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THE USE OF A DIDACTIC SEQUENCE WITH THE USE OF PUZZLES AS AN ALTERNATIVE METHODOLOGY FOR TEACHING PLANE GEOMETRY

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ABSTRACT

The study carried out in this article occurred through the use of a didactic sequence using a puzzle, in order to facilitate the learning of plane geometry. The research aimed to verify the contributions of a Didactic Sequence to the teaching and learning process of plane geometry. The study carried out is qualitative, and seeks to analyze the development of students in the 2nd year of high school in a state public school in Belém do Pará. For the analysis of this research, a didactic sequence with three blocks of activities is used, the first block consisting of 8 questions, the second block with 4 questions and the third and last block with 7 questions. To authenticate these results, the answers collected through the applied didactic sequence were used, whose data revealed that the students are able to present examples of everyday objects similar to the plane figures, but still have difficulties in calculating the area. In conclusion, it is clear that the way Geometry is seen within the educational environment still requires care to obtain positive results in the study of this area of mathematics.

Keywords: Didactic Sequence. Plane Geometry. Areas of Plane Figures.

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INTRODUCTION

When studying Plane Geometry, it is expected that students will perceive it to determine that it is present in various everyday situations, such as the measurement of areas and volumes and the construction of objects. By studying geometric content, students can learn to apply this knowledge in real-world situations, as Nogueira (2017) considers when he points out that the basic knowledge of Geometry is fundamental for individuals to interact in their environment. According to Valente and Silva (2017), it is considered that teaching Geometry is important because it has always occupied a place of undeniable prominence in the development of mathematical knowledge.

However, what can be noticed is the teaching of Geometry going through some difficulties. Fischer (2015) states that "even today little emphasis is given to the teaching of Geometry in our schools and mechanical and repetitive calculations are prioritized." (p. 1), which shows the need to develop new methodological suggestions that can be made for learning geometry. One of the means that can be highlighted is the use of manipulative materials, as highlighted by Oliveira (2020) when he highlights that the use of manipulable materials produces a higher performance of students, which favors meaningful learning.

In the search to outline the difficulties linked to the process of teaching and learning Geometry, Pais (2006) highlights the importance of the use of drawings, material objects, concepts and mental images, which cannot be detached from each other and considers that "the articulations between these elements condition the didactic work and the student's reasoning in the construction of geometric knowledge." (Pais, 2006, p. 93)

It is worth noting the importance of paying attention to the ways of teaching Plane Geometry in schools, so that it becomes comprehensive for all students, contributing to them being attracted and participating more actively in classes, facilitating the learning process.

In this sense, it is worth questioning, which guides the present research: How do the activities of a didactic sequence contribute to the teaching and learning process of Plane Geometry? From this question, we undertook a study whose general objective is to verify the contributions of a didactic sequence to the teaching and learning process of Plane Geometry.

To this end, the organization of this article is structured as follows: Theoretical Basis, Methodological Aspects, Description and Analysis of Results, Final Considerations and, finally, References.

THEORETICAL FOUNDATION

To carry out this study, a theoretical reflection is presented on the use of didactic sequences in the educational sphere, based on what Zabala (1997) and Cabral (2017) recommend. A survey of research already carried out on the use of didactic sequences for the teaching of Plane Geometry is also made from the studies developed by Santos Neto (2018), Tavares (2016) and Tojo (2006).

The research carried out by Santos Neto (2018) aimed to propose an alternative for learning that values the development of student autonomy with the teacher as a mediator. To this end, a survey of problems proposed in OBMEP was carried out to instigate students about their resolution strategies. The author identified that his work was a viable alternative to encourage student autonomy and learning.

In the study carried out by Tojo (2006) the aim was to investigate how students in the 1st grade of high school appropriated and used the concept of congruence in order to answer some questions about the activity, such as: To what extent does the process of transition from concrete to space-geography contribute to the appropriation of the concept of congruence? And to what extent does this process favor the passage from the empirical to the deductive? The results indicate that the analysis of the productions revealed favorable aspects to the passage from the empirical to the deductive and others unfavorable, the first activities were correctly resolved, but the final ones were not.

The investigation proposed by Tavares (2016) aimed to develop, apply and evaluate the results of a didactic sequence that works on Plane and Spatial Geometry. The author found that classroom practice can be different, and that student involvement makes learning rewarding not only for the student, but also for the teacher.

According to the analysis of the aforementioned researches, we observed the use of didactic sequences as an important tool for the teaching process of the content of Plane Geometry.

When we turn our gaze to the didactic sequences, we rely on the perspective of Zabala (1998) when he defines it as "a set of ordered, structured and articulated activities for the achievement of certain educational objectives, which have a beginning and an end known to both teachers and students" (Zabala, 1998, p. 18) and points out some phases for its development, which are: planning, application and evaluation.

From Cabral's (2017) point of view, the didactic sequence requires the teacher to be able to plan and systematize data, as well as the ability to produce texts that will support the students' learning process.

The great bet of this model of teaching intervention is that the environment created for the classroom will be clothed, in theory, with a greater involvement of students among themselves and with the teacher. The emphasis on verbal interactions makes it possible to understand the children's ways of thinking, generating a fruitful environment for the development of argumentative capacity (Cabral, 2017, p. 34-35).

The perspectives of Zabala (1998) and Cabral (2017) show the importance of the didactic sequence for the classroom, as it is an instrument that helps the teacher and helps the student to understand the content. In addition, the use of geometry allows students to acquire new perceptions in their daily lives, to solve mathematical problems that are around them. In this way, we developed a didactic sequence that makes it possible to simplify the interpretation of how the area of plane figures is calculated and the way geometry is seen by the student.

In the next section, the methodological procedures adopted in the research are highlighted.

METHODOLOGICAL ASPECTS

Initially, a search was carried out in the Portal of Journals of the Coordination for the Improvement of Higher Education Personnel (CAPES), pages of Graduate programs, among others. When surveying research related to the use of didactic sequences for the teaching of plane geometry, from the perspective of evidencing what research had already been done in this area and what its conclusions were, the studies of Santos Neto (2018), Tavares (2016) and Tojo (2006) were found.

The research was developed according to the qualitative approach of the case study type, in which a didactic sequence on Plane Geometry was applied to students of the 2nd year of high school of a public school in the municipality of Belém (PA). The duration of the sequence was four schedules of 45 minutes each (180 minutes), the class was divided into 6 groups with 4 people in each.

The didactic sequence worked with the students consisted of 3 blocks of activities, the first block being called "Analyzing the puzzle", which contained 8 questions; the second block called "Playing to assemble figures" with a total of 4 questions; and, finally, the third block entitled "Calculating the area of the figures", with a total of 7 questions.

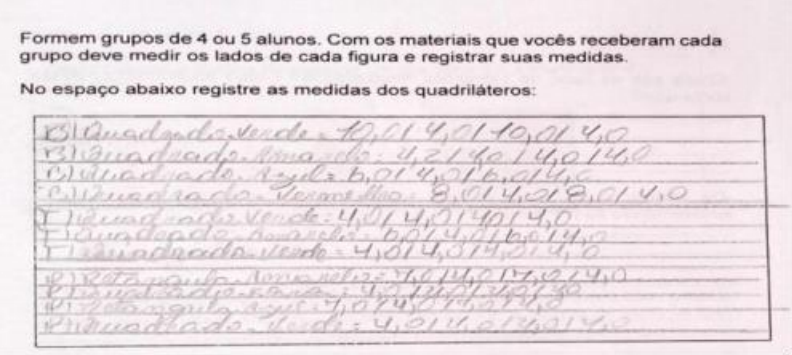
The application of the research protocol in this class made it possible to analyze the resolutions of the investigated students and verify the contributions of the didactic sequence elaborated in the teaching and learning process of Plane Geometry. For this work, the results of the application of all blocks of activities are presented with a total of 19 questions.

The results achieved in this study are shown below, with emphasis on some answers, with the aim of contributing to achieving the established objective.

DESCRIPTION AND ANALYSIS OF RESULTS

To carry out the first activity, some cardboard figures were given to the participating students, so we asked the students to measure the sides of each figure and make their records. For the analysis of the records made by the students, the answer of group 6 stands out below (Figure 1).

Figure 1 - Group 6's answer to question 1



Source: Research Protocol

Figure 1 shows the record of the response of group 6, in which they specify the measurements by means of current language: for the "green square=10.0/ 4.0/ 10.0/ 4.0". The answer explained above reveals that the use of didactic material resources in Geometry activities, through experimentation, can provide greater motivation and participation of students, as stated by Oliveira (2020). In addition, the activity also enables different paths in the response process, respecting the student's experiences and cognitive process.

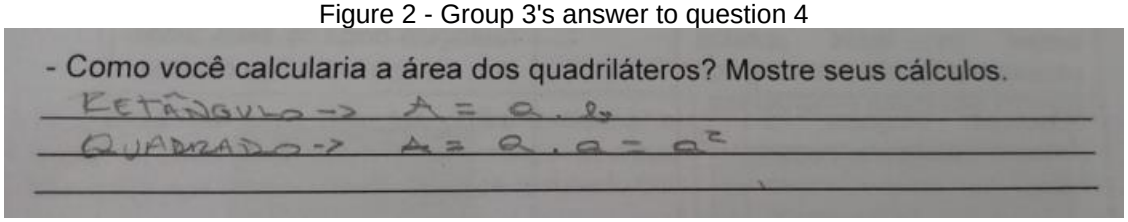
In the next activity, they were asked to write down the types of quadrilaterals that the students identified and how they came to this conclusion. It was noticed that, in general, the groups were able to identify the types of quadrilaterals. Group 1 answered that they would be "square because it has all sides equal and rectangle because it has a greater length in width", demonstrating that in addition to portraying the types of quadrilaterals, they also point out characteristics of the figures. The answers obtained in this activity indicate that the way we can identify the figures is actually linked to a preformed view that we already have of them. According to the PCNs (Brasil, 1997) geometric figures are recognized by their shapes, by their physical appearance, in their totality, and not by their parts or properties.

For question 3, the groups were asked to indicate examples of objects that resemble the figures they identified and present their measurements. In the answer of group 1, the

students indicated objects such as "cell phone, TV", thus relating the objects to the characteristics they found in the figures. According to Valente and Silva (2017), knowledge and skills in the field of geometry have been important throughout history and remain fundamental in our daily lives. Therefore, there is a need to understand that Geometry is present in every environment that the student inhabits.

In question 4, the students were asked how they would calculate the area of the quadrilaterals and then asked to show their calculations. When analyzing the answers of the investigated students, it was noted that there were different perceptions in relation to the calculation of the area of plane figures. To authenticate the analysis of the results, the response of groups 3 is demonstrated, according to Figure 2 below.

Figure 2 - Group 3's answer to question 4



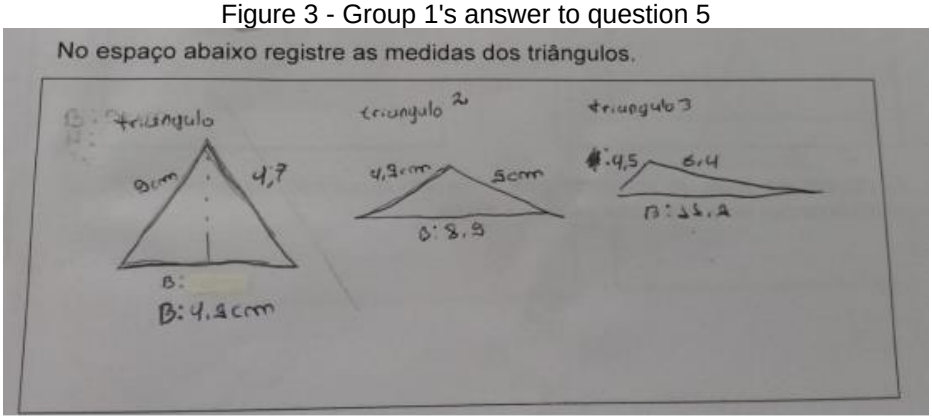
Source: Research Protocol

Based on the research protocols, the resolution of group 3 (figure 7) stands out, which portrays the formulas for calculating the area of squares and rectangles. In turn, group 4 presented only one sequence of numbers. Such answers reveal that while one group understands the concept of area, the other did not have the perception of what should be done correctly.

Santos Neto (2018) in his research states that "it is necessary for the student to ask himself questions. This should be the starting point of learning: reflection and decision-making as to what can be done to solve a given problem. (Santos Neto, 2018, p. 27). Thus, it is possible to infer that the student is responsible for answering the established questions, according to their acquired knowledge and lived experiences.

In the following question, verifying the answers obtained, it can be seen that there was a difference in the answers in relation to the measurements of the triangles. To validate the analysis of the results, the response of group 1 is presented, as shown in Figure 3 below.

Figure 3 - Group 1's answer to question 5



Source: Research Protocol

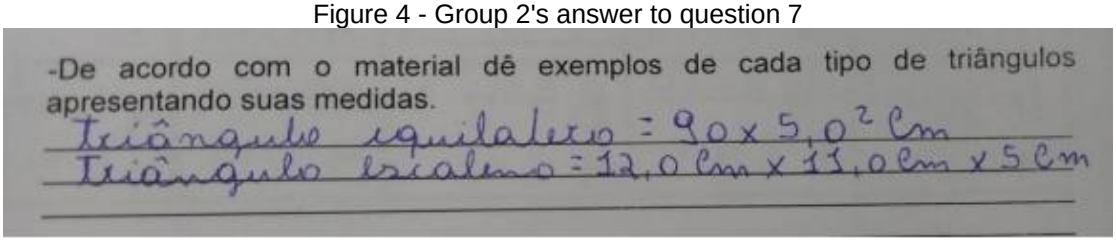
In this question, students are asked to measure the triangle-shaped figures that were delivered and record their measurements. Group 1 drew the triangles and placed their measurements on the corresponding sides, while group 6 placed the measurements and determined each triangle by its color. Both groups responded satisfactorily to the activity.

The answers explained above reveal that when using the pedagogical resource in the teaching of Plane Geometry, these resources provide the student with the possibility of having a more pleasurable learning and a greater participation in mathematics activities. In this sense, we agree with Nogueira (2017) when he mentions that "geometry is one of the branches of mathematics that can stimulate interest in learning this science, as it can reveal the reality that surrounds the student, giving opportunities to develop creative skills" (Nogueira, 2017, p. 3).

In the next question, students are asked to present the types of triangles found in the materials delivered and how they came to this conclusion. Group 1 answered that they would be the "scalene triangle, because it has all its different sides" and also the "isosceles triangle, because it has two equal sides and one different". It is noticed when analyzing the answers found in the research protocols that group 1 can indicate the names of the triangles according to their characteristics, however, other students did not present a detailed view of Plane Geometry, because even recognizing a triangle cannot differentiate them. In this sense, Pais (2006) reports that "it is not enough to impose content without respecting differences, just as it is not enough to deal with differences without paying attention to the historical references of knowledge." (p. 21). This fact can be observed in the response of group 3, when an "incomplete" knowledge of the content is verified.

In question 7, each group was asked to write examples of objects similar to the figures in the triangles delivered and to indicate the real measurements. It can be seen from the data obtained that the answers do not fully adapt to what was requested, as illustrated n the answers of group 2, according to Figure 4 indicated below.

Figure 4 - Group 2's answer to question 7



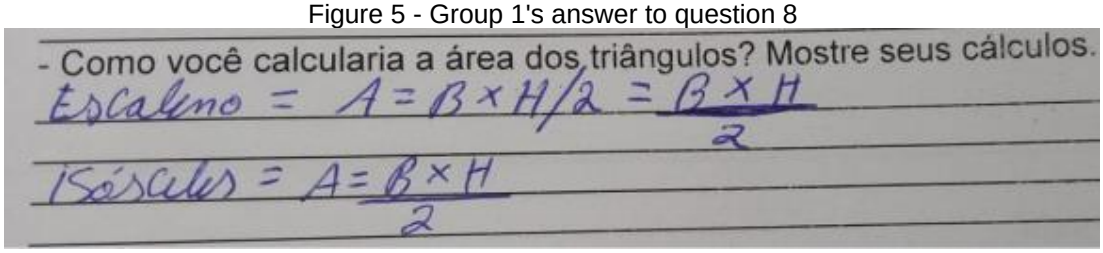
Source: Research Protocol

As can be seen above (Figure 4), group 2 interpreted the question in a non-proposed way by naming triangles and their measurements, not citing examples of objects. On the other hand, group 1 interpreted the question in an expected way, since they were able to cite objects in their environment, but did not cite their measurements, as shown in figure 14.

Nogueira (2017), "considers that geometry is a very important tool for the description and interrelationship of man with the space in which he lives" (p. 3). In this sense, this aspect emphasizes the importance of observing mathematics in everyday life, with this it is understood that mentioning triangular objects, as requested in the question, would show the vision of geometry in everyday life. Thus, it was found that group 1 was able to visualize and cite examples effectively, thus contemplating a geometric view in everyday life.

In question 8, the students were asked to think and write how they would calculate the area of the triangles that were delivered, we noticed that there is a divergence of understanding between them, regarding the notions of area of a triangle. To evidence the results, the response of group 1 is indicated, as shown in Figure 5 below.

Figure 5 - Group 1's answer to question 8



Source: Prepared by the authors

As can be seen, group 1 was able to associate what was requested, placing the formulas for calculating the area of triangles that exemplified even the types of triangles, scalene and isosceles, as shown in figure 5. On the other hand, when analyzing the response of group 5, it was possible to identify that they should use a ruler to measure the "tips" of each triangle.

The answers found in the study show the lack of understanding of the geometric concepts related to the figures. Silva (2019) considers that "geometry is taught by knowledge that focuses on the education of the child's hand and sight, not only by observation.", (Silva, 2019, p. 377). This fact shows that the geometric concepts learned in

the classroom must start, not only from what the student sees, but also through manipulation.

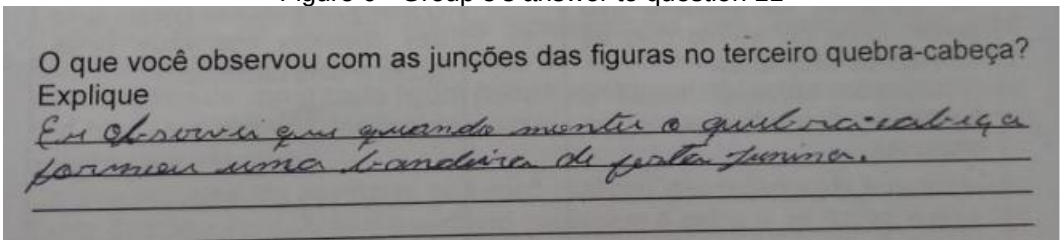
In the ninth question, the students were asked to determine what they observed in the assembly of the first puzzle. For the analysis of the students' answers, the answer of group 5 stands out, which observes that when assembling the puzzle "it formed a BOAT". In turn, group 1 named the figure by its type, "a trapeze". In the answers obtained, it is verified that each group used its own perception to evidence what it understood, revealing the experiences lived with the geometric figure.

In the tenth question, it was established that the students determined what they observed in the assembly of the second puzzle. In the analysis of the answers reached, group 5 stands out when it indicates "I observed that when I assembled the puzzle it formed a kite". Again, from the answers analyzed, it is possible to identify that each group used its own perception to evidence what it understood.

In the two initial questions of this 2nd block, the answers show two types of perception of the groups for the determination of the figures. Group 5 sought a more informal view, pointing out that the figure is similar to an object they know, while group 1 knew how to correctly point out which geometric figure the mounted figure refers to. According to Pais (2006) "the diversity of the room shows different levels of reasoning, observation, argumentation, analysis, communication of ideas, formulation of hypotheses, memorization and teamwork" (p. 21). It can then be seen that from this perspective, group 5 sought in their reality something that could point to their answer.

In the eleventh question, the students were asked to explain what they had observed about the joining of plane figures, and to validate this analysis, the answer of group 1 was used, as illustrated in Figure 6 below.

Figure 6 - Group 5's answer to question 11



Source: Research Protocol

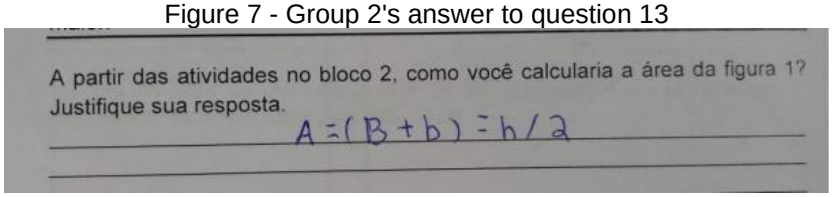
As can be seen, group5, as well as other groups, had the same perception about the junction of the plane figures, that is, they perceived that the figure formed by others resembles a June festival flag as shown above. It is noted that visual interpretation can be influenced by things similar to everyday life. In addition, it is important to stimulate the

student's imagination, allowing students to make a perception when it comes to mathematical content, which enables a broad view within other areas of knowledge. Pais (2006) states that to encourage the student to practice mathematics, it is important to take advantage of all the pedagogical moments to involve him with the concepts, in this aspect, it can be observed for this issue that the students compare the geometric figure with a June party flag.

In the next question, the students are asked about what they had observed in relation to the joining of figures in block 2, and they are asked to explain their answers. Group 3 mentions "we note that a plane figure can be formed with the junction of other plane figures and we notice that if we add the areas of the smaller figures, we find the area of the larger figure". In turn, group 6 perceived the importance of the concept for teaching and learning and answered that it was very important for development.

With regard to block 3 of activities, in the thirteenth question, it was asked how they would calculate the area of the figure of block 2 of activities, followed by a justification for the answer provided. To confirm these analyses, the responses of group 2 are highlighted, as shown in Figure 7.

Figure 7 - Group 2's answer to question 13



Source: Research Protocol

From the answer above, it can be inferred that group 2 answered according to what was requested, as they used the trapezoid area formula) to answer the question, while group 5 ended up confusing the calculation of the trapezoid area with the calculation of the area of a polygon formed from the junction of other plane figures. Therefore, it is important to emphasize the use of formulas to calculate the area of each geometric figure, as each plane figure has a specific formula for its area calculation.$((B + b).h/2$

Consequently, based on block 2 of activities, the students were asked to calculate the area of the indicated figure and justify their answer. In the answer of group 1, the students indicate appropriately that "they would divide the figure with 3 elements, using 2 triangles and a rectangle, calculate the areas of each one and add the results". Group 6, on the other hand, used only numbers that were not related to the parallelogram area calculation.

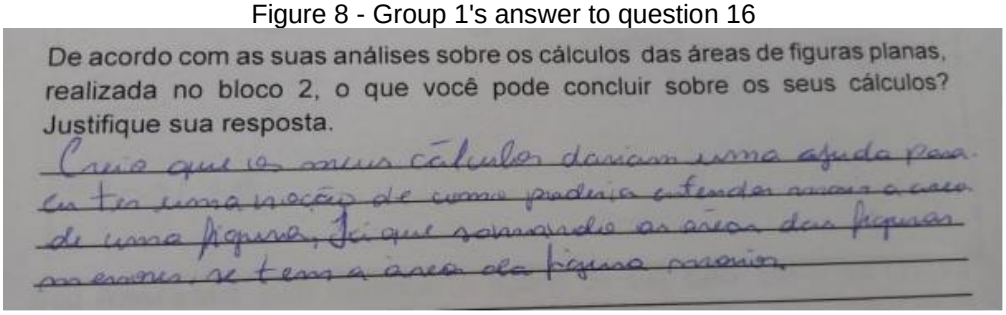
In this question, also based on block 2 of activities, the students were asked to calculate the area of the figure, represented by a non-conventional figure, and to justify their

answer. Group 1 answered that they would divide the figure into 3 plane figures, better known as triangles and rectangle, as they fit within the concept of area of plane figures, and thus would answer the question according to what was asked. In turn, group 3 answered that they would multiply the base by the height.

In these two questions, it was observed that the answer of group 1 is more appropriate to the context, on the other hand, the answer of group 3 does not meet what was requested, but they created ideas to calculate this area. Therefore, it can be inferred that the group 1 answer is a way to solve the area calculation of unconventional plane figures, it is very important to have creativity and flexibility to solve mathematical problems. As Nogueira (2017, p. 4) states, "the teaching of geometry should be focused on open problems (with more than one answer and/or with different forms of resolution), with a dynamic character, which provide a process of search and investigation to solve them".

Moving forward with the verification of the questions, the students were asked to point out their conclusions about the calculations made in block 2 of activities and justify their answers. To validate the results, the responses of groups 1 and 3 are obtained, as shown in Figure 8 below.

Figure 8 - Group 1's answer to question 16



Source: Research Protocol

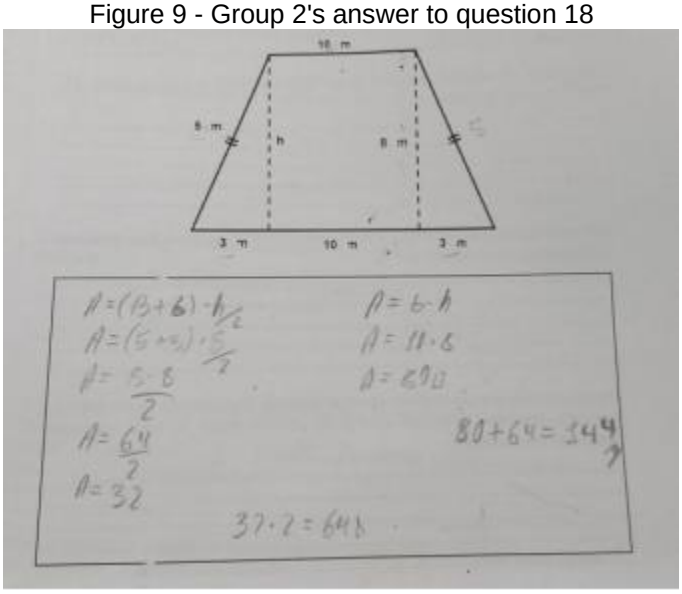
When analyzing the answers of the investigated students, it is noticed that group 1 demonstrated more knowledge about the calculation of the area of plane figures, as they know about the relation of the sum of the smaller figures to find the larger area. Group 3, on the other hand, could not identify the relationship with the subject, nor did they know how to answer the question. This fact reinforces the need to teach area calculation, as it is very important for the teaching of Geometry. For this, Oliveira (2020) states that through the construction of geometric figures with manipulable materials, we study all the concepts of the figure, which stimulates the interest and motivation of students, providing them with geometric and mathematical reasoning. From this, it is observed that with the help of these materials, group 1 was able to identify a way to answer the question.

In the seventeenth question, the students were asked to explain what they understood by the area of plane figures. To this question, group 3 presented as an answer

"a plane figure can be formed by joining the plane figures", revealing their knowledge about area calculation. It is of great value to emphasize the importance of calculating the area of certain plane figures such as squares, triangles, rectangles, among others, because from the calculation of the area of these figures it becomes more feasible to calculate the area of other figures, such as: trapezoids, parallelogram, etc. The answers obtained show the way in which the interpretation of the question was made by each group, in this sense the point of view of Pais (2006) is evidenced when he indicates the importance of valuing strategies by which the student can do mathematics, which implies identifying action schemes specific to his reasoning.

Continuing with the analysis in question number eighteen of block 3 of activities, the students were asked to calculate the area of a plot of land that was divided into triangular, rectangular and quadrangular parts. To validate these results, the response of group 2 is highlighted, shown below in Figure 9, relatively.

Figure 9 - Group 2's answer to question 18



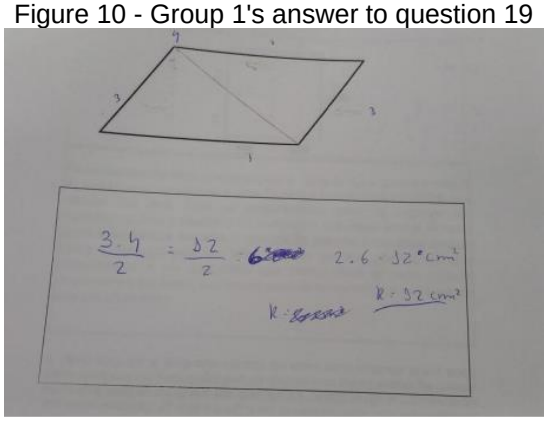
Source: Research Protocol

When analyzing the answers, it was found that group 3 correctly used the trapezius formula to answer the question according to what was requested. In turn, group 2 divided the figure into three parts, two triangles and a rectangle, they solved the area of the rectangle correctly, but they confused the formula when solving the area of the triangles, because they used the trapezoid formula to solve the area of the triangles. So only group 3 answered according to what was requested.

Continuing with the analyses, in the last question of block 3 of activities, the students were asked to calculate the area of a kitchen in the shape of a parallelogram, divided into 2

triangular parts. To authenticate this analysis, the response of group 1 was used, shown below in figure 10.

Figure 10 - Group 1's answer to question 19



Source: Research Protocol

From the answers found, it can be inferred that group 1 solved the question by means of the direct formula of the parallelogram, thus correctly answering the question (Figure 10). Group 3, on the other hand, tried to solve the question through the trapezoid formula and ended up getting the question wrong, this fact may have occurred due to confusion in the use of the formulas or even because they did not know how to use it.

The answers obtained by the investigated groups in the last two questions reinforce the need for it to be important to have a more correct view of Geometry and how there are differences in the perceptions of how to solve questions. From this perspective, we consider the point of view of Silva (2019) when he elucidates that the teacher's professional knowledge is based on the formulation of questions that encourage the student to identify characteristic properties of the figures. In this way, the intention is to lead students to observe and compare measurements.

The following section indicates the final considerations of the present study.

FINAL CONSIDERATIONS

The research carried out aimed to verify the contributions of a didactic sequence to the teaching and learning process of Plane Geometry. This aspect is relevant when considering that the teaching of this content often faces challenges, such as the difficulty of abstraction and spatial visualization of students.

When analyzing the results of this research, some divergences are noticed in the answers of some groups, but we can notice that some answers were very similar. In the analysis of the results, what drew a lot of attention was the way the groups answered the questions, for example, in a question about how they would calculate the area of the

quadrilaterals, one group put it directly, that is, they just wrote how they would calculate, but another group made the drawings and presented their calculations.

It is worth noting that all groups were able to respond when asked to cite examples of everyday objects that were similar to flat figures, which made them think about how they are surrounded by geometric figures in their daily lives, also helping in the interaction and communication of the groups.

Regarding the potential of using a didactic sequence, the motivation of the students, group participation, critical thinking, and the stimulation of learning are evidenced. Other aspects that deserve to be highlighted were the inequality in learning, the limitation of concepts and time, because some students have more skills to develop this type of activity than others, but among the points mentioned were only issues of the daily life of each student, but in the course of the work with some adjustments it was possible to achieve the objective of the research.

Therefore, a well-structured didactic sequence with questions and appropriate language can contribute satisfactorily in the school environment. In addition, the didactic sequences lead students to come up with new concepts in view of what they already knew about the subject, thus being able to advance knowledge effectively.

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