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USING GEOGEBRA IN TEACHING CONES TO DEVELOP THE COMPETENCY USING MATHEMATICAL AIDS AND TOOLS FOR GRADE 9 STUDENTS

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Abstract. This article, based on theoretical and practical research on applying GeoGebra software in teaching cones, aims to highlight the current situation related to teaching cones. This is based on a survey involving 34 mathematics teachers and 63 ninth-grade students. Additionally, the article illustrates the development of a lesson plan for ninth-grade cones, emphasizing the direction of enhancing the students' competency in using tools and mathematical learning resources through integrating GeoGebra software. Building dynamic models using GeoGebra software helps students describe the concept of a cone and the relationship between GeoGebra and real-life situations in ninth grade while enhancing visual and dynamic aspects compared to traditional teaching methods. Furthermore, the article introduces a tool for teachers, which only needs a GeoGebra file with pre-set tools. This tool can be applied for teaching in any location if a computer with GeoGebra software is installed.

Keywords: software GeoGebra, the relationship between GeoGebra and real-life situations, competency in using mathematical aids and tools.

1. Introduction

In recent years, the application of mathematical learning tools, especially mathematical software, in education has experienced considerable growth. Among these software tools are Cabri 2D and Cabri 3D, GeoGebra, Geometer's Sketchpad, Maple, Matlab, and others. Proficiency in using GeoGebra is considered an essential skill for developing competency in utilizing mathematical aids and tools.

Key features of GeoGebra include as following: Drawing mathematical graphs for algebra, geometry, and tables; Supporting drawing tools for mathematical shapes; Fast and accurate computations; User-friendly interface for ease of use in the learning process.

GeoGebra has become a significant educational tool in the secondary school curriculum, particularly since its introduction at the grade 6 level in Vietnam, starting with the Canh Dieu series textbooks in the 2021 – 2022 school year. Some research on applying GeoGebra to teaching mathematics, particularly functions, helps students enhance their ability to use mathematical tools actively and positively engage in learning activities Asmin, Sembiring BN & Surya E [1], Bui MD [2], Le VMT [3], Hohenwarter M, Hohenwarter J, Kreis Y & Lavicza Z [4], Nguyen HN [5],

Nguyen TH [6], Singh LK [7], Vu LH [8], Wah LK [9], Wassie YA & Zergaw GA [10], Yorganci S [11].

The ninth-grade Geometry curriculum is designed to explore geometric concepts closely related to daily life, such as cones, cylinders, and spheres. According to the 2006 Math program in Vietnam, the topic of Visual Geometry, especially the lesson on cones, mainly introduces and solves concepts and formulas related to the lateral area, total surface area, and volume of a cone. However, in the 2018 Mathematics Curriculum in Vietnam (issued with Circular No. 32/2018/TT-BGDĐT on December 26, 2018, by the Minister of Education and Training), the requirements for cone content are more specific and detailed. These include: Describing and constructing a cone, including the vertex, generatrix, height, and base radius; Calculating the lateral area of the cone; Calculating the volume of the cone; and Solving practical problems related to calculating the lateral area and volume of cones.

For example, we have calculated the volume or lateral area of familiar cone-shaped objects. [12]. Therefore, the 2018 Math program in Vietnam provides more specific instructions for students to develop their ability to learn and apply concepts related to cones in real-life situations DT Do [13].

In this article, we focus on constructing models to clearly illustrate the concept of a cone and its surface area using mathematical tools, supported by GeoGebra software instead of presenting "the rotation of a right-angled triangle around a fixed right-angle edge to form a cone". This approach aims to make the students' learning experience more dynamic and engaging, allowing them to grasp the knowledge visually. According to this article, teachers and students require only a laptop or desktop computer, along with the GeoGebra model file, to teach and learn about cones at any time and from any location. Furthermore, through these models, students can improve their ability to engage in self-directed learning and enhance their proficiency in utilizing mathematical tools.

Some studies related to the application of GeoGebra software in teaching visual geometry at the secondary school level such as the Master's thesis: "Application of GeoGebra software in teaching geometry proof at grade 7 secondary school" by author Cao Hai Dang at VietNam National University, Hanoi has provided steps to build and guide students to apply GeoGebra software to prove geometry problems in grade 7 HD Cao [14].

According to Irene Mukiri Mwingirwa and Miheso-O'Connor, teachers' feedback showed that GeoGebra was considered useful for teaching and learning Mathematics and would help learners grasp concepts in Geometry, as cited in the article "Status of Teachers' Technology Uptake and Use of GeoGebra in Teaching Secondary School Mathematics in Kenya" Mwingirwa IM & O'Connor M [15].

2. Content

2.1. GeoGebra

GeoGebra is a powerful and versatile mathematical software designed to support teaching and learning mathematics. It uniquely combines geometry and algebra, allowing users to create dynamic and visually interactive models with mathematical objects. A range of tools and functions such as graphs, algebra, geometry, calculus, and statistics are integral parts of the GeoGebra software. User capabilities encompass solving equations, computing derivatives and integrals, graphing, conducting statistical data analysis, and performing a variety of other tasks.

The ability to create dynamic models, enabling users to move, modify, and interact with mathematical objects in real time, is a standout feature of GeoGebra. This enhances the clarity and engagement of the mathematics learning process. GeoGebra is extensively used in research and mathematical applications across various fields, in addition to its role in supporting

mathematics education from elementary to university levels. The software boasts a simple and user-friendly interface, is easy to use, and supports multiple platforms, including mobile phones, tablets, and personal computers.

We appreciate GeoGebra because it provides all the necessary tools for users to draw various types of objects such as lines, circles, and three-dimensional geometry, meeting the needs of mathematics teachers when designing instructional models.

2.1.1. Components for the competency of using mathematical aids and tools

According to the Ministry of Education and Training (2018), the components of competency in using tools and resources for teaching mathematics in the general education mathematics curriculum of 2018 are as follows:

- Recognizing the names, functions, usage guidelines, and storage methods of common visual aids, as well as technological tools and resources (particularly those utilizing information technology) that are essential for mathematics learning.

- Proficiently using mathematical tools and resources, especially technology-based tools, to explore, discover, and solve mathematical problems, tailored to the cognitive characteristics of the respective age group.

- Recognizing the advantages and limitations of various tools and supporting resources to employ them judiciously.

We present the components of the competency of using mathematical aids and tools with the support of GeoGebra as follows:

- Demonstration 1: Recognize the names, effects, and how to use Mathematical Aids and Tools with the support of GeoGebra.

- Demonstration 2: Can use mathematical aids and tools with the support of GeoGebra to explore, discover, and solve math problems (suitable for age cognitive characteristics).

- Demonstration 3: Recognize the advantages and limitations of Mathematical Aids and Tools with the support of GeoGebra.

2.1.2. Some current situations related to teaching visual geometry

We conducted a survey using questionnaires distributed to 34 mathematics teachers at secondary schools and 63 ninth-grade students via Facebook from February 16, 2023, to February 22, 2023. The purpose is to get opinions from teachers and students about using GeoGebra and the difficulties encountered when learning cone content in 9th-grade visual geometry. Based on this, we designed tools using GeoGebra to support the teaching and learning of cone-related content for ninth-grade students.

The following are survey questions related to teachers, ranging from question 1 to question 5. the purpose is to gain insight into teachers' opinions, perceptions, and evaluations concerning the importance of using mathematical aids and tools, supported by GeoGebra software, in teaching cone geometry within the visual geometry curriculum for ninth-grade students. We conduct survey question 1 to gather insights. Question 2 was designed to understand how teachers use GeoGebra to teach cone geometry in grade 9. Survey question 3 aimed to identify the challenges teachers encounter when teaching cone geometry within the visual geometry curriculum for ninth grade. Survey question 4 was used to assess teachers' opinions on the extent to which tools and resources supported by GeoGebra are utilized in teaching the surface area of cones in the visual geometry curriculum for ninth grade. To gather teachers' opinions on the extent to which tools and teaching resources, supported by GeoGebra, are used in teaching volume problems related to cone geometry within the visual geometry curriculum for ninth grade, we conducted survey question 5.

Question 1. In your opinion, is it important to develop the Competency of Using Mathematical Aids and Tools through teaching cones for grade 9 with the support of GeoGebra?

Figure 1. Teachers' opinions, perceptions, and evaluations regarding the importance of developing competency in using mathematical aids and tools through teaching cone geometry in the visual geometry content for ninth grade with the support of GeoGebra software (34 answers)

Question 2. What activities do teachers often organize to develop the Competency of Using Mathematical Aids and Tools through teaching cones for grade 9 with the support of GeoGebra?

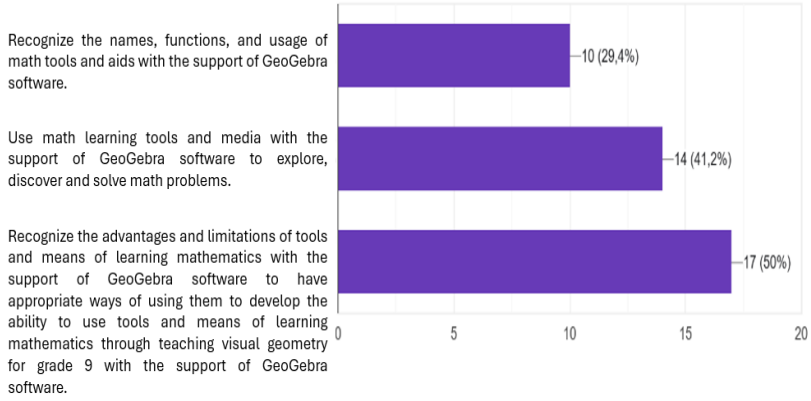

Figure 2. Teachers' opinions on activities aimed at developing competency in using mathematical aids and tools through teaching cone geometry in the visual geometry content for ninth grade with the support of GeoGebra software (34 answers)

Question 3. When teaching grade 9 students about cones, what challenges do teachers often encounter?

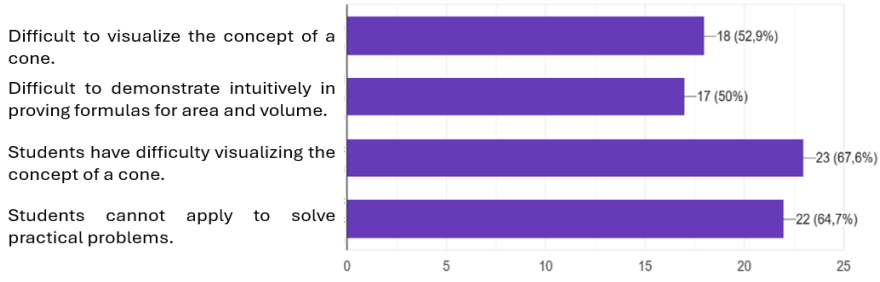

Figure 3. Teachers' opinions on the challenges faced when teaching the lesson on cone geometry within the visual geometry content for ninth-grade students (34 answers)

Question 4. In your opinion, how often do you use Mathematical Aids and Tools in the problem of calculating the *surface* area of a cone with the support of GeoGebra?

Question 5. How often do you use Mathematical Aids and Tools in calculating the volume of a cone for grade 9 with the support of GeoGebra?

Figure 4. Teachers' opinions on teaching to develop competency in using mathematical aids and tools in problems related to calculating the surface area of cones within the visual geometry content for ninth grade, with the support of GeoGebra software (34 answers)

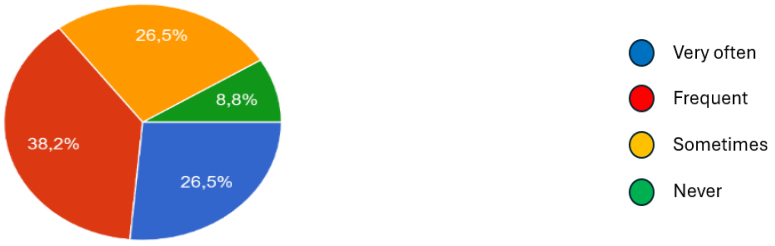

Figure 5. Teachers' opinions on teaching to develop competency in using mathematical aids and tools in volume problems related to cone geometry within the visual geometry content for ninth grade, with the support of GeoGebra software (34 answers)

From questions 6 to 10, we surveyed students' opinions and experiences related to their learning of cone geometry. Survey question 6 was designed to understand students' perceptions of the difficulty level of learning about cones. Question 7 aimed to examine the challenges that students encounter during their study of cone geometry. Survey question 8 inquired about students' views on the importance of developing their ability to apply, explore, and discover mathematical tools and learning resources. Question 9 assessed the frequency with which students develop these skills in solving surface area problems related to cones within the visual geometry curriculum for ninth grade, supported by GeoGebra software. Finally, survey question 10 evaluated how often students develop the ability to apply, explore, and discover mathematical tools and resources in solving volume problems in a visual geometry class for ninth grade, with the support of GeoGebra software.

Question 6. What do you think about the cone lesson?

Figure 6. Students' perceptions of the difficulty level in learning about cones within the visual geometry topic for the ninth grade (60 answers)

Question 7. Which aspects of learning about cones do you find difficult?

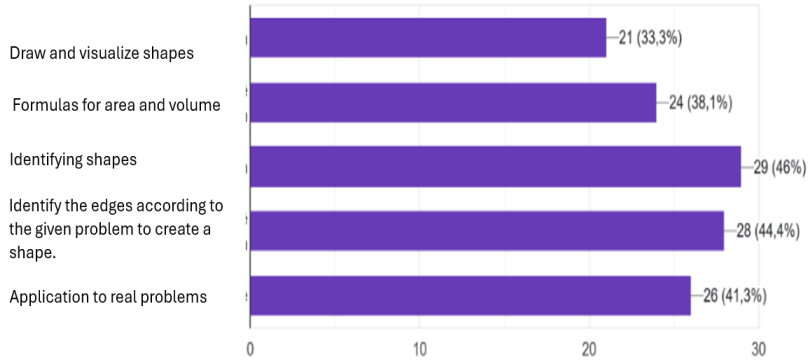

Figure 7. Students' difficulty level in learning about cones (63 answers)

Question 8. In your opinion, is it important for students to develop the ability to apply, explore, and discover tools and means of learning mathematics?

Question 9. In your opinion, how often do you develop the ability to apply, explore, and discover using Mathematical Aids and Tools about the area problem in cones with the GeoGebra support?

Question 10. In your opinion, how often do you develop the ability to apply, explore, and discover using Mathematical Aids and Tools about the volume of cones with the GeoGebra support?

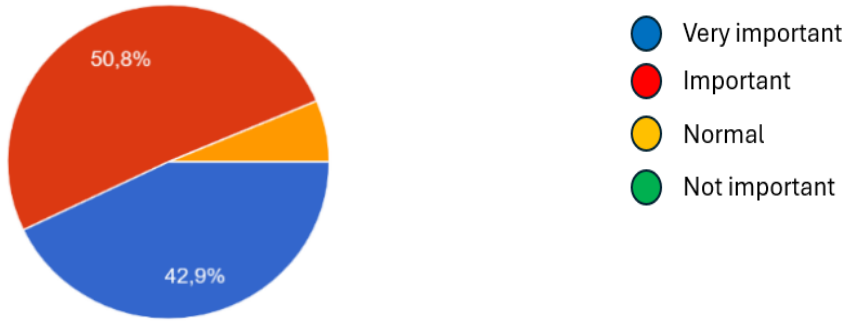

Figure 8. Students' perspectives on the importance of developing the ability to apply, explore, and discover tools and mathematical learning resources (63 answers)

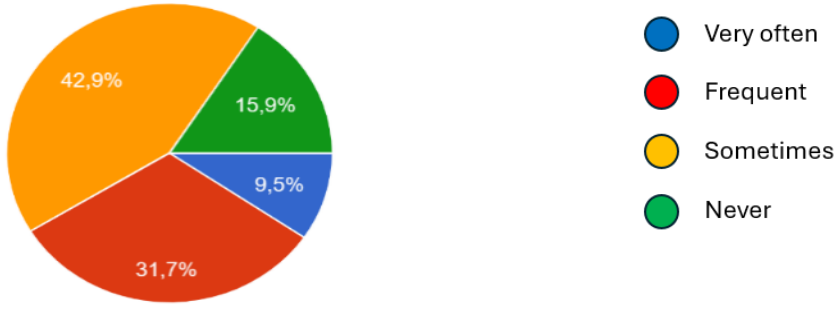

Figure 9. Students' perspectives on the development of competence in using mathematical aids and tools for solving problems related to the surface area of cones with the support of GeoGebra software (63 answers)

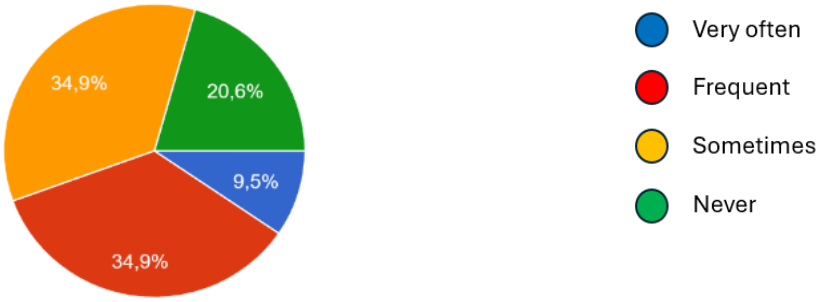

Figure 10. Students' perspectives on the development of competence in using mathematical aids and tools for solving problems related to the volume of cones with the support of GeoGebra software (63 answers)

The results of both surveys, capturing the opinions of teachers and students, have helped us clearly define the objectives, directions, and content to proceed with building models that serve the teaching activities, as well as enhancing students' competencies to use mathematical aids and tools.

The survey results indicate that teachers recognize and acknowledge the importance of teaching cone geometry within the visual geometry content for ninth grade with the support of GeoGebra. This underscores the commitment to creating an innovative learning environment, enabling students to experience and apply mathematical knowledge with the support of GeoGebra (question 1).

With the assistance of GeoGebra, approximately 50% of teachers engage in building activities and identify the strengths and weaknesses of mathematical aids and tools. They can then use them judiciously in teaching visual geometry, specifically cone geometry for ninth grade, with the support of GeoGebra (question 2).

The results reveal that teachers require additional training in the use of mathematical aids and tools for teaching visual geometry. Despite a considerable number of teachers utilizing these tools, a significant proportion have not applied these mathematical aids and tools to instruct problems related to areas in visual geometry for the ninth grade (question 4).

According to the survey results, we found that many teachers either do not use GeoGebra software to teach cone geometry or have not familiarized themselves with it. We discovered that utilizing GeoGebra software to create models allows teachers to incorporate cone geometry concepts into teaching, and simulate the structure of cones (question 5).

Several students reported difficulties with concepts related to cones (Question 6), and a significant number of ninth-grade students struggled with learning about cones (Question 7).

The survey further reveals that most students recognize the importance of developing the ability to use, explore, and discover mathematical tools and learning resources. This suggests that students value the exploration of learning tools to enhance their learning efficiency and apply mathematical knowledge in real-world contexts (Question 8). However, the survey also found that a large number of students have not learned about the area and volume of a cone with the support of GeoGebra software (Questions 9 and 10).

2.2. Cone conceptual model

2.2.1. Model construction

Model identification: According to the 9th grade Math textbook, Volume 2 of the 2006 program in Vietnam, the definition of a cone is given as follows: "When rotating the right triangle AOC around a fixed OA, a cone is formed". In this section, we will design a scenario to build an

illustrative model of a cone, aiming to clarify the process of building a cone and provide a more intuitive representation of the activities introduced in the textbook.

Idea and Steps for Implementing the Scenario: We draw the right-angled triangle *AOC* and fix the edge *OA* on the *Oz* axis. Subsequently, we use rotation operations to rotate this triangle around the *OA* edge for one revolution. Simultaneously, we employ the "BeMat" command in GeoGebra to draw the base and lateral faces of the cone.

Here's how we proceed:

+ *Step 1*: Open the GeoGebra software version GeoGebra Classic 5.0.426.

+ *Step 2:* Use the “Circle: Centers and Radius” to draw a circle with center O as the origin and radius 2 centimeters.

+ *Step 3:* Use the “Point on Object” tool to make C belong to the circle just drawn.

+ *Step 4:* Select View and 3D Graphics. Then work on the 3D Graphics.

+ *Step 5:* Use “Segment” to connect O to C.

+ *Step 6*: Use “Perpendicular Line” to draw a line passing through A and perpendicular to line segment AB.

+ *Step 7*: Use the “Point on Object” tool to make A belong to the line just drawn.

+ *Step 8:* Use “Segment” to connect O to A, and C to A.

+ *Step 9:* Hide unnecessary objects.

+ *Step 10*: Right-click on line segments AC and OC in turn and select “Trace on”. Right-click on C and select “Trace on”.

+ *Step 11*: Given point C moving on the circle (O;2), we see that the right triangle AOC rotates around side OA to create a cone.

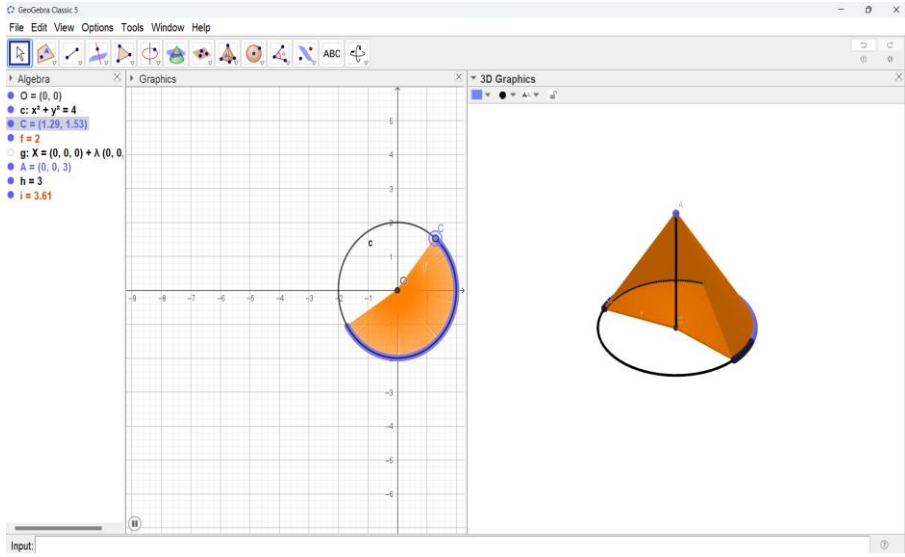

Figure 11. Cone definition model with the support of GeoGebra software

Therefore, through this dynamic model-building scenario, students can realize that rotating a right-angled triangle around a fixed edge will create a cone. In addition, it helps students visualize the structure of the cone, such as the base of the cone being a yellow circle, the lateral surface of the cone being blue, the height of the cone being edge *OA*, the base radius being edge *OC*, and the main diagonal being edge *AC*. These are the geometric factors related to the cone that students can easily observe and articulate through the model.

2.2.2. Discussion

Through the provided step-by-step instructions, students can develop the competence to use mathematical aids and tools using the GeoGebra software.

Students recognize the advantages of the GeoGebra software, such as flexible drawing steps, creating a model that illustrates the concept of a cone, and providing vivid and dynamic visuals that are easy to use once the complete product model is obtained. However, alongside these benefits, the software still has a drawback in terms of the width of the 3D workspace display area. If students zoom in on R beyond the software's display limit, they won't be able to see the entire cone. To overcome this limitation, students can move the mouse to the 3D workspace and use the mouse scroll wheel to resize the image to fit within the software's display frame. After completing the model, both teachers and students only need a computer or laptop with GeoGebra installed (or even a smartphone) to use the model at any time and from any location, without the need for an internet connection. This facilitates the long-term application of the model in the teaching process, allowing teachers to use it across multiple academic years, ensuring long-term accessibility and storage.

Table 1. Assessment of the ability to use mathematical tools and means through the situation of building a model of the surface area of a cone

Step	Expression of the competence to use mathematical aids and tools
Step 1	Students know that the software's name is GeoGebra.
Step 2	Students know how to use "Circle: Centers and Radius" to draw a circle given a center and radius.
Step 3	Students know how to use "Point on Object" to draw a point on a given object.
Step 4	Students know how to open 3D Graphics.
Step 5	Students know how to use "Segment" to draw a line segment through two points.
Step 6	Students know how to use a "Perpendicular Line" to draw a line perpendicular to a given line segment.
Step 7	Students know how to use "Point on Object" to draw a point on a given object.
Step 8	Students know how to use "Segment" to draw a line segment through two points.
Step 9	Students know how to hide unnecessary objects.
Step 10	Students know how to hide the "Trace on" selection to open the object's motion traces.
Step 11	Students know how to make objects move.

2.3. Integration of cone model design into cone teaching practices

**** Purpose***

The formation of a cone can be visually and vividly observed using GeoGebra.

*** *Teaching* without using the GeoGebra software**

The teacher introduces students to real-life images of a cone and guides them to examine the illustrations in the textbook depicting the rotation of a right-angled triangle around a fixed right-angle edge to form a cone. Students learn the concept of a cone from the previous activity.

Discuss: When examining an image in the 9th grade Math textbook, Volume 2 of 2006, It has been observed that introducing the concept of a cone to students requires them to visualize

the rotation of a right-angled triangle around the vertex of the right angle, which can render the cone concept somewhat unclear and challenging for students. The GeoGebra software can help teachers and students address these issues.

It is important to note that the main activity of this task involves rotating a right-angled triangle around a right-angle vertex of that triangle. The movement of the image and the results of that movement are crucial to help students better understand the cone. This highlights that constructing a model for the cone formation activity requires the use of mathematical tools and learning resources combined with the GeoGebra software.

**** Implementing teaching of Cone concepts using GeoGebra software***

This lesson was tested in class 9A1 during the 2023 - 2024 school year at Phu Chanh Secondary School, Tan Uyen district, Binh Duong Province on April 5, 2024.

Step 1: Exploration

Teacher's Activity: Have students observe familiar images of cones in everyday life.

Figure 18. Real-life images of a cone – Source: Internet

Figure 19. Cao Van Lau Theater Source: Internet

Figure 20. Cone-shaped lantern Source: Internet

The images above illustrate that the cone is a shape commonly encountered in everyday life.

Step 2: Formation of the Cone Concept

Teacher's Activity: The teacher constructs the cone concept with the assistance of GeoGebra software by projecting a pre-designed GeoGebra file to explain the formation of the cone.

Students' Activity: Follow the teacher's instructions, observe the complete presentation file, and gain a more visual and vivid understanding of the cone formation process. This helps students comprehend the issue more thoroughly, see the overall picture, and avoid ambiguity and abstraction.

Step 3: Reinforcement

The Teacher poses questions to reinforce the cone concept.

Example: Given right-angled triangle ABC with $AB = 3$ *cm*, $AC = 4$ *cm*. What shape is obtained by rotating triangle ABC around edge AB? Identify the radius, height, and generatrix of the resulting figure. Calculate the length of the generatrix.

Step 4: Practice and Application

The teacher instructs students to name real-life objects that have a cone shape to reinforce their understanding and recognition of cones.

Example: Please list real-life images of cones. Desired student answer: A cone-shaped tent.

Thus, through the activities and examples provided, students have recognized the representation of cones in real life and the methods used to construct a cone.

Figure 21. A cone-shaped tent Source: Internet

2.4. Research effectiveness

After applying mathematical tools and teaching aids to instruct the lesson on cones, the majority of our students have shown a heightened interest in the subject. They can actively participate in discussions and answer questions related to the lesson. Their performance in assessments, particularly those covering cone-related content, has significantly improved.

Student A: As a high-achieving student, I successfully constructed a cone model using GeoGebra software and answered questions related to cone properties, such as determining the height, radius, and generatrix, and calculating related edges.

Student B: As a student with a fairly good academic performance, I successfully constructed a cone model using GeoGebra software. However, the process was slightly slower, and I needed assistance from the teacher to determine the height, radius, and generatrix, and calculate related edges of the cone.

Student C: As a student with an average academic performance, I found some challenges in using mathematical tools and aids, particularly with the support of GeoGebra software. However, I managed to sketch the lateral surface of the cone (without drawing the base and control buttons). Despite some initial confusion, I developed a growing enthusiasm for using GeoGebra tools in mathematical learning. I was also able to correctly answer questions related to cone properties.

Student D: As a student with weak academic performance, I initially struggled. However, after the lesson, I made progress and developed an interest in using mathematical tools and aids. I learned to use basic commands to draw a triangle (although I couldn't complete the model), showing significant improvement compared to before the lesson on using mathematical tools. I still face challenges in answering all questions correctly regarding cone properties.

After the lesson, the majority of students expressed a high level of enthusiasm when exposed to new knowledge with the support of mathematical tools, particularly the GeoGebra software. Students actively paid attention during the lecture, expressed their opinions, and posed questions to seek assistance from the teacher in resolving uncertainties and difficulties encountered while using mathematical tools. This has stimulated a passion for utilizing tools to solve various problems.

3. Conclusions

Becoming proficient in the use of mathematical tools, particularly with the support of GeoGebra software, empowers teachers to take a more proactive role in teaching cone-related lessons. All activities related to the conceptualization of cones are made clearer through the use of the models' outputs, thereby improving the efficiency of instruction. For students, it fosters

greater interest in learning, making the subject less abstract and more vivid. This approach not only sparks a passion for mathematics but also encourages students to see its practical application in geometry and real life. It eliminates the monotony of learning, allowing students to experience mathematics as both enjoyable and practical. Additionally, it encourages students to explore and utilize modern mathematical tools, fostering the development of skills that will support their future growth and application in both teaching and learning.

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