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GeoGebra *Software* as a tool for the construction and projection of prisms parallel to the projection planes

O *Software* GeoGebra como ferramenta para a construção e projeção de prismas paralelos aos planos de projeção

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ABSTRACT
This article is part of a study that aimed to demonstrate, using the GeoGebra software, the representation and projection of prisms in projection planes or in planes parallel to these, in a group of 40 students from Grade 11 in the option of Physical and Biological Sciences at Liceu do Bembe (Uíge-Angola). To achieve this objective, a bibliographical review was carried out in materials related to information and communication technologies in teaching, where concepts were extracted that served as prerequisites. In addition, through action research, activities were carried out in the institution's computer room using the GeoGebra software, with the questionnaire as the main instrument for data collection. From the results obtained and the students' satisfaction in the activities developed, it is concluded that the GeoGebra software is a practical and attractive resource that develops spatial visualization skills and can contribute to the teaching-learning process of Descriptive Geometry. Therefore, it is expected that, with this research, the GeoGebra software will be used as an ally of conventional means, as it enables the realization of practical activities, based on problem solving, making the student the protagonist of the learning process.

Keywords: Descriptive Geometry, Prism, Projections, GeoGebra Software, Information and Communication Technology.

RESUMO
Este artigo é recorte de um estudo que objetivou demonstrar por meio do software GeoGebra a representação e projeção de prismas em planos de projeções ou em planos paralelos a estes, num grupo de 40 alunos da 11ª Classe na opção de Ciências Físicas e Biológicas no Liceu do Bembe (Uíge-Angola). Para o alcance deste objetivo, realizou-se uma revisão bibliográfica em materiais relacionados as tecnologias de informação e comunicação no ensino, onde extraíram-se conceitos que serviram de pré-requisitos. Além disso, por meio da investigação-ação as atividades foram realizadas na sala de informática da instituição

utilizando o software GeoGebra, tendo como principal instrumento de recolha de dados o questionário. Pelos resultados obtidos e a satisfação dos alunos nas atividades desenvolvidas, conclui-se que o software GeoGebra é um recurso prático e atrativo que desenvolve habilidades de visualização espacial podendo contribuir para o processo de ensino-aprendizagem da Geometria Descritiva. Por isso espera-se que, com esta pesquisa o software GeoGebra seja utilizado como aliado dos meios convencionais, pois possibilita a realização das atividades práticas, com base na resolução de problemas, tornando o aluno protagonista do processo de aprendizagem.

Palavras-chave: Geometria Descritiva, Prisma, Projeções, Software GeoGebra, Tecnologia de Informação e Comunicação.

1 INTRODUCTION

Descriptive Geometry has contributed to the achievement of the general objectives of the young generation through the use of specific means of Mathematical science. In order to achieve the objectives, methodological innovations have been sought that make it possible to mediate between Mathematics and the student, so that knowledge is significant, that is, it contributes effectively to improving the quality of the student and, therefore, of society. It is in this dynamic that point 3 of article 2 of the Basic Law of the Education and Teaching System of Angola, defines:

> The Education and Teaching System is the set of structures and modalities, through which the educational process is carried out, tending to the harmonious and integral formation of the individual, with a view to building a free, democratic society, of law, peace and social progress. (LEI-Nº17/16, October 7, 2016, p. 3994).

Descriptive Geometry is one of the subjects that constitute the curriculum reform and the foundation of the general education of engineers. The teaching-learning process of descriptive geometry has proved to be very difficult because only conventional means have been used. From the current social and cultural point of view, changes in teaching must confer new educational mentalities, more adapted to Information and Communication Technologies (ICT) through educational *software*, including *GeoGebra*, which has helped students in learning the subject in question.

having regard to the purposes of the Education and Teaching System, Article 4(a) of the Basic Law (LEI-Nº17/16, October 7, 2016)describes that the Education and Teaching System shall:

> (a) To develop harmoniously the intellectual, occupational, civic, moral, ethical, aesthetic and physical capacities, [...] especially of young people, in a continuous and systematic manner and to raise their scientific, technical and technological level in order to contribute to the socio-economic development of the country.

And in relation to the specific objectives of the II cycle of General Secondary Education, article 33 (a) and (g) of the same Law (LEI-Nº17/16, October 7, 2016)describe that the Education and Teaching System must (a) ensure a solid and in-depth training in a given area of knowledge and (g). favor the orientation and vocational training of young people, through technical and technological preparation, with a view to entering the world of work;

In a study on *Geogebra* educational *software* in Angola, Van-Dúnem (2016) points out that:

> The interests of the Ministry of Education in Angola regarding the inclusion of digital technologies as a cognitive tool in the educational process, have been developed in recent years, digital environments in schools with technological equipment, which allow meaningful and active learning for students. The use of *Geogebra software* allows the development of skills inherent in critical and creative thinking. (VAN-DÚNEM, 2016, p. 19).

That is why, although there is some variety of educational *software* dedicated to the teaching of Descriptive Geometry, in this research *GeoGebra* was chosen because it has didactic characteristics and because it is an attractive tool that facilitates the student's understanding, making and visualization of figures.

One of the goals of Descriptive Geometry is to transpose the spatial image of an object into a two-dimensional representation, however, according to some students, the lack of clear and evident visualization of the figure is the main difficulty of the whole process. Transposing objects, representing them in a two-dimensional way, is a difficult barrier to overcome as well as the visualization of these objects in projection planes. In view of these difficulties, the following question was raised: in Angola in general and in particular at the Liceu do Bembe School between teaching mediated by *GeoGebra* and teaching mediated only by conventional means, which one guarantees greater effectiveness the representation and projection of prisms in projection planes or in planes parallel to them?

Unfortunately, the teaching of this theme has shown several difficulties because it is mostly stuck in traditional teaching, where the student and the teacher work only with objects in the two-dimensional plane, studying the relationship of these three-dimensional objects. This method naturally requires a very large degree of abstraction for the understanding and consequent manipulation of these objects in space, as described by Alves (2012):

> [...] the difficulty lies partly in the teaching methodology used, which starts from abstraction and a code rather than from "reality". In other words, it lies in the inadequacy of the methodologies used, which do not allow the student to develop the capacity for spatial reconstruction, based on his understanding at the level of two-dimensionality and vice versa. Most students show greater difficulty with regard to the passage of the spatial object to the two-dimensional representation, because they have not yet mastered the representation code (ALVES, 2012, p. 14).

On the same theme, Quimuanga and Dominguez (2021) state that the teaching-learning process of Descriptive Geometry is carried out only with conventional means. Still the same authors describe that, in some Angolan schools, there are teachers who use their creativity seeking within the possibilities, with conventional means, to project on the board or manufacture models that facilitate visualization.

But the identification of three-dimensional objects is not always clear to students when using only conventional means, as Alves points out (2012)As Alves (2012) points out, the student needs to see objects in different spatial positions and the combination of several three-dimensional models in line with their handling does not always allow a clear and explicit view.

However, it is noted that there is a need to experiment with another methodology in the teaching of Descriptive Geometry (GD), subject to stimulate better learning and understanding of its concepts. Still Alves (2012) states that it is important that the discipline of DG captures the attention of students and develops their spatial vision. For this, it is important to have an attractive methodology that favors the participation of students, through learning by doing.

According to Oliveira (2016, p. 12)"technologies contribute greatly to communication and interaction between people, especially between students and teacher in the classroom". For Van-Dúnem (2016)in education, information and communication technologies allow a deep understanding of the world, enriching knowledge.

Based on Van-Dúnem's idea, it is argued that it requires persistent teachers in research and trained for the development of educational methodologies with the use of technology as described by Silva (2017)In addition to the above, it requires prepared professionals, willing to research and innovate and, above all, convinced of the importance of school education for digital and social inclusion. It is still perceived that applying technology in teaching is to engage in new discoveries, to update and create an innovative pedagogical path.

Still on ICTs in Angola, the purposes of the Teaching and Education System, article 4 (a) of the Basic Law (LEI-Nº17/16, October 7, 2016)describes that the Teaching and Education System should:

> (a) To develop harmoniously the intellectual, occupational, civic, moral, ethical, aesthetic and physical capacities, [...] especially of young people, in a continuous and systematic manner and to raise their scientific, technical and technological level [emphasis added], in order to contribute to the socio-economic development of the country.

And in relation to the specific objectives of the II cycle of General Secondary Education, paragraph g) of article 33 of the same Law No. 17/16 of 7 October describes that "the Education and Teaching system must favor the orientation and vocational training of young people, through technical and technological preparation, with a view to entering the world of work" (LEI-Nº17/16, October 7, 2016).

It is noted that the executive has been showing great interest in the development of ICTs in Angola as well as their insertion in teaching, an aspect that brought the incentive of this research to use educational *software* in Mathematics classes in particular Descriptive Geometry.

For Silva (2017)the study of the computer in the teaching of mathematics, as a way of innovating traditional resources, has been affirmed as one of the most active and relevant areas of mathematics education. Therefore, new technologies for teaching do not appear as substitutes for traditional strategies, but as complements to them, that is, they have come to add and revolutionize teaching, as Alves (2012). (2012)emphasizes that the purpose of teaching resources is to mediate the transmission of knowledge between teacher and student.

Didactic resources such as educational *software*, arise to enrich and streamline the teaching-learning process, a more fun, more attractive learning. In this perspective, Santana and Silva (2017)say that educational *software* is understood as a program that serves educational purposes by meeting pre-established educational objectives. The form of application of this *software*, however, will depend on the target audience, context of this audience, objectives of the teacher and available resources.

In Geometry, educational *software* serves as tools to develop visualization skills among others, facilitating the movement of figures, an aspect that involves more students with the discipline, with the contents, with a more facilitated and fun learning. As Almeida reports (2014)According to Almeida (2014), educational *software is* developed as resources that seek to attract the attention of students, while leading to a meaningful learning of the contents present in the game and the teacher is called to embrace the challenges of globalization, because the insertion of technologies in teaching, the teacher assumes the role of mediator of the interaction between student, knowledge and computer.

Realizing this, the incentive came to appropriate the potentialities available in *GeoGebra* for the representation of prisms in planes of projections or in planes parallel to them because as Quimuanga and Dominguez (2021) point out, *GeoGebra software* is a practical, dynamic and attractive resource that can break paradigms in order to transform the student into an increasingly active agent, thus improving the quality of the teaching-learning process of Descriptive Geometry.

GeoGebra is a free dynamic mathematics *software* (see https://www.geogebra.org/?lang=pt) created in 2001 by Markus Hohenwarter, from the University of Salzburg, located in Austria as part of his master's thesis, which allows the construction of various geometric objects, such as points, vectors, segments, lines, conic sections, graphs representing functions, among others, which can be dynamically modified (Martínez, 2017). (MARTÍNEZ, 2017).

For Silva (2017)the term dynamic geometry refers to the use of interactive *software* that favors environments where you can move objects, allowing you to modify the figures while preserving their original geometric relationships.

In the teaching of Descriptive Geometry mediated by the *GeoGebra software*, one of the problems detected is related to the coordinates of the point, as Souza (2017) describes that:

> [...] in relation to the coordinates of the point, which in Descriptive Geometry, has all the positive coordinates on the first dihedral, in particular, the distance, however in the projection plane developed in *GeoGebra*, the coordinate "distance", represented by the axis "y", has the opposite sign,

> so, given a point $A = (x, y, z)$it must be represented in *GeoGebra in* the coordinates $A = (x, -y, z)$. However, it is important to emphasize that this problem becomes insignificant in view of the other potentialities of this resource. (SOUZA, 2017, p. 20)

On the other hand, if a point has only two coordinates, i.e, $A = (y, z)$ when entering it in the input field, three coordinates are entered which are considered to be abscissa equal to zero, i.e. it will be entered with the following coordinates $A = (0, -y, z)$.

The representation of geometric solids in general and in particular prisms in projection planes or in planes parallel to them, is a content addressed in Descriptive Geometry specifically in Grade 11 that using only traditional means raises enormous difficulties both in construction and visualization.

2 OBJECTIVE

Demonstrate through the *GeoGebra software* the representation and projection of prisms in projection planes or in planes parallel to them.

3 METHODOLOGY

It is a qualitative study of an applied nature (ZANELLA, 2013) which sought to generate knowledge about *GeoGebra software* for its application in the representation and projection of prisms in projection planes or in planes parallel to them.

In order to achieve the objective, a bibliographic consultation was carried out to understand the way in which the *GeoGebra software* influences the teaching-learning process of Descriptive Geometry. After the identification of the problem and the survey of the bibliography that theoretically supported this research, a set of activities was carried out in the classroom as well as in the computer room, in order to stimulate the active participation of the students of the 11th Class of the Liceu do Bembe for the teaching of Descriptive Geometry with the aid of the *GeoGebra software*.

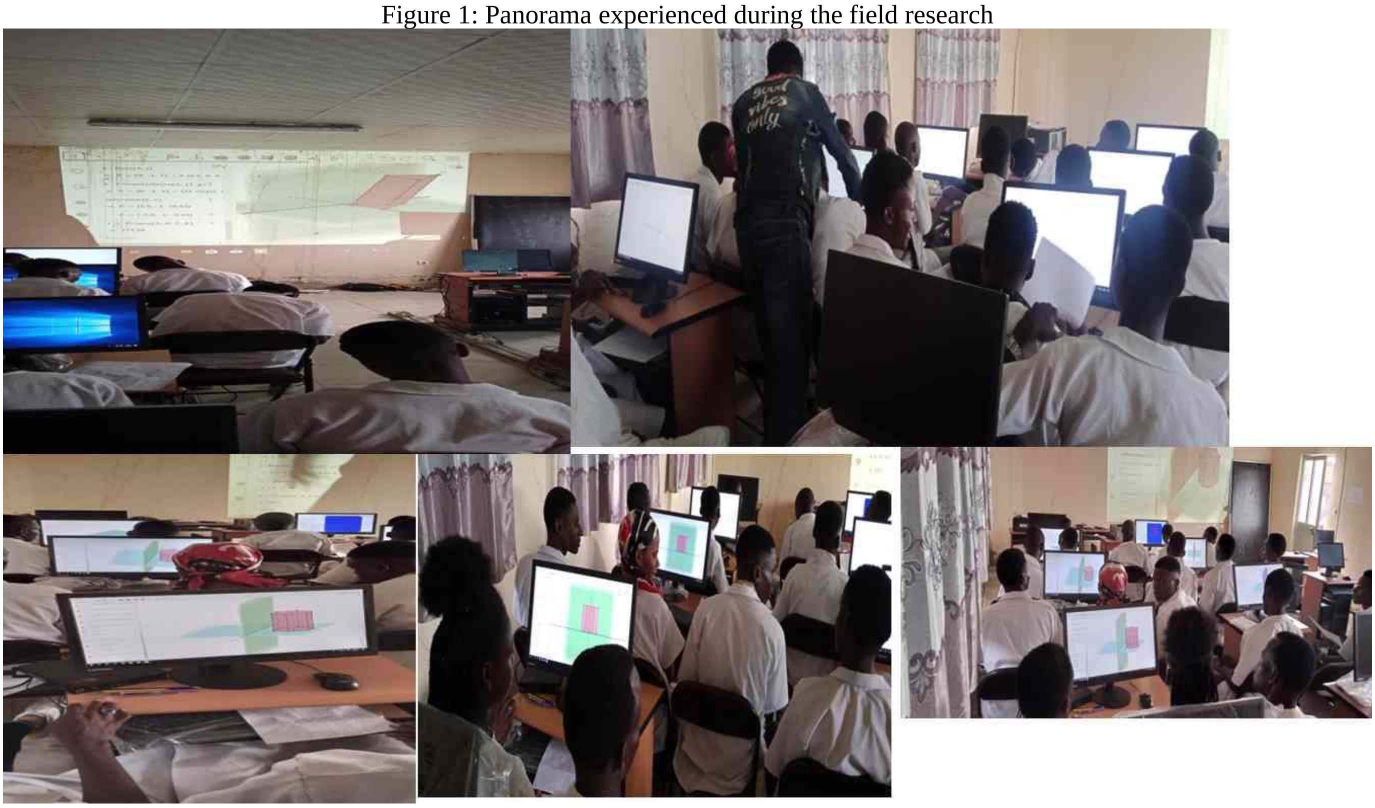
The Liceu do Bembe is a public secondary school, created under Executive Decree No. 53/020 of November 27, located in the Municipality of Bembe in the Province of Uíge (Angola), consisting of 12 classrooms and 4 offices for the operation of the school administration, as well as 10 changing rooms (bathrooms) for the working staff. The school has a maximum capacity of 864 students, as it operates in 2 distinct periods (morning and afternoon), with each of these periods having a capacity corresponding to half of the total capacity referenced above.

The activities were carried out in the institution's computer room and for data collection, a questionnaire composed of closed and open questions was applied, which was directed and answered by the students of the 11th Class of Liceu do Bembe. The closed questions had the objective of standardizing and standardizing the data, since each question has alternative answers that correspond to the local reality of the student. While the open questions were intended to collect more information regarding opinions on the use of *GeoGebra software* for teaching Descriptive Geometry.

4 DEVELOPMENT

The activities were carried out in the school's computer room where unfortunately some students were grouped two by two because the number of students was slightly higher than the number of computers available. For the students who were grouped two by two, permutations were made during the realization of the projections so that everyone had the possibility to handle the computer. Initially, the *GeoGebra software* was installed on all computers and through the overhead projector they were presented with the *GeoGebra* work environment and all its windows with greater emphasis on the 3-dimensional visualization window (JV3D) which was the area of practical application of the research. The figure below shows some moments of the work in the field.

Figure 1: Panorama experienced during the field research



Source: Kindness of the class teacher

Thus, taking into account the potential of *GeoGebra* tools, students' skills were strengthened because it favors learning. The activities with *GeoGebra software* were carried out in the 3-dimensional visualization window (JV3D) with the aim of increasing the ability to visualize geometric solids in a clear and evident way so that there are no doubts about the figure presented in different positions, as well as in different views.

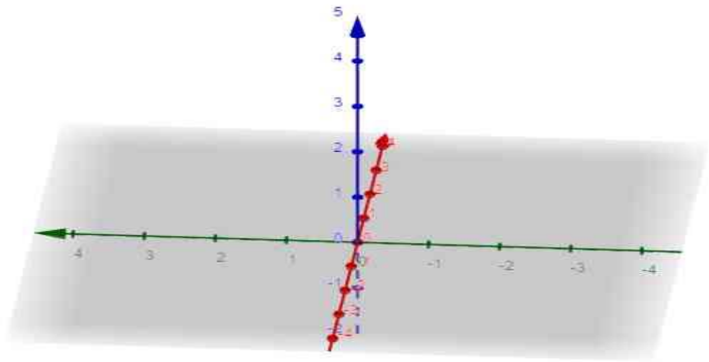
On the other hand, each activity developed was projected on the board and the step-by-step resolution was presented in an expository-practical, interrogative and individualized way (taking into account the degree of understanding of each student).

The step-by-step described here serves to guide potential readers of this article so that they can understand and execute on the same guidelines.

Exercise 1: Draw the projections of a hexagonal prism that is 6 cm of height, knowing that: the base **[LMNOPQ]** is on the horizontal plane of projection and has two lateral faces facing each other; the edges of the bases measure 3 cm; the axis of the prism is 5 cm of distance.

Resolution of exercise 1: To perform all activities, it is essential to position the coordinate axes of the 3D visualization window as follows:

Figure 2: Position of the coordinate axes in GeoGebra



Source: Author of the paper

So, with the computer on and the *GeoGebra* window open, using the 3D visualization window, the resolution proceeds as follows:

Step 1: trace the projection planes, inserting in the field of entry $z = 0$ for horizontal projection plane (plane xoy) e $y = 0$ for the frontal plane of projection (plane xoz). And for better visualization, change the color with a right click on the respective plane, select in configuration and then in color. Then choose the desired color and close the dialog box.

Step 2: With the "Intersection of two surfaces" tool, select the horizontal projection plane and the frontal projection plane.

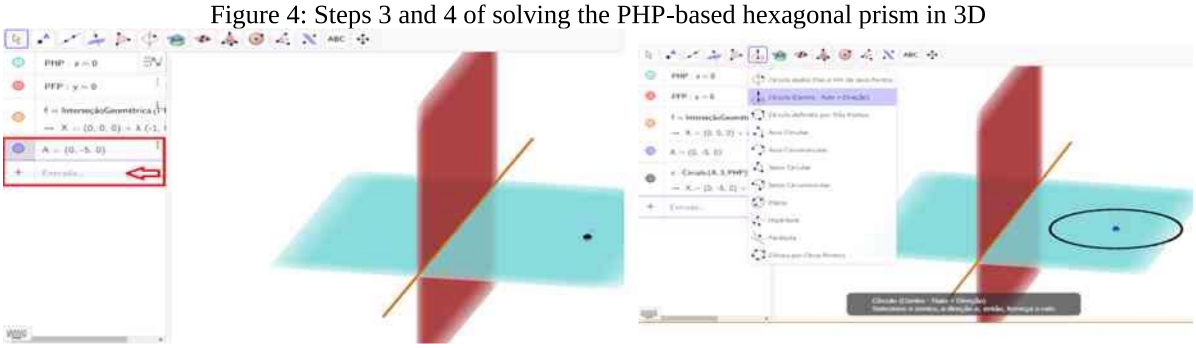
Figure 3: Steps 1 and 2 of solving the PHP-based hexagonal prism in 3D

Source: Author of the paper

Step 3: enter in the input field the point $(0, -5, 0)$ corresponding coordinates of the axis of the prism being center of the hexagon.

Step 4: With the "circle (center-radius+direction)", select respectively point A and horizontal projection plane, finally mark the radius of 3 cm (the measurement of the side of the base is the same as the radius).

Figure 4: Steps 3 and 4 of solving the PHP-based hexagonal prism in 3D

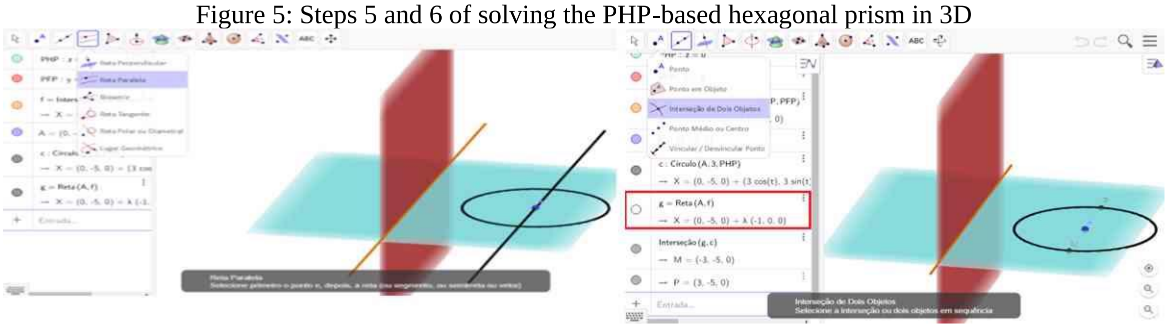


Source: Author of the paper

Step 5: With the "Parallel Line" tool, select point A and the line of intersection between PHP and PFP respectively.

Step 6: With the "intersection of two objects" tool, select the line passing through point A and the circle and then activate invisibility on the line.

Figure 5: Steps 5 and 6 of solving the PHP-based hexagonal prism in 3D

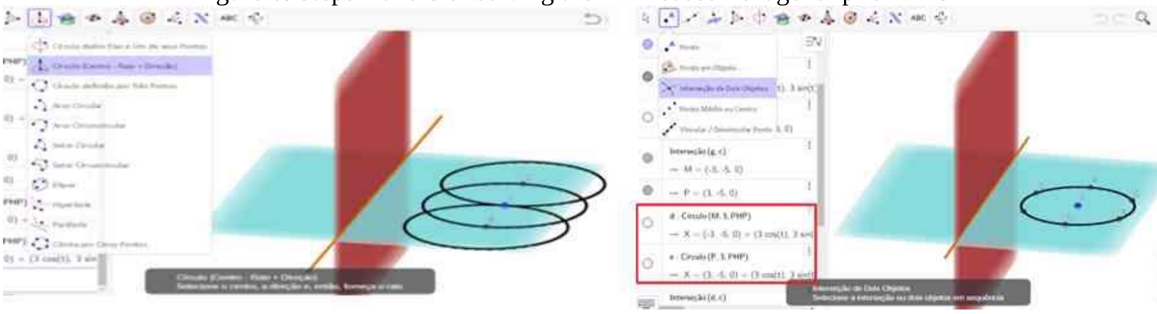


Source: Author of the paper

Step 7: With the "circle (center-radius+direction)", draw two circles of radius 3 cm with center respectively at points M and P, with direction at PHP.

Step 8: With the tool "intersection of two objects" select the first circle with the circle of center B and the first circle with the circle of center C, determining points. At the end activate invisibility on the last two circles.

Figure 6: Steps 7 and 8 of solving the PHP-based hexagonal prism in 3D

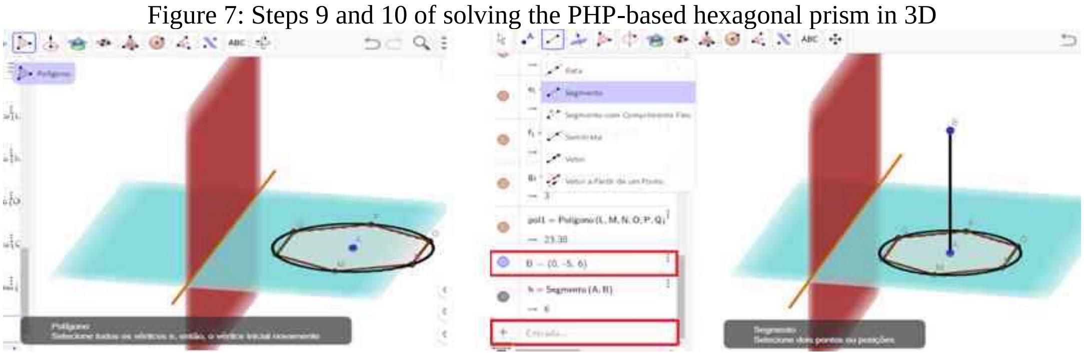


Source: Author of the paper

Step 9: With the "Polygon" tool select all the vertices contained in the circle and again return to the initial vertex.

Step 10: Since the height of the prism is 6 cm, in the input field enter the coordinate point $(0, -5, 6)$. And with the "segment" tool select point A with point B obtained earlier determining the axis of the prism.

Figure 7: Steps 9 and 10 of solving the PHP-based hexagonal prism in 3D

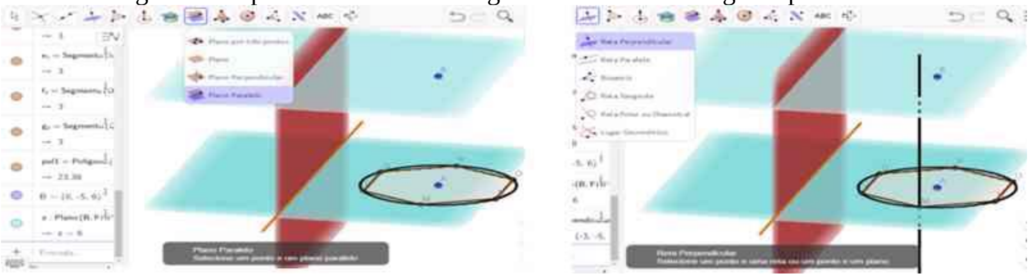


Source: Author of the paper

Step 11: With the "parallel plane" tool, select the horizontal projection plane (PHP) and point B.

Step 12: With the "perpendicular line" tool, select point M and plane parallel to PHP.

Figure 8: Steps 11 and 12 of solving the PHP-based hexagonal prism in 3D

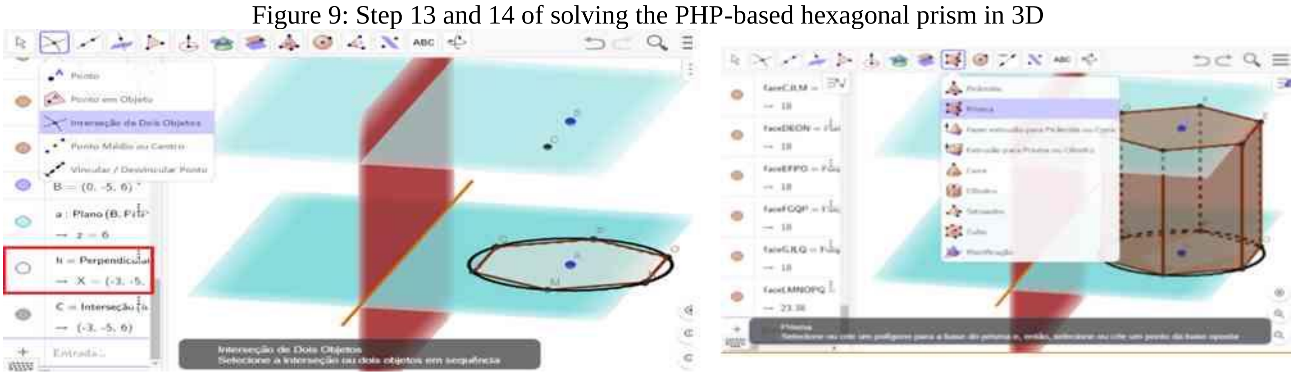


Source: Author of the paper

Step 13: With the tool "intersection of two objects" select the plane parallel to the PHP and the perpendicular line. Then the invisibility on the line perpendicular to the PHP.

Step 14: With the "Prism" tool, select the vertices of the base (starting from vertex M), returning again at the initial vertex and at the end select point higher than the point selected initially.

Figure 9: Step 13 and 14 of solving the PHP-based hexagonal prism in 3D



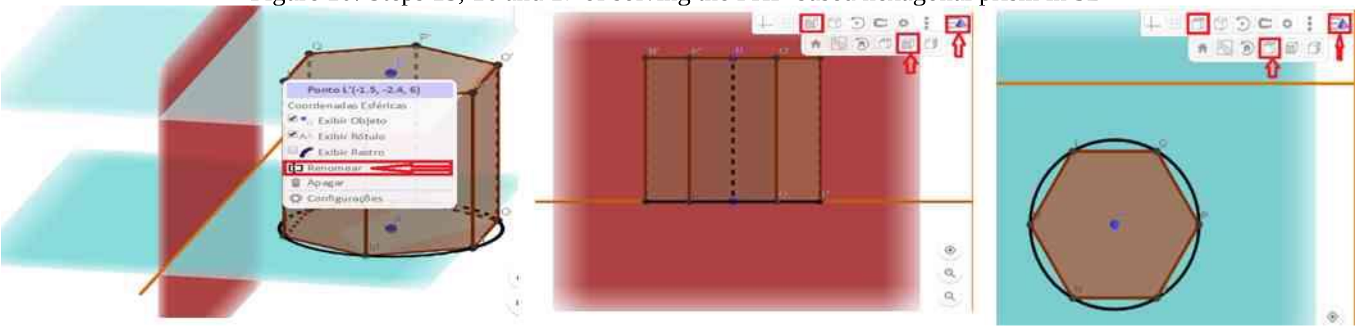
Source: Author of the paper

Step 15: Rename the points, those of the lower base by **[LMNOPQ]** and those of the upper base by **[L'M'N'O'P'Q']**, by right clicking on each of the points.

16th step: click on the top corner of JV3D then properties of this window will appear, click on views, from there select the front view.

17th step: click on the top corner of JV3D then properties of this window will appear, click on views, from there select the top view.

Figure 10: Steps 15, 16 and 17 of solving the PHP-based hexagonal prism in 3D



Source: Author of the paper

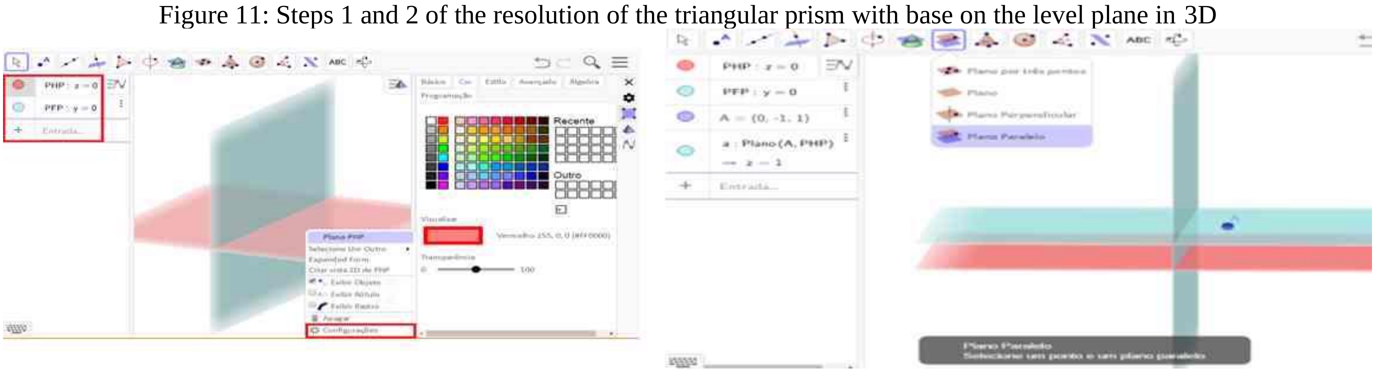
Exercise 2: An oblique triangular prism is located on the first dihedral of projection and rests with one of its bases on a level plane with elevation equal to 1 cm. The bases are equilateral triangles of side 6,5 cm side and the leftmost side is the top and its end is closest to φ_0 distances from this 1 cm. The lateral edges are facing, make with ν_0 angles of 60º opening to the right and measure 11 cm.

Solving exercise 2: with the computer on and the *GeoGebra* window open, using the 3D visualization window, the resolution proceeds as follows:

Step 1: draw the projection planes, inserting in the field of entry $z = 0$ for horizontal projection plane (plane xoy) e $y = 0$ for the frontal plane of projection (plane xoz). And for better visualization, change the color with a right click on the respective plane, select in configuration and then in color. Then choose the desired color and close the dialog box.

Step 2: enter in the input field the coordinates $(0, -1, 1)$determining point A. And with the tool "Parallel plane" select the point A (entered previously) and the PHP.

Figure 11: Steps 1 and 2 of the resolution of the triangular prism with base on the level plane in 3D

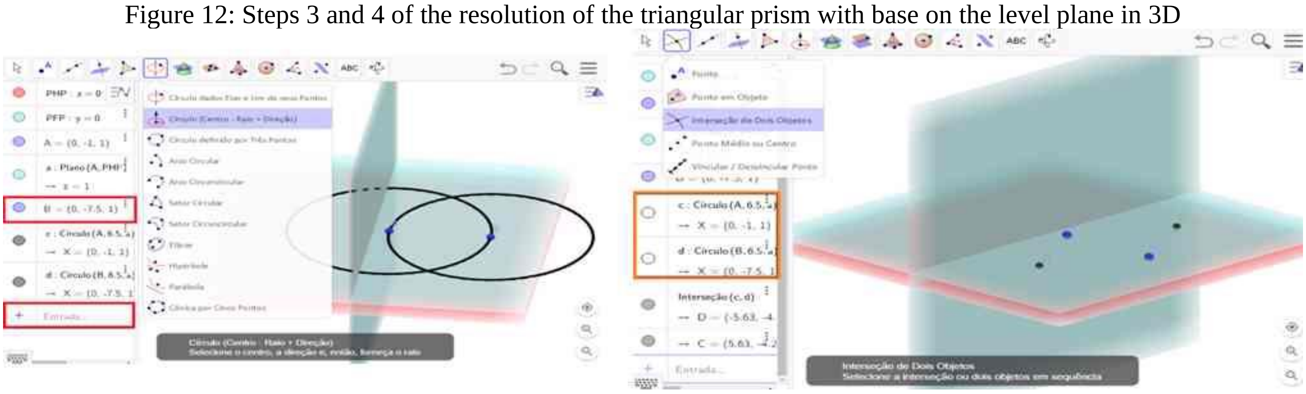


Source: Author of the paper

Step 3: enter the coordinates in the input field $(0; -7.5; 1)$determining point B. And with the tool "circle (center-radius+direction)", draw two circles of radius 6.5 cm with center respectively at point A and B, with direction on the level plane.

Step 4: With the "intersection of two objects" tool, select the two circles. At the end activate the invisibility of the auxiliary elements by deactivating the black color associated with the two circles.

Figure 12: Steps 3 and 4 of the resolution of the triangular prism with base on the level plane in 3D

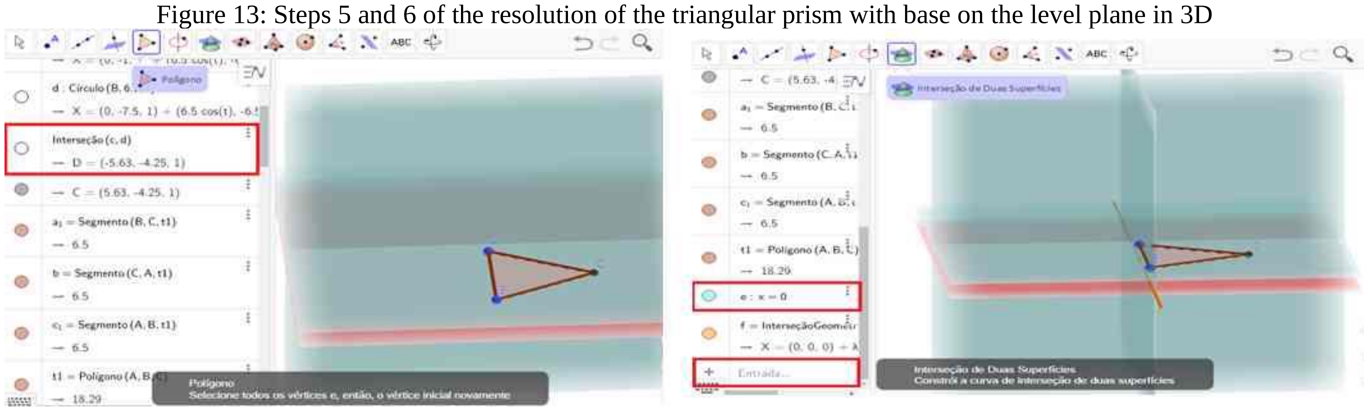


Source: Author of the paper

Step 5: as the leftmost side is the top, the point to the right of points A and B is considered, activating the invisibility of the point to its left. Then with the "Polygon" tool select A, B and the point to their right and again return to the initial vertex.

Step 6: draw the profile plan by entering in the input field $x = 0$. And with the tool "intersection of two surfaces" select the horizontal projection plane and the profile plane.

Figure 13: Steps 5 and 6 of the resolution of the triangular prism with base on the level plane in 3D

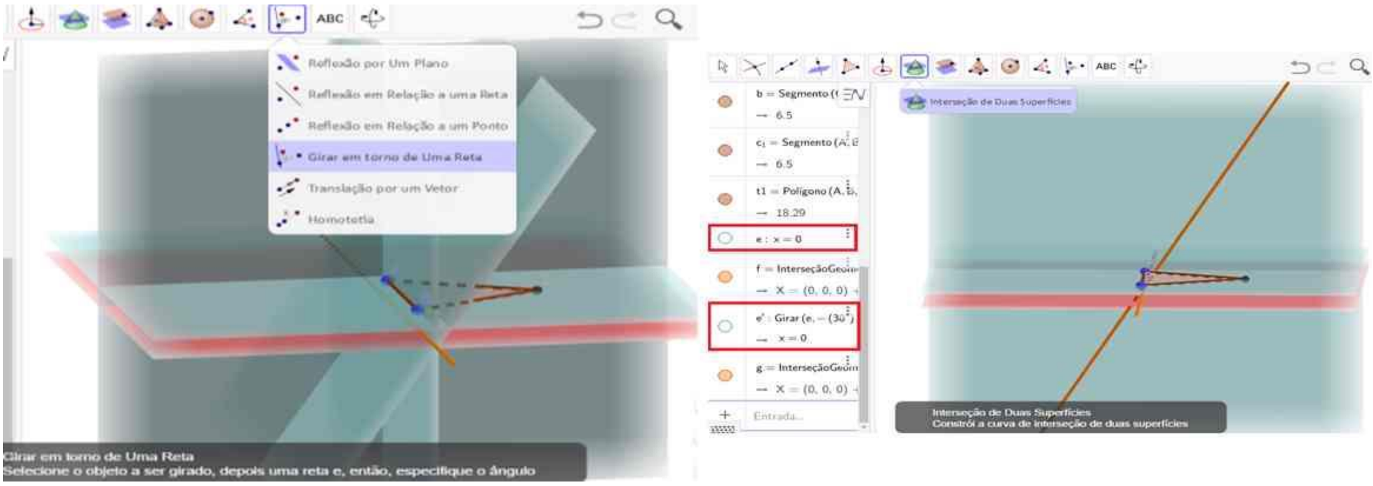


Source: Author of the paper

Step 7: With the tool "Rotate around a line" select the profile plane, the line of intersection of the profile plane with PHP and at the end specify the angle of 30° clockwise.

Step 8: With the "intersection of two surfaces" tool, select the front projection plane and the rotation plane. And activate invisibility on the profile plane and its rotation.

Figure 14: Step 4 of solving the base triangular prism on the level plane in 3D

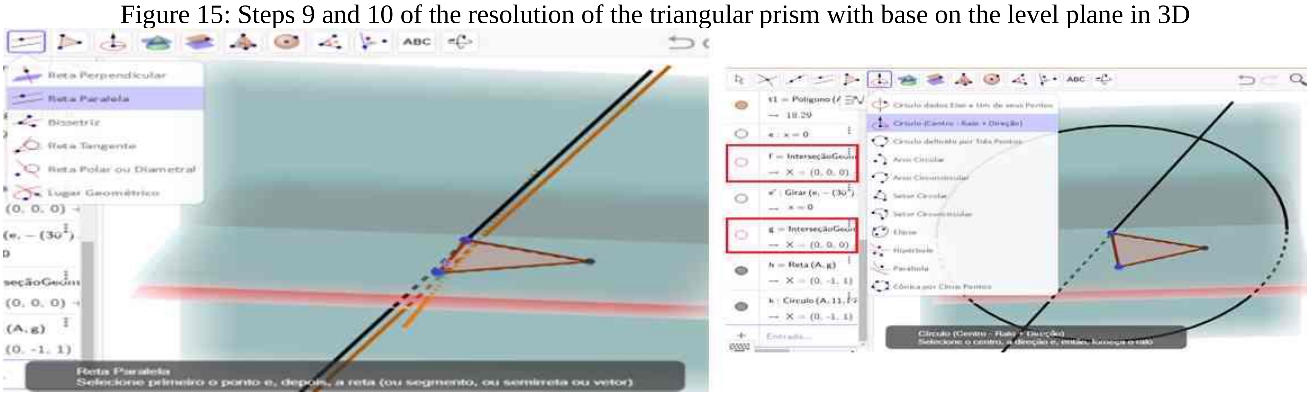


Source: Author of the paper

Step 9: With the "parallel line" tool, select point A and the line obtained at the intersection of the frontal projection plane and the plane of rotation.

Step 10: Activate invisibility on the two lines obtained by intersecting the surfaces. And with the tool "circle (center-radius+direction)", select point A and the frontal projection plane, finally mark the radius of 11 cm (respective height of the prism).

Figure 15: Steps 9 and 10 of the resolution of the triangular prism with base on the level plane in 3D

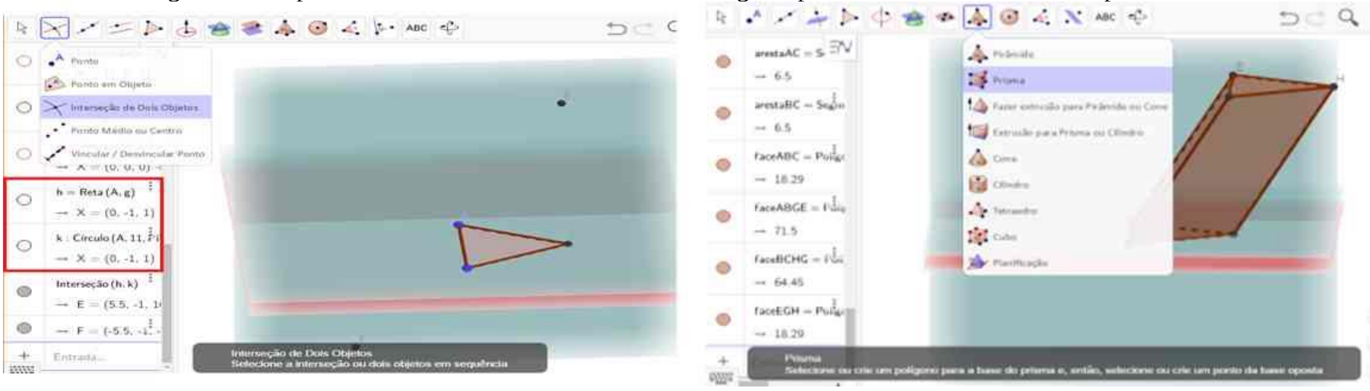


Source: Author of the paper

Step 11: With the tool "intersection of two objects" select the circle with center at point A and the line passing through point A. At the end activate the invisibility on the line passing through point A and the circle.

Step 12: with the "prism" tool, select the vertices of the base (starting from vertex A), returning again at the initial vertex and at the end select point higher than the initially selected point in this case point E.

Figure 16: Steps 11 and 12 of the resolution of the triangular prism with base on the level plane in 3D



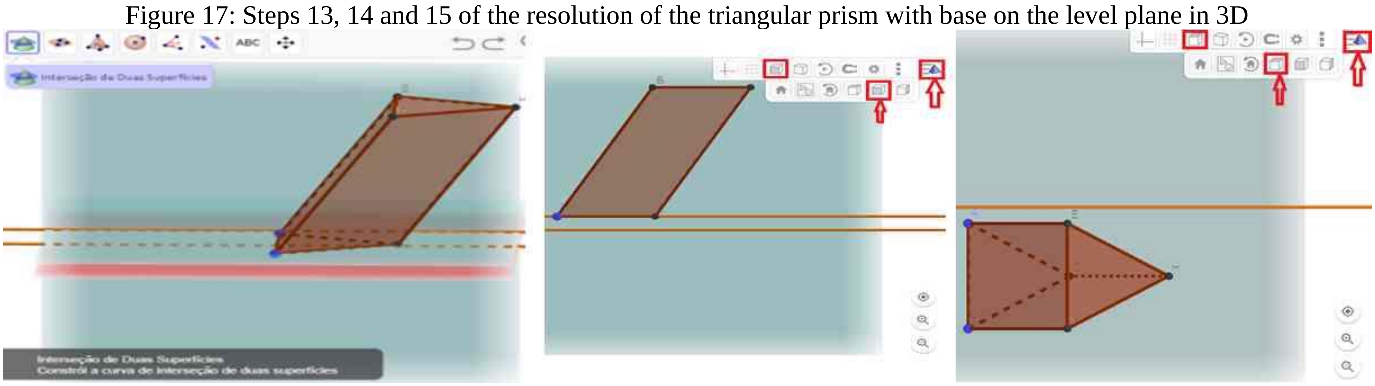
Source: Author of the paper

Step 13: With the "intersection of two surfaces" tool, select the horizontal projection plane and the frontal projection plane. The same is done by selecting the PFP and the level plane.

Step 14: Click on the top corner of the JV3D then some tools will appear, click on views, from there select the front view.

Step 15: Click on the top corner of JV3D then properties of this window will appear, click on views, from there select the top view.

Figure 17: Steps 13, 14 and 15 of the resolution of the triangular prism with base on the level plane in 3D



Source: Author of the paper

Exercise 3: Draw the projections of a right hexagonal prism, knowing that the base **[ABCDEF]** is on the frontal plane of projection and has two lateral faces are level; the edges of the bases measure 2 cm; the prism is 5 cm of height; the axis of the prism has 6 cm of elevation.

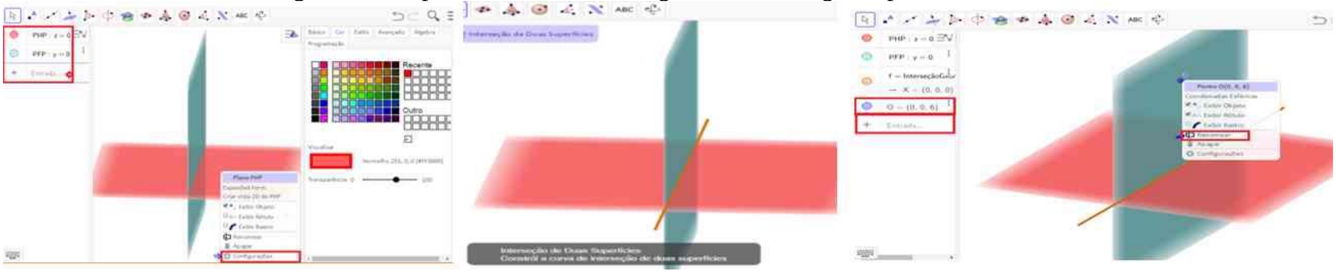
Resolution: With the computer on and the *GeoGebra* window open, using the 3D visualization window, the resolution proceeds as follows:

Step 1: draw the projection planes, inserting in the field of entry $z = 0$ for horizontal projection plane (plane xoy) e $y = 0$ for the frontal plane of projection (plane xoz). And for better visualization, change the color with a right click on the respective plane, select in configuration and then in color. Then choose the desired color and close the dialog box.

Step 2: with the "intersection of two surfaces" tool, select the horizontal projection plane and the frontal projection plane, determining the line of intersection between the two planes.

Step 3: Enter in the input field the point (0,0,6) corresponding coordinates of the axis of the prism being center of the hexagon and rename the point in O.

Figure 18: Steps 1, 2 and 3 of solving the base hexagonal prism in 3D PFP

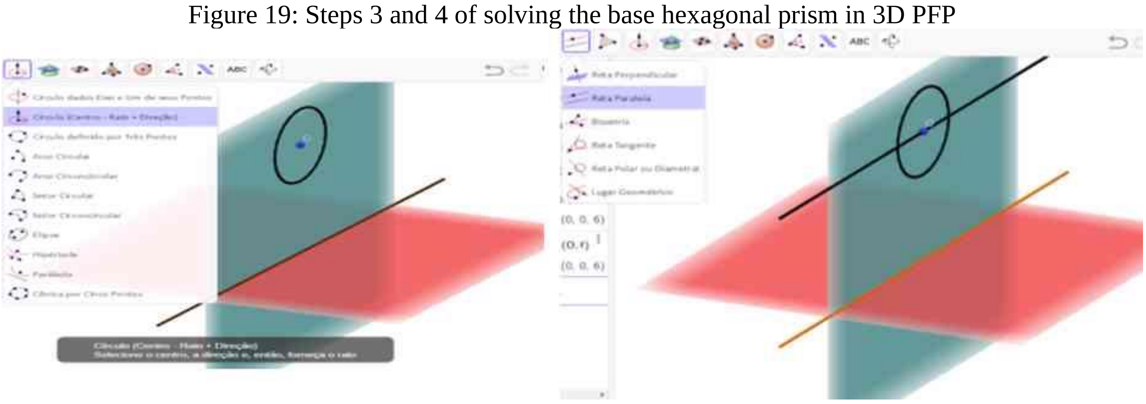


Source: Author of the paper

Step 4: With the "circle (center-radius+direction)", select respectively the point O and the frontal projection plane, finally mark the radius of 2 cm (the measurement of the side of the base is the same as the radius).

Step 5: with the "parallel line" tool, select point O and the line of intersection of PHP and PFP.4

Figure 19: Steps 3 and 4 of solving the base hexagonal prism in 3D PFP

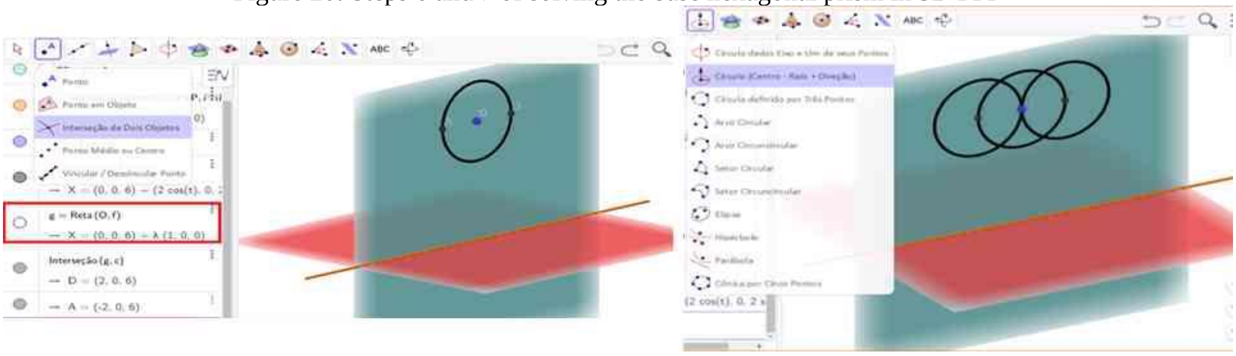


Source: Author of the paper

Step 6: With the "intersection of two objects" tool, select the line passing through point O and the circle. Then activate invisibility on the line.

Step 7: With the tool "circle (center-radius+direction)", draw two circles of radius 2 cm with center respectively at points A and D, with the direction on the PFP.

Figure 20: Steps 6 and 7 of solving the base hexagonal prism in 3D PFP



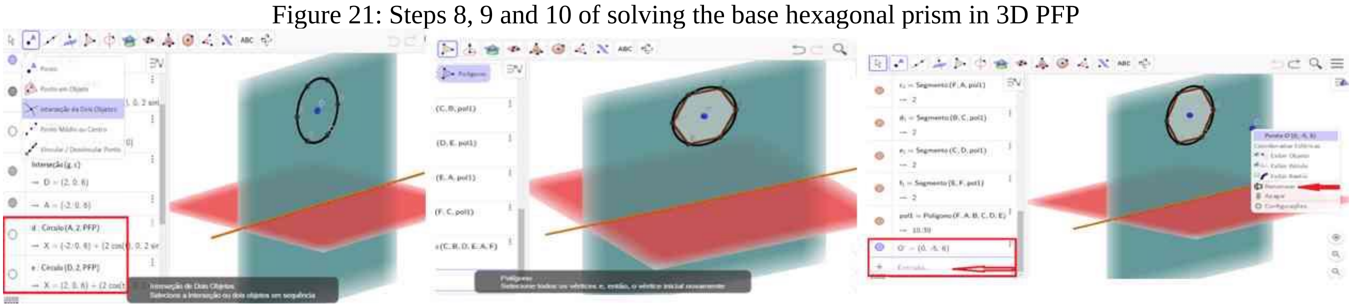
Source: Author of the paper

Step 8: with the tool "intersection of two objects" select the first circle with the circle with center A and the first circle with the circle with center D, determining points. At the end activate invisibility on the last two circles.

Step 9: with the "polygon" tool select all the vertices contained in the circle and again return to the initial vertex.

Step 10: As the height of the prism is 5 cm, in the input field enter (0,-5,6) and rename the point O'.

Figure 21: Steps 8, 9 and 10 of solving the base hexagonal prism in 3D PFP



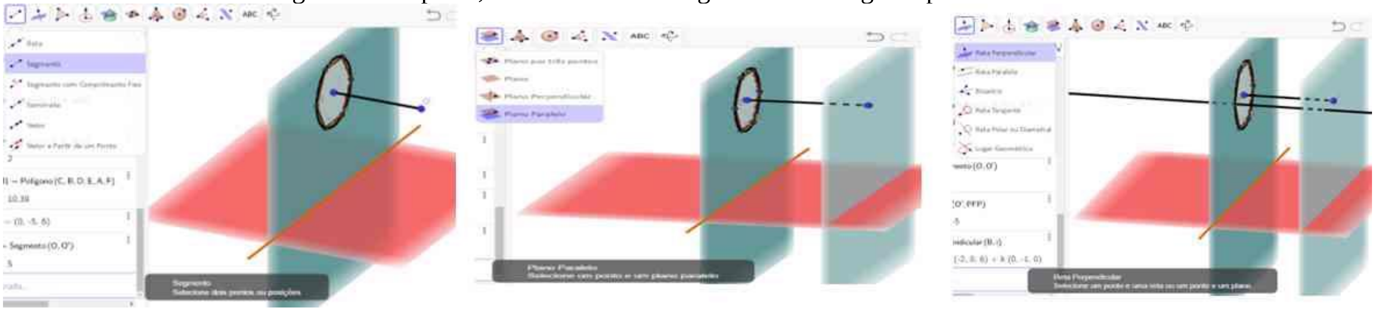
Source: Author of the paper

Step 11: With the "segment" tool select point O with point O' determining the axis of the prism.

Step 12: With the "parallel plane" tool, select the frontal projection plane (PFP) and the point O'.

Step 13: With the "Perpendicular line" tool, select point B and plane parallel to the PFP.

Figure 22: Steps 11, 12 and 13 of solving the base hexagonal prism in 3D PFP

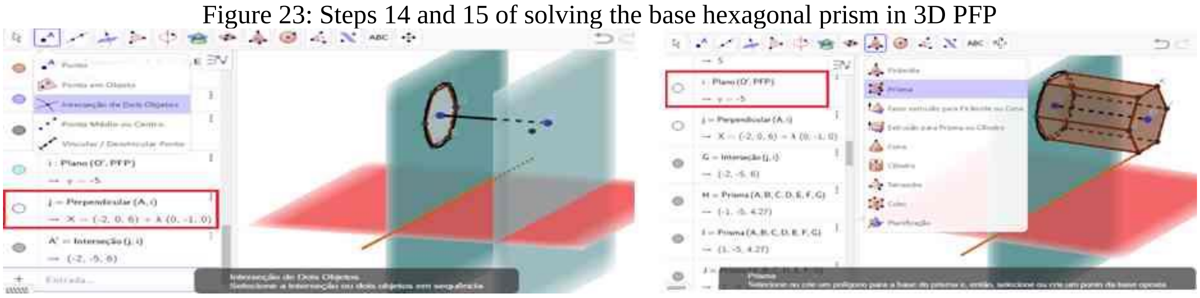


Source: Author of the paper

Step 14: With the tool "intersection of two objects" select the plane parallel to the PFP and the perpendicular line. And activate invisibility on the perpendicular line.

Step 15: With the "Prism" tool, select the vertices of the base (starting from vertex B), returning again at the initial vertex and at the end select point higher than the point selected initially. And activate the invisibility in the plane parallel to the PFP.

Figure 23: Steps 14 and 15 of solving the base hexagonal prism in 3D PFP



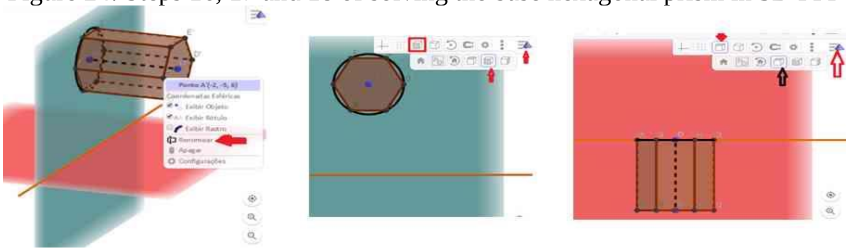
Source: Author of the paper

Step 16: Rename the points, those of the lower base by **[ABCDEF]** and those of the upper base by **[A'B'C'D'E'F']**, by right clicking on each of the points.

Step 17: Click on the top corner of the JV3D then properties will appear in this window, click on views, from there select front.

Step 18: Click on the top corner of JV3D then properties of this window will appear, click on views, from there select the top view.

Figure 24: Steps 16, 17 and 18 of solving the base hexagonal prism in 3D PFP



Source: Author of the paper

Example 4: Represent the regular hexagonal prism knowing that its bases are situated on frontal planes 5 cm apart and that the center of the circle circumscribed by the hexagon with the greatest distance is the point $O(6;4)$. On the other hand, the hexagon has side 3 cm and two lateral faces are horizontal.

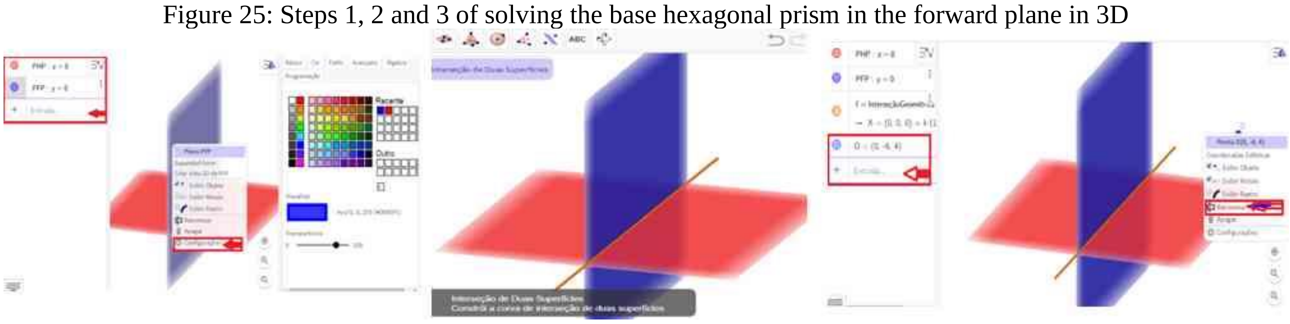
Resolution: With the computer on and the *GeoGebra* window open, using the 3D visualization window, the resolution proceeds as follows:

Step 1: draw the projection planes, inserting in the field of entry $z = 0$ for horizontal projection plane (plane xoy) e $y = 0$ for the frontal plane of projection (plane xoz). And for better visualization, change the color with a right click on the respective plane, select in configuration and then in color. Then choose the desired color and close the dialog box.

Step 2: With the "intersection of two surfaces" tool, select the horizontal projection plane and the frontal projection plane.

Step 3: Insert in the input field the center O (0, -6, 4), then right click on the point, select rename and change the name to O.

Figure 25: Steps 1, 2 and 3 of solving the base hexagonal prism in the forward plane in 3D



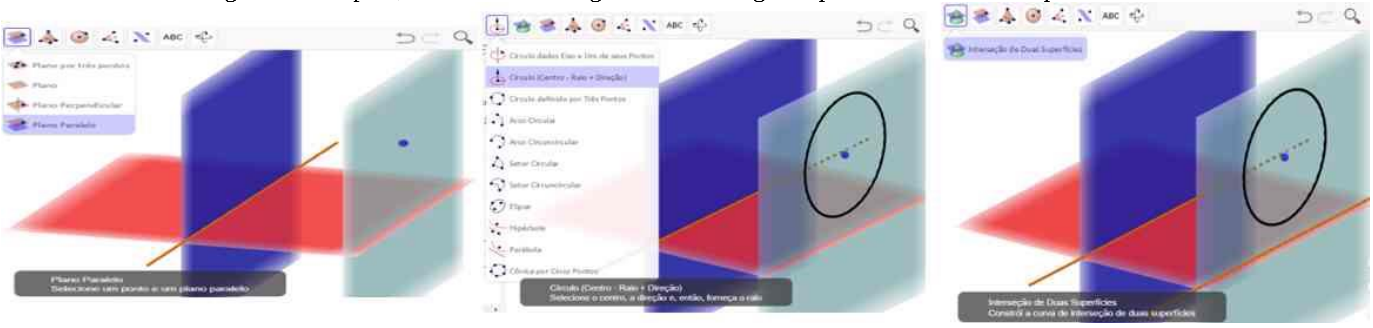
Source: Author of the paper

Step 4: With the "parallel plane" tool, select the frontal projection plane (PFP) and point O, determining the frontal plane (frontal plane) of greatest distance.

Step 5: with the "circle (center-radius+direction)", select respectively point O and front plane, finally mark the radius of 3 cm (the measurement of the side of the base is the same with the radius).

Step 6: With the "intersection of two surfaces" tool, select the frontal plane and horizontal projection plane (PHP).

Figure 26: Steps 4, 5 and 6 of solving the base hexagonal prism in the forward plane in 3D



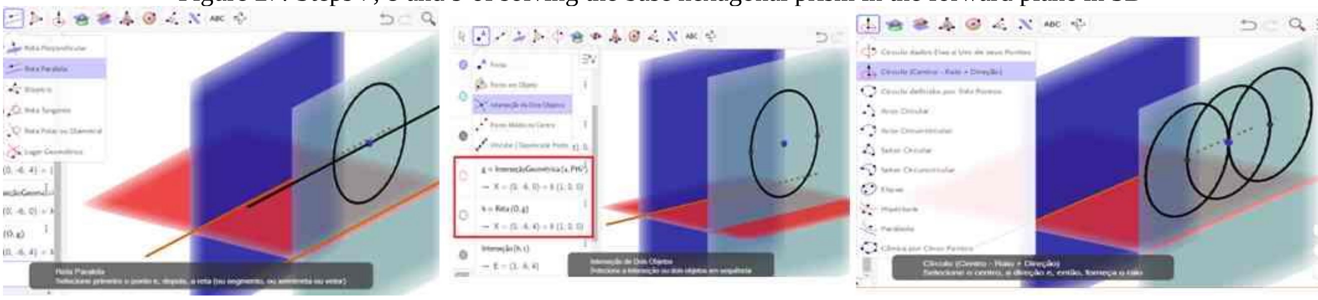
Source: Author of the paper

Step 7: with the "parallel line" tool, select the point respectively the point O and the line of intersection between the frontal plane and PHP.

Step 8: With the "intersection of two objects" tool, select the line passing through point O and the circle. Then activate invisibility on the two lines parallel to each other.

Step 9: With the tool "circle (center-radius+direction)", draw two circles of radius 3 cm with center respectively at points A and B, with the direction in the frontal plane.

Figure 27: Steps 7, 8 and 9 of solving the base hexagonal prism in the forward plane in 3D



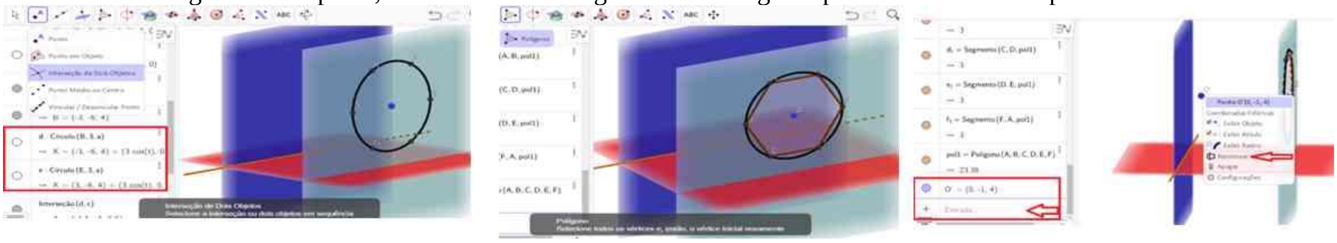
Source: Author of the paper

Step 10: with the tool "intersection of two objects" select the first circle with the circle of center A and the first circle with the circle of center B, determining points. At the end activate invisibility on the last two circles.

Step 11: with the "polygon" tool select all the vertices contained in the circle and again return to the initial vertex.

Step 12: Since the height of the prism is 5 cm, the center of the other base has coordinates O'(0,-1,4), enter these coordinates in the input field. At the end you name the point O'.

Figure 28: Steps 10, 11 and 12 of solving the base hexagonal prism in the forward plane in 3D

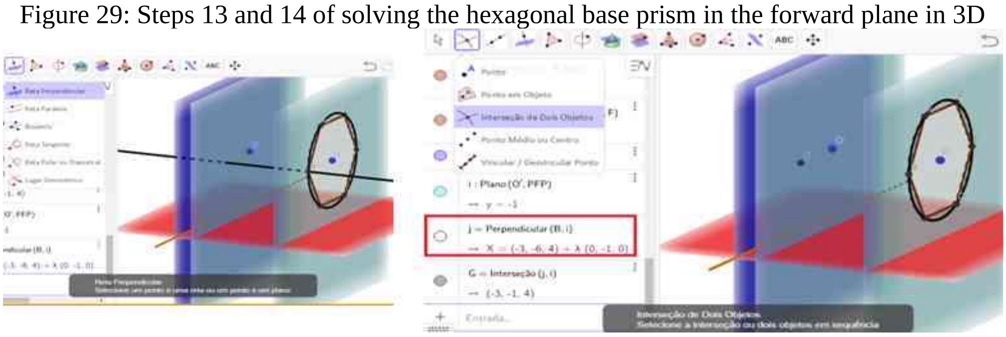


Source: Author of the paper

Step 13: With the "parallel plane" tool, select the frontal projection plane (PFP) and point O, determining the frontal plane (frontal plane) with the smallest distance.

Step 14: With the "perpendicular line" tool, select point B and the frontal plane.

Figure 29: Steps 13 and 14 of solving the hexagonal base prism in the forward plane in 3D



Source: Author of the paper

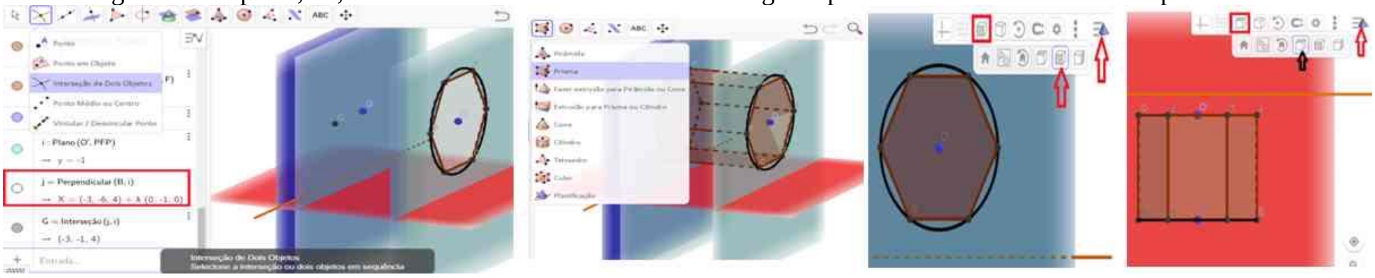
Step 15: With the "intersection of two objects" tool, select the front plane with the smallest distance and the perpendicular line. Activate invisibility on the perpendicular line.

Step 16: With the "prism" tool, select the vertices of the base (starting from vertex B), returning again at the initial vertex and at the end select point higher than the point selected initially.

Step 17: Click on the top right corner of the JV3D then the properties of this window will appear, click on views, from there select the front view.

Step 18: Click on the top corner of JV3D then properties of this window will appear, click on views, from there select the top view.

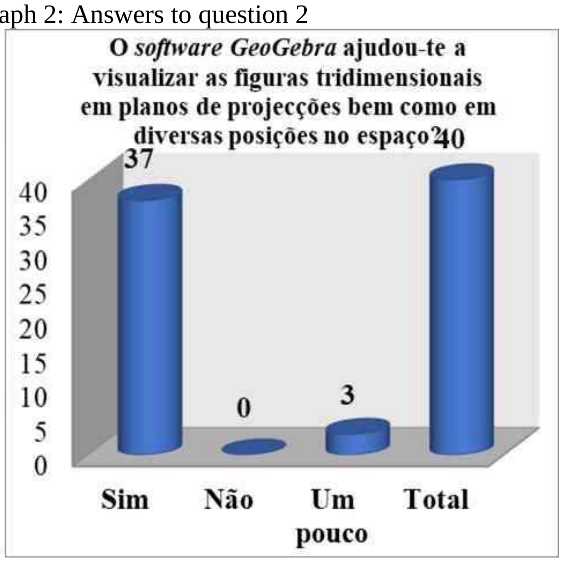
Figure 30: Steps 15, 16, 17 and 18 of the resolution of the hexagonal prism with base in the forward plane in 3D



Source: Author of the paper

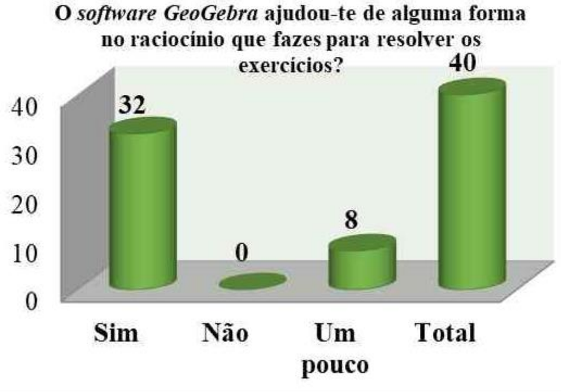
Throughout the practices in the computer room with the use of *GeoGebra software*, the motivation of the students was observed, because the 3D visualization and the dynamic movements held and stimulated the attention of the students for teaching-learning of Descriptive Geometry. Therefore, to record the data at the end, a questionnaire was distributed and each of the participants answered it. The results obtained are presented below.

Graph 1: Answers to question 1 Graph 2: Answers to question 2



Source: Survey data

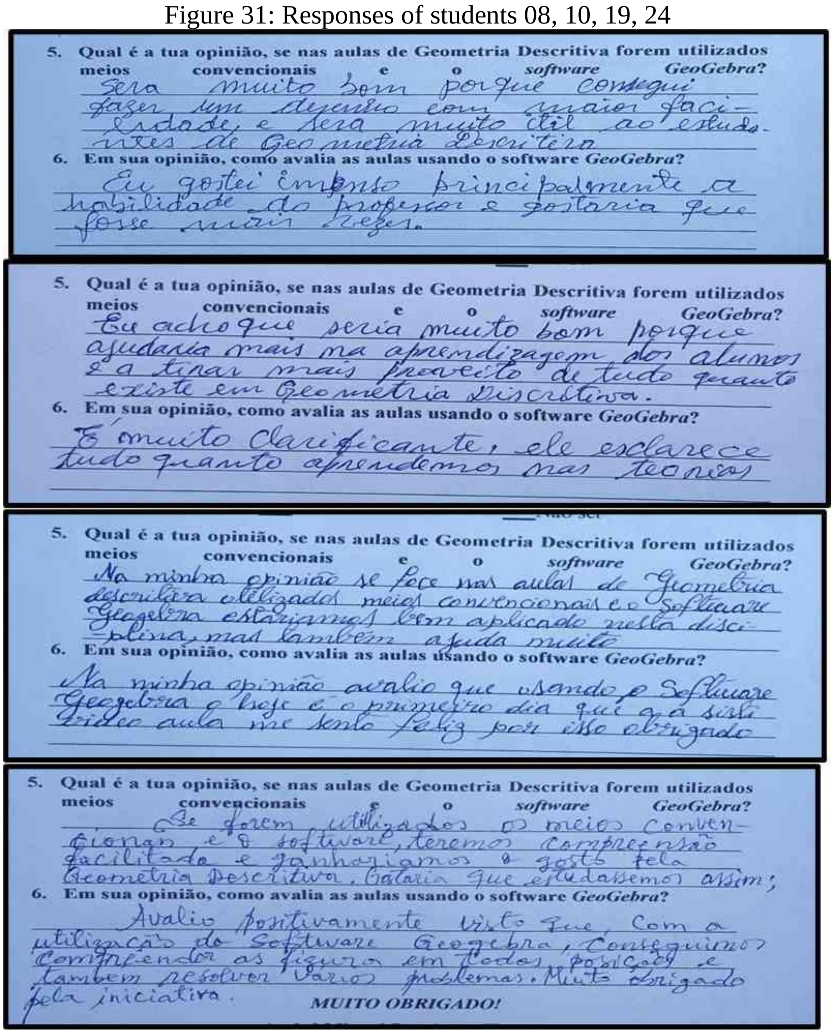
Graph 3: Answers to question 3 Graph 4: Answers to question 4



Source: Survey data

We can infer that the use of technology motivates students to study, we realize this, through the speech of some students about the use of conventional means and *GeoGebra software* in Descriptive Geometry classes as some students describe.

Figure 31: Responses of students 08, 10, 19, 24


5. **Qual é a tua opinião, se nas aulas de Geometria Descritiva forem utilizados meios convencionais e o *software GeoGebra*?**
Seria muito bom porque consegui fazer um desenho com maior facilidade, e seria muito útil aos estudantes de Geometria Descritiva
6. **Em sua opinião, como avalia as aulas usando o software *GeoGebra*?**
Eu gostei imenso principalmente a habilidade do professor e gostaria que fosse mais vezes.

5. **Qual é a tua opinião, se nas aulas de Geometria Descritiva forem utilizados meios convencionais e o *software GeoGebra*?**
Eu acho que seria muito bom porque ajudaria mais na aprendizagem dos alunos e a tirar mais proveito de tudo quanto existe em Geometria Descritiva.
6. **Em sua opinião, como avalia as aulas usando o software *GeoGebra*?**
É muito clarificante, ele esclarece tudo quanto aprendemos nas teorias

5. **Qual é a tua opinião, se nas aulas de Geometria Descritiva forem utilizados meios convencionais e o *software GeoGebra*?**
Na minha opinião se fosse nas aulas de Geometria descritiva utilizados meios convencionais e o Software Geogebra estaríamos bem aplicado nesta disciplina, mas também ajuda muito
6. **Em sua opinião, como avalia as aulas usando o software *GeoGebra*?**
Na minha opinião avalio que usando o Software Geogebra hoje é o primeiro dia que já assisti uma aula me sinto feliz por isso obrigado

5. **Qual é a tua opinião, se nas aulas de Geometria Descritiva forem utilizados meios convencionais e o *software GeoGebra*?**
Se forem utilizados os meios convencionais e o software, teremos compreensão facilitada e ganharíamos o gosto pela Geometria Descritiva. Gostaria que estudássemos assim;
6. **Em sua opinião, como avalia as aulas usando o software *GeoGebra*?**
Avalio positivamente visto que, com a utilização do Software Geogebra, conseguimos compreender as figuras em todas posições e também resolver vários problemas. Muito obrigado pela iniciativa.
MUITO OBRIGADO!

Source: Survey data

Thus, from the data and the students' testimonies, it is possible to make a comparison between the class with conventional means and a class using technologies. The results obtained clearly demonstrate that students like and get better results when the teacher makes use of technology in their classes.

5 FINAL CONSIDERATIONS

In an attempt to seek methodological innovations that make it possible to mediate between Mathematics and the student, so that knowledge is significant, this article provides *GeoGebra software* as an auxiliary *software* to improve the teaching-learning process of Descriptive Geometry in general and in particular in the representation of prisms in projection planes.

To represent a prism in projection planes, which is a three-dimensional geometric figure, is to make it a two-dimensional geometric figure, that is, flat. When the teacher teaches the concept of the representation of objects in projection planes using only conventional means, many students cannot understand the idea of what is being performed, generating many difficulties, which makes new concepts that need this idea of representation become more difficult to learn. Therefore, to minimize this problem, we made use of *GeoGebra*, which has a 3D viewing window that helps the visualization of objects in space, because technologies in general and in particular *GeoGebra* makes classes more dynamic, interactive in order to stimulate and expand students' knowledge. This was remarkable in the practical activities developed in the computer room with the aid of *GeoGebra software*, positive aspects were observed such as greater interest and motivation of the students, they questioned about the tools that served to solve exercises and were satisfied when they finished successfully; greater ease in interaction and participation between student and trainee teacher.

The results of the questionnaire clearly reveal the motivation and satisfaction of the students, because *GeoGebra* held their attention allowing the concise visualization of objects in different spatial positions, in different views and the dynamic movement of these helping them in the reasoning they do in solving the exercises.

Thus, taking into account the results obtained and the satisfaction of the students in the activities developed, it is concluded that the *GeoGebra software* is a practical and attractive resource that develops spatial visualization skills and can contribute to the teaching-learning process of Descriptive Geometry. Therefore, it is expected that, with this research, the *GeoGebra software will* be used as an ally to conventional means, as it allows the realization of practical activities, based on problem solving, making the student the protagonist of the learning process.

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