cuantitativo de nivel descriptivo y correlacional para determinar hallazgos que faciliten la explicación de esta situación problémica. En el trabajo de campo se aplicó una batería de preguntas para los estudiantes y una encuesta para los docentes del área de matemáticas. Los resultados demuestran que el 85.7 % de los adolescentes tienen una calificación inferior a 7, lo que significa que no han superado los niveles de aprendizaje requeridos en la resolución de problemas. Por su parte, los docentes utilizan procesos didácticos creativos con mucha frecuencia, pero con un tiempo limitado para que los estudiantes reflexionen sobre las posibles soluciones de un problema. El docente asume una gran responsabilidad en el proceso de aprendizaje de las matemáticas, porque es el mediador de construir esos conocimientos para que los estudiantes puedan comprenderlos.

Palabras clave: estrategias didácticas creativas; material didáctico; pensamiento creativo; pensamiento lógico-matemático; proceso didáctico.

RESUMO

Os resultados obtidos no Equador no relatório do Programa Internacional de Avaliação de Estudantes administrado pela Organização para Cooperação e Desenvolvimento Econômico em 2018, o teste Ser Bachiller; e, recentemente, o Exame de Admissão ao Ensino Superior revela uma profunda fraqueza na aprendizagem e no desenvolvimento de habilidades de resolução de problemas. A herança metodológica dos professores não está ajudando a resolver esta questão, razão pela qual este artigo tem como objetivo analisar as estratégias didáticas criativas e o pensamento lógico-matemático de adolescentes de uma instituição de ensino fiscal no cantão de Portoviejo. Foi realizado um estudo quantitativo descritivo e correlacional para determinar achados que facilitem a explicação dessa situação problemática. No trabalho de campo, foi aplicada uma bateria de perguntas aos alunos e um questionário aos professores da área de matemática. Os resultados mostram que 85,7% dos adolescentes têm nota inferior a 7, o que significa que não ultrapassaram os níveis de aprendizagem exigidos na resolução de problemas. Por sua vez, os professores utilizam com muita frequência processos didáticos criativos, mas com tempo limitado para que os alunos reflitam sobre possíveis soluções para um problema. O professor assume uma grande responsabilidade no processo de aprendizagem da matemática, pois ele é o mediador da construção desse conhecimento para que os alunos possam compreendê-lo.

Palavras-chave: estratégias criativas de ensino; material didático; pensamento criativo; pensamento lógico-matemático; processo didático.

INTRODUCTION

Logical thinking is essential in the educational field due to the connotation it has in the different areas of knowledge, since it makes it possible for students to contemplate different points of view, express specific criteria and establish timely resolutions.

In his considerations, Medina (2018) states that:

> The development of this thinking is key to mathematical intelligence and it is essential for the well-being of boys and girls, since this type of intelligence goes far beyond numerical abilities, it provides important benefits such as the ability to understand concepts and establish relationships based on logic in a schematic and technical way. It implies the ability to use calculation, quantifications, propositions or hypotheses in an almost natural way (p. 128).

Strengthening thinking is essential in the teaching process in students, since it contributes to acquiring knowledge and helps them to appropriate the resolution of logical operations. For this reason, it is important that children integrate this learning from the preschool stage, so that they reach an optimal development in the management of mathematics.

The PISA-D test (2018) was carried out in Ecuador "with the purpose of evidencing the academic reality, especially in the resolution of mathematical problems, since 70.9% of the country's students do not reach level 2 (basic performance level).[1]" (p. 44).

According to the Ministry of Education (2016), the mathematics curriculum contemplates that "the teaching of Mathematics has as its fundamental purpose to develop the ability to think, reason, communicate, apply and assess the relationships between ideas and real phenomena (…)" (p. 52).

As it is a topic of academic interest, a documentary review was carried out, in order to present research with similar characteristics to the subject of study, which will serve as a background to the research.

Creative didactics is a set of strategies that facilitate student learning.

López (2017), cited by De la Torre (2006), indicates that:

> In his definition of creative teaching strategies, he sees six essential elements permeated by creativity such as vision, action and research practice for innovation in teaching, these are: theoretical foundation, purpose, adaptive sequence, adaptation to contextual reality, role of agents, functionality and effectiveness. Thus, it seeks to promote a work environment different from that of conventional classrooms, giving priority to the needs of the subjects who create - above the usual standardized tests and predetermined curricula-, changing the role of the teacher as a center to that of project tutor, who in turn is trained and researches on their practice. It is intended that the teacher learn to be creative, since creative teachers foster creative learning environments, not the other way around (p. 22-23).

According to Delgado (2022), cited by Hernández and Guaraté (2019):

> Didactic strategies are considered procedures and actions, through which teachers outline and apply

> their teaching-learning sessions, using various methods and techniques, in order to carry out the educational process where students must develop skills and competencies towards learning achievement of their learning (p. 56).

In education it is important and fundamental to encourage creative thinking in students, in addition, it should be considered as an essential tool in the teaching-learning process.

For their part, Ramírez and Rincón (2019) tell us in their analysis that:

> (...) creative thinking is put to the test every time it is necessary to respond to a human need or when a problem is found that needs to be solved, it emanates from sensitive knowledge and mental flexibility. So, we have that, to a large extent, at each moment that individuals exercise creativity, they generate learning through the discernment of attributes, which develops new concepts (p. 93).

The success of the didactic process depends on the knowledge, capacity and performance of the teacher to carry it out with different appropriate activities, which tend to achieve the same goal, which is to facilitate student learning.

On this subject, Molina Suarez del Villar (2020) indicates that:

> The didactic procedures are a complement to the teaching methods, they constitute and tools that allow the teacher to orient do and direct the activity of the student in collective, in such a way that the influence of others propitiates e individual development, stimulating logical thinking, theoretical thinking and independence Cognitive decency, motivating him to learn in a favorable learning climate. It considers that it is a joint activity that is interrelated with the teacher and student to improve the teaching-learning process (par. 6).

It is necessary for the teacher to use didactic material that contributes to the development of the didactic processes. On the other hand, the use of technology will help the student to develop their skills and improve academic performance.

In the field of teaching-learning in the classroom, there are countless factors that intervene in the didactic processes in order to guarantee the best results for the students. Within the range of agents participating in educational environments are didactic resources, considered as a fundamental part of curricular design (...), on the other hand, new technologies have changed our way of accessing information, the way of interacting with her, as well as how to learn with and from her. Ensuring that the learning environments together with the teacher consider these changes and adapt to the current reality of digital student communication could be beneficial (Trejo González, 2018, pág. 619).

ForCeli, Quilca, Sánchez and Paladines (2021), logical-mathematical thinking is:

> (...) the possibility of generating skills for the development of mathematical intelligence and also for the

> use of logical reasoning, benefiting children and preparing them to understand concepts and establish relationships based on logic in a schematic and technical way. In addition, naturally bring out abilities for calculation, quantifications, propositions and hypotheses (p. 834).

This article aims to analyze the creative teaching strategies applied by teachers and the logical - mathematical thinking of adolescents. In addition, it is intended to encourage teachers to stimulate in students the ability to propose and solve problems with a variety of methods, strategies and active techniques; as well as stimulating resources, not only as an application tool, but also as a basis for the general approach to the work of each of the periods of the education and learning process in the area of mathematics.

MATERIALS AND METHODS

This research work was developed from a non-experimental design, with cross-sectional quantitative techniques and descriptive and co relational level. The study did not compromise the management of the variables, but rather collected information directly from the primary sources to determine the results that are expressed in the analysis of this article. It was cross-sectional, in that a cut in time and a data collection that was compared with it was taken as a reference. The study has a descriptive part with measures of central tendency, to explain the variables of the first category -creative didactic strategies-. The second category (logical-mathematical thinking) was analyzed through calculations of central tendency and correlations of the variables evaluated as dimensions of the study category.

The research was carried out in a fiscal institution in the city of Portoviejo, with a student population that is made up of 325 female students and 204 male students legally enrolled. The institution has 10 Mathematics teachers in the Higher Basic Education sublevel. The sample size required 222 participating students, considering a margin of error of 5% and 95% confidence. The subjects were selected by means of a simple random sampling and for the teaching staff the universe of the institution was contemplated.

The instrument used to collect the material from the first category was a structured base survey with 11 questions aimed at exploring the use of technology from the beginning of creativity. This survey consisted of 11 variables that were recalculated based on the responses to interpret the data obtained.

For the collection of information from the second category, the battery of logical thinking was used in the formal stage, an instrument that consists of six dimensions: seriation, classification, identification, laterality, correspondence and comparison. Each dimension is structured in five graded exercises with which the degree of maturity of the intellectual skills required for problem solving in the stage of formal thought can be assessed. The questionnaire was subjected to Cronbach's alpha coefficient and obtained a global score of 0.79, which determines an adequate degree of confidence in its structure. This test is applied to subjects who are between 12 and 15 years old or who are studying the level or grade corresponding to the sublevel of Higher Basic Education of the Ecuadorian National Education System.

The instrument is assessed by dimensions on a scale of 1 to 10, whose approval value accepted in this study is seven, which has been quantified based on the accumulated percentage that was calculated from the sample for validation. It is advisable to make comparisons of the means obtained by the subjects evaluated to establish significant differences between the groups.

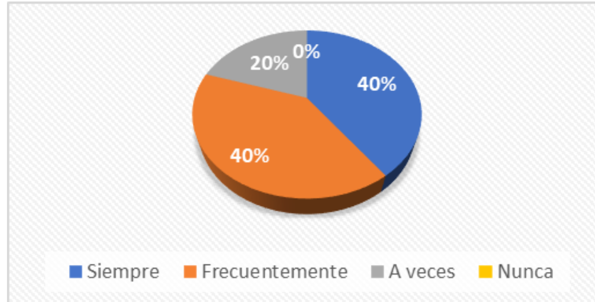
For data analysis, the measures of central tendency of the data were quantified. In the first category (creative use of technology), the relative frequency of responses obtained from the application of the survey was calculated. To represent the dimensions, an integrating variable was recalculated, as represented in graphs 1 to 4 as the result of the variables included in it.

As for the second category, the variables evaluated are integrated into the dimensions evaluated by the instrument. In the first instance, the measures of central tendency of the global result of the scale (mean, mode, deviation, minimum, maximum and percentiles) were calculated. Then, the central tendencies of the performances for each dimension were evaluated, to carry out a detailed analysis of the logical capacities explored in this study.

Finally, the Pearson correlation was calculated in the results of the evaluable dimensions of the logical thinking scale. With these data, the conclusions of the study and the relationships between the methodology applied for research, the use of flowcharts and the logical thinking capabilities that are involved in the mathematical learning of adolescents were determined.

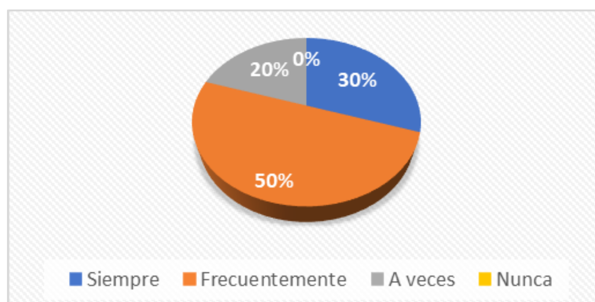
RESULTS

The purpose of the survey was to explore the creative didactic processes applied by teachers in the teaching-learning process in mathematics, for which a population of 10 teachers who teach this subject in the educational institution was taken.



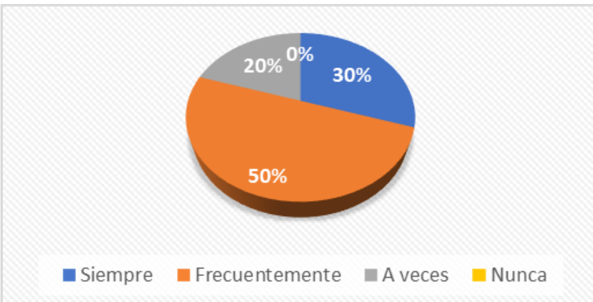
Graph 1 - Reflection of possible solutions
Source: own elaboration. Survey addressed to teachers in the mathematics area of a public educational institution in the city of Portoviejo

The survey inquired about the time and space that teachers provide their students to reflect on their respective solutions to a problem. Graph 1 shows that 40% do it always and frequently, while 20% only sometimes. It is important to mention that, within the classroom, teachers have the challenge of encouraging students to express their opinion about what they think about what they have learned, since in this way they will discover how to reflect on their own.



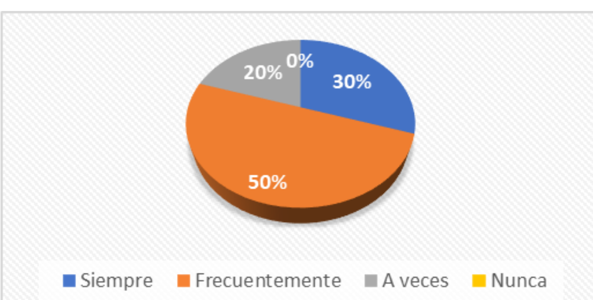
Graph 2- Use of questions to explore problems
Source: own elaboration. Survey addressed to teachers in the mathematics area of a public educational institution in the city of Portoviejo

On the other hand, the statistical results of graph 2 show that 30% of teachers raise questions about the meaning of the representations made by students in solving a problem; 50% do it frequently, and 20% sometimes. Thus, it is inferred that teachers are not applying inquiry to knowledge, and this is an appropriate space to monitor the student's level of knowledge about the content explained.



Graph 3- Meta -reflection of the problem-solving process
Source: own elaboration. Survey addressed to teachers in the mathematics area of a public educational institution in the city of Portoviejo

As can be seen in graph 3, 30% of teachers resort to motivation to stimulate their students in the development of mathematical processes; 50% do it frequently, and 20% sometimes. These data show insufficiency on the part of teachers, although they do not allow students to reflect on how they have reached a result or solution based on their own experience.



Graph 4- New concepts and explanations
*Source***:** own elaboration. Survey addressed to teachers in the mathematics area of a public educational institution in the city of Portoviejo

From the data in Graph 4, it can be deduced that 30% of teachers authorize students to put new concepts into practice so that they can elaborate explanations that constitute the solution to the problem, while 50% do so frequently, and 20% sometimes. . By presenting a low percentage in this criterion, students will have difficulties to formulate or pose new situations of problems and questions.

Consolidation of logical thinking processes in problem solving

Table 1- Consolidated results of the battery of questions.

N	**valid**	222
	lost	0
Half		4.82
fashion		4.00
Deviation		2.07
Asymmetry		0.45
Skewness standard error		0.27
Minimum		0.00
Maximum		9.67
Percentiles	25	3.33
	15	4.67
	75	6.00

Note: equivalence is the average of the scores obtained in each dimension of the logical thinking battery

85.7% of the students have obtained a score lower than 7.00 in the score equivalence of the logical-mathematical thinking battery. The average score of the students' performance is equivalent to 4.82 out of 10, with a standard deviation of 2.07, which implies that there is a wide distance between the scores achieved by the students in the instrument. The mode of the results equals 4.00; this means they are in a performance percentile of less than 50%. The minimum mark of the students is equal to 0.00 and the highest mark is 9.67. Based on the above, it could be described that there are students with high consolidation in their logical thinking for problem solving, as well as others with very low performance.

Table 2- Results by dimensions of the logical thinking battery in the formal stage

		Serialization	ID	Classification	Laterality	Corresponde nce	Comparison
N	valid	222	222	222	222	222	222
	lost	0	0	0	0	0	0
Half		3.74	7.82	4.49	4.68	3.82	4.49
fashion		4.00	10.00	4.00	4.00	4.00	4.00
Deviation		2.30	2.78	2.92	2.61	2.68	3.18
Asymmetry		1.06	-1.20	0.36	0.55	0.41	0.27
Skewness standard error		0.27	0.27	0.27	0.27	0.27	0.27

Note: dot is used to separate decimals

Once the battery has been applied, with the data obtained by categories, it can be seen that the dimension with the best score was identification, with a mean of 7.82 and a standard deviation of 2.78; in this case there is no normality in the data distribution. The values become unstable and the range between the student groups is very wide. For its part, the seriation dimension was the lowest of all, with a mean equivalent to 3.74 and a standard deviation of 2.30; here, the data distribution does not conform to normality. Likewise, these results allow us to describe that, from the dimension of the seriation, 100% of the evaluated group had a score equal to or less than 10 points out of 10. It is noted that the distribution adjusts to normality and the values are ratified with the average mentioned in table 2. In the identification dimension, it is observed that the data do not adjust to normality, although 50.6% of the student body received scores equal to or less than 8. For the classification dimension, 90.9% of the population consigned this annotation. In the laterality test, results of 90.9% were evidenced with scores equal to or less than 8; correspondingly 96.1%, and in comparison, 87%.

Table 3- Correlation of the dimensions of the logical thinking battery in the formal stage

	Serialization	ID	Classification	Laterality	Corresponden ce	Comparison
Serialization	1	.454**	.645**	.521**	.496**	.506**
ID	.454**	1	.550**	.257*	.385**	.499**
Classification	.645**	.550**	1	.494**	.502**	.534**
Laterality	.521**	.257*	.494**	1	.538**	.587**
Correspondence	.496**	.385**	.502**	.538**	1	.647**
Comparison	.506**	.499**	.534**	.587**	.647**	1
**. The correlation is significant at the 0.01 level (unilateral)						
*. The correlation is significant at the 0.05 level (unilateral)						

The repercussions of the application of the logical thinking battery showed results in the formal stage according to the Pearson correlation test, which shows that the variables are strongly correlated with each other. This could be interpreted as a strength group in the logical thinking of the evaluated adolescents.

DISCUSSION

From the diagnostic stage applied to teachers, it was possible to determine that they do not always apply creative didactic processes in teaching and learning. Based on this research, the following analysis emerges: regarding the criterion of reflection of the possible solutions, an average percentage of application is manifested, something worrying; since the reflective facet implies that the teacher facilitates and promotes a constant reflection of the students. about how they assimilate, how they can learn better and with what resources, as well as providing tools and opportunities to plan, monitor and evaluate their own process.

With the above, we can cite Prieto, MN (2021): (...) "Reflection supposes a capacity, an awareness of our actions, a process that is enriching if it allows transformations in our daily practices for the improvement of processes of teaching and learning" (p. 101). On the other hand, Delgado (2019) states that: "Student reflections can help teachers modify and plan future lessons, see what strategies are helping and which students need additional attention, and what connections they establish between the lesson and what come out of the classroom" (p. 14).

Regarding the criterion on the use of questions to explore problems, it was highlighted that they are always formulated by a minimum percentage of teachers. In the teaching of mathematics, questions are a very important instrument for the development of logical thinking, so the great work of the teacher is applauded to generate spaces for discussion or formulation of questions in a personal way around the subject matter. It could be suggested that, for the application of skills or strategies, teachers should consider the formulation of questions, since it is a way of generating a dialogue with students and, at the same time, fostering an environment of trust for that they can answer without any fear.

In this regard, Ordoñez, Coraisaca, and Espinoza (2020) believe that:

> Asking good questions allows the teacher to measure students' understanding. When they respond, the teacher can assess what the group understands and what they don't. "You get this measure of your students by listening to the answers they give to your questions." A teacher can teach above or below the level of the students' knowledge, which, in either case, causes boredom. Student feedback allows the teacher to make optimal use of the allotted time by clearly covering points that have not been understood. This also makes students understand the principles that are being taught (p. 227).

Regarding the meta-reflection criterion of the problem-solving process, it can be said that mathematics teachers adopt it in a minimal percentage, although a reasonable number of them do so frequently. Reflection is always present during the interaction between the student and the teacher, since it establishes a media relationship with knowledge. It is crucial to create a calm environment to facilitate concentration when considering the analysis of a problem.

Carrión (2019) asserts that:

> The problem-solving structure in the classroom implies as its main action a demonstration by the teacher, who poses a problem and then develops its solution as a model. The students, for their part, repeat the solution presented by the teacher and then apply identical procedures to the solution of similar problems. In the latter case, the teacher evaluates the students' response and says whether it is correct or not (p. 467).

Within the student learning process, it is vital that the teacher knows how to explain the steps to be followed in solving a problem. This will be done through a hierarchical order and without omitting certain resolution guidelines, which means that the student appropriates their own knowledge.

In view of the criterion of new concepts and explanations, it was appreciated that a minimum percentage of teachers take advantage of it. By limiting them, we are preventing students from investigating, proposing or simply not applying strategies to solve a problem.

From the perspective of Barrera, Reyes, Campos and Rodríguez (2021): "Problem solving is the ideal means to learn mathematics, since students, in their training phase, can carry out experiments with mathematical objects, formulate and justify conjectures, as well as raising new problematic situations or questions, activities that integrate the experimental and inductive axes of the discipline" (p. 11).

After applying the logical thinking battery in the formal stage to 222 adolescents from an educational institution and after checking their results, it is concluded that there is no acceptable degree of ability to solve mathematical problems. This affirmation is corroborated by the evidence of the low percentage of teachers who do not always use creative didactic processes, according to the yields that the inquiry in the teaching field yielded. It should be noted that these methods constitute strategies for constructivist learning that, with the help of technology and teaching materials, are of great help for students to generate good cognitive development through reasoning, creativity and imagination through each content that is presented in the classroom.

Based on the data obtained, when in the didactic approach the seriation function is stimulated in the student body, it moderately collaborates in the progress of the functions of identity, laterality, correspondence and comparison. However, exercising the seriation directly stimulates the classification. Serialization is a fundamental part of children's development, because it helps them to optimize the cognitive part, which means that students will be able to establish comparative relationships with respect to a referential system. The use of creativity in the classroom encourages students to improve their cognitive skills: relate, solve, investigate and interpret. In this way, the teacher will contribute so that they acquire a better learning that helps them to solve the problems of daily life with creativity.

According to the data obtained, the identification moderately favors the increase of the classification in the students. Thus, in addition to exercising identification, it also directly encourages the advancement of serialization and comparison. From this point of view, it is extremely important to analyze the problem to identify the most appropriate type of solution. A creative teacher is one who trusts their students and provides them with spaces for participation, allows them to express themselves, believes in their abilities and, most importantly, does not block their ideas.

As can be seen from the data extracted in the Pearson correlation test, the classification function in students helps in some way to enhance identification, laterality, correspondence and comparison. However, exercising the classification clearly drives the progress of the seriation dimensions. Nowadays, creativity has great importance as a transversal axis in the different activities of the human being, mainly within education.

In the same way, it has been shown that in the function of laterality in the students they collaborate moderately for the serialization, classification and correspondence, although exercising laterality directly motivates the comparison. Laterality is significant for the learning process of mathematics, so it requires information processing for the student to improve their numerical skills. Didactics in education reveals forms, methods of teaching and learning, stimulating the educational process in all stages of formation.

Taking into account the analysis of the functions table for the students, it can be seen that the correspondence moderately collaborates to improve the functions of seriation, classification and laterality. Instead, it exercises correspondence, since it directly stimulates comparison. Didactics is important in education because it helps the teacher to select and use the materials that facilitate the skills and evaluation indicators, while favoring reflection on the different learning strategies.

Consequently, the data obtained in the comparison function in the students can be detailed, since it contributes relatively to the functions of seriation, identification, classification and laterality. However, exercising comparison directly encourages correspondence. The use of didactic strategies is relevant in the framework of teaching and learning because through it mathematical content can be taught in different ways and constructive knowledge can be achieved.

According to Guaypatin, Fauta, Galvez, Montaluis(2021):

> It is important to stimulate the learning of mathematics from an early age, since all people are born with the abilities, which will depend on the stimulation given to each person; If adequate stimulation is developed, mathematics helps to have a logical thought based on reality and thus solve the problems of everyday life with the best solutions and proposing new proposals or methodologies for learning mathematics (pp. 108-109).

Based on the analyzed findings, the convenience of creative didactic processes in the mathematics learning section is verified, to become familiar with the problems and execute strategies with more scope for students in understanding concepts and analyzing results.

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[1]According to the PISA-D Ecuador report, "the basic performance level implies that students know how to interpret and recognize situations in contexts that only require direct inference. Students at this level can extract information from a single source and use a single mode of representation. Students can use basic-level algorithms, formulas, procedures, or conventions to solve problems involving whole numbers. They are able to make literal interpretations of the results" (INEVAL-OCDE, 2018, p. 37).

Conflict of interest:

Authors declare not to have any conflicts of interest.

Authors´ Contribution:

The authors have participated in the writing of the work and analysis of the documents.