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# DESIGN OF ALGORITHM AND PROGRAMMING TEXTBOOK WITH GEOGEBRA AUGMENTED REALITY VISUALIZATION

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***ABSTRACT***

Students of the Mathematics Education (Tadris Matematika) study program often face difficulties in understanding abstract concepts in the Algorithm and Programming course, such as geometry, matrices, and three-dimensional figures. To address this challenge, this study aimed to develop a GeoGebra Augmented Reality (AR)-based textbook that can visualize concepts in a real and interactive manner. The research employed a Research and Development (R&D) design with the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The instruments included validation and practicality questionnaires completed by experts, lecturers, and students. The results indicated a very high level of feasibility, with validation scores of 83.33% from material experts, 86.67% from language experts, and 97.50% from media experts. Meanwhile, the practicality level was 93.33% according to students and 90% according to lecturers. These findings suggest that the integration of GeoGebra with AR facilitates the construction of mental representations and reduces cognitive load in abstract topics, thereby improving learning effectiveness. Thus, the developed textbook is not only valid and practical but also contributes to providing innovative learning media that enhance spatial abilities and mathematical problem-solving strategies among higher education students.
***Keywords****:* ADDIE; algorithms and programming; augmented reality; geoGebra; textbook

**ABSTRAK**

*Mahasiswa program studi Tadris Matematika kerap mengalami kesulitan dalam memahami konsep abstrak pada mata kuliah Algoritma dan Pemrograman, seperti geometri, matriks, dan bangun ruang. Untuk menjawab tantangan ini, penelitian ini bertujuan mengembangkan buku ajar berbasis GeoGebra Augmented Reality (AR) yang dapat memvisualisasikan konsep secara nyata dan interaktif. Metode penelitian menggunakan pendekatan Research and Development (R&D) dengan model ADDIE yang meliputi analisis, desain, pengembangan, implementasi, dan evaluasi. Instrumen yang digunakan berupa angket validasi dan kepraktisan yang diisi oleh ahli, dosen, dan mahasiswa. Hasil penelitian menunjukkan tingkat kelayakan sangat tinggi, dengan validasi ahli materi 83,33%, bahasa 86,67%, dan media 97,50%, sedangkan tingkat kepraktisan menurut mahasiswa 93,33% dan dosen 90%. Temuan ini menunjukkan bahwa integrasi GeoGebra dengan AR mempermudah mahasiswa membangun representasi mental dan menurunkan beban kognitif pada materi abstrak, sehingga meningkatkan efektivitas pembelajaran. Dengan demikian, buku ajar ini tidak hanya valid dan praktis digunakan, tetapi juga berkontribusi dalam menyediakan media pembelajaran inovatif yang mendukung penguatan kemampuan spasial serta strategi pemecahan masalah matematis mahasiswa di pendidikan tinggi.*
**Kata kunci**: *ADDIE; algoritma dan pemrograman; augmented aeality; buku ajar; geoGebra*

## Introduction

Students' spatial skills are crucial, particularly for those studying mathematics. These talents are important for students' success and the development of their life skills, and they are advantageous in a variety of industries and occupations. Thus, developing spatial skills early on, especially in higher school, aids students in comprehending difficult abstract ideas and equips them for jobs demanding spatial analysis and visualization (Zalukhu et al., 2023) . Topics including matrices, flat forms, geometry, determining the distances between points in three-dimensional space, and linear programming were all addressed in the fourth semester's required Algorithm and Programming course. Understanding these subjects required a great deal of abstract thought and visualizing abilities. However, because the subject matter was so abstract and complicated, pupils frequently found it difficult (Ayuni Sara & Danawak, 2021) . This issue was made worse by the dearth of educational materials that could interactively and visually illustrate mathematical ideas.

In this situation, mental rotation and spatial imagery were essential for assisting students in comprehending and resolving visual mathematical issues. Students with spatial ability were able to visualize geometric objects, comprehend translation and rotation, and translate visual structures into algorithms Parkinson & Margulieux (2025) . Students' performance in computer science and algorithm learning was greatly enhanced, and it was highlighted that spatial skills were flexible and transferable to programming abilities.

According to Herrera et al. (2024) , 3D visualization exercises greatly improved students' spatial comprehension when teaching mathematics. In contrast to the control group, which improved by only 5%, the experimental group improved by almost 25%. This illustrated how visual-based methods can help make difficult programming and mathematics easier to understand.

Spatial aptitude was crucial in lowering students' cognitive burden in linear programming. Students frequently faced significant mental strain when understanding solution sets in two or three dimensions and visualizing them graphically. Li et al. (2025) integrated multimodal cognitive diagnostic modeling, eye-tracking, and object assembly tasks. According to their findings, students who were proficient in spatial visualization techniques were able to create organized mental models and complete challenging assignments like linear programming more quickly and with less cognitive strain.

These results demonstrated that the use of visual technology, like GeoGebra AR, was an effective way to improve students' spatial and conceptual comprehension as well as to help them overcome difficulties in learning programming and algorithms in higher education.

The usefulness of GeoGebra as a visualization tool for teaching mathematics, particularly abstract ideas like geometry, algebra, and calculus, was demonstrated by earlier study by Askar (2022) . The findings showed that GeoGebra's dynamic and interactive elements, which provide more visual possibilities than traditional teaching techniques, improved pupils' comprehension. Its application was still restricted to two-dimensional computer screen displays, though, and it was not integrated into three-dimensional or real-world settings.

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In contrast to Askar's research, this study explicitly created an interactive textbook that combines Augmented Reality (AR) with GeoGebra. Through this connection, users were able to examine and edit mathematical objects in real space, enabling mathematical visualization not only digitally but also contextually and immersively. The study concentrated on the Algorithm and Programming course, which needed a lot of visual aids but had not received much attention in the creation of learning materials based on GeoGebra AR. Thus, this study made a contribution by offering a more relevant and integrative learning tool that helped students meet their demands for spatial visualization in order to comprehend mathematical algorithms in a more dynamic and tangible way.

The learning process should use instructional media that can give the mathematical concepts being taught more tangible form, considering the features of the Algorithm and Programming course. Technology-based learning is one of the most crucial strategies, and learning medium are always changing (Batubara, 2022) . Students can study abstract mathematical concepts with the help of a variety of technology, including mathematics applications.

Learning media are instruments that link the sender and the recipients of messages, claims (Abi Hamid, 2020) . They can improve one's motivation to actively engage in the learning process as well as one's thoughts, emotions, and focus. One such approach is the digital visual based learning application GeoGebra.

Numerous digital learning resources are available to assist students in viewing mathematical concepts in an interactive manner thanks to advancements in educational technology. One of the most well-known is GeoGebra, a program that uses dynamic visual simulations to assist students comprehend complex ideas like geometry, algebra, and calculus (Askar, 2022) . Nevertheless, GeoGebra's traditional application is currently restricted to two-dimensional computer screens and does not yet enable real-world involvement.

By fusing real time digital elements with the physical world, augmented reality (AR) offered a fresh strategy. AR improved visualization and engagement by enabling students to immediately observe, control, and interact with digital items in their physical surroundings. According to Sirakaya & Sirakaya (2018), AR sped up the comprehension of abstract mathematical ideas.

Additionally, Petrov & Atanasova (2020) discovered that combining AR with GeoGebra greatly enhanced pupils' comprehension of three dimensional shapes. In a similar vein, Nita & Pratiwi (2022) created augmented reality (AR) materials for programming algorithm courses and found that students' comprehension of algorithmic flow and visual logic improved when they interacted directly with virtual objects.

According to Tomaschko & Hohenwarter (2019) , utilizing AR in conjunction with GeoGebra enhanced students' comprehension of geometry ideas, making it a creative, useful, and successful teaching tool. This project created an interactive textbook for the Algorithm and Programming course that incorporates GeoGebra with AR based on these factors. This study established a combined medium that offered dynamic simulations in three-dimensional environments, intended to help students understand complicated and abstract algorithmic principles, in contrast to earlier research that utilized GeoGebra or AR individually and mostly to basic mathematics.

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This study was developing an interactive textbook that integrated GeoGebra with Augmented Reality (AR) technology for teaching the Algorithm and Programming course. Unlike previous studies that generally employed GeoGebra or AR separately and were limited to basic mathematics topics, this research introduced an innovation in the form of a learning medium that combined dynamic mathematical simulations with three dimensional visual interactions in real contexts. It was designed to help students understand algorithmic concepts that were complex and abstract.

The created product could be used in programs relating to mathematics, such as engineering, information systems, or physics education, in addition to the Mathematics Education curriculum. It was anticipated that this study will aid in the creation of visual technology based learning models for mathematics that emphasize improving spatial awareness, conceptual comprehension, and immersive learning opportunities.

Therefore, this study's goal was to overcome the shortcomings of the visual-based learning materials that were already available, which did not yet fully incorporate AR and GeoGebra. Furthermore, the goal was to offer educational materials that matched the needs of students in higher education as well as the features of algorithmic content.

## Research Methods

This study was carried out at UIN Sulthan Thaha Saifuddin Jambi's Mathematics Education Program, which is situated in Jl. Jambi–Ma. Bulian KM 16, Sei. Duren, Kec. Jaluko, Kabupaten Muaro Jambi, Jambi Province. With the help of GeoGebra AR, the research aimed to create a legitimate and useful product in the shape of a mathematics textbook. The study was designed utilizing the Research and Development (R&D) technique. The ADDIE development model, which is thought to be more intricate and structured than the 4D model, was used. It comprises the following thorough and methodical stages: Analysis, Design, Development, Implementation, and Evaluation (Dick et al., 1996) . For the development of a GeoGebra AR textbook that needed iterative integration of visualization and interactivity, the ADDIE model was selected because it offered flexibility for the processes of revision, validation, and evaluation of technology-based learning materials (Buchori et al., 2023; Sarah et al., 2025).

The creation of this product was highly relevant to each of the ADDIE model's stages: the Analysis stage was used to determine how students needed to visualize mathematical concepts; the Design stage helped organize the content, interactive flow, and integration of GeoGebra AR, the Development stage made sure that the product was developed and approved by subject-matter and media experts, the Implementation stage concentrated on textbook trials in the classroom, and the Evaluation stage measured the product's validity, usefulness, and efficacy prior to its wider use (Gusteti et al., 2025).

Thirty fourth-semester Mathematics Education Program students enrolled in the Algorithm and Programming course participated in this study. In order to evaluate the viability of the GeoGebra AR-assisted textbook, the subjects were chosen by purposive selection, taking into account that fourth-semester students already had pertinent basic knowledge in mathematics and programming. To update and improve the created textbook, the study used a validation procedure. Two knowledgeable lecturers from UIN Sulthan Thaha Saifuddin Jambi's Faculty of Tarbiyah and Teacher Training's Mathematics Education Program served as the validators, evaluating the language, media, and content. The two validators were chosen because they were experts in media design, educational technology, and the creation of technology-based instructional materials, and they had taught the required courses for more than five years. This study was more concerned with product validation than with gathering data in a variety of ways. In order to more objectively assess the textbook's quality, the research exclusively used source triangulation, which involves comparing the validators' evaluations with the students' comments and the course lecturers' input.

Here’s the English translation of your sentence in academic style:

A thorough identification of the subject matter to be taught, the learning environment, and the learning needs was done at the analysis stage. This analysis includes knowing the participants' characteristics, any competency gaps, and the technical setup, including the devices needed to use GeoGebra. Ar. In depth study is necessary to guarantee an accurate and pertinent instructional design, according to (Morrison et al. (2019).

Data collecting, the creation of the learning flow (flowchart), and the creation of an interactive GeoGebra AR-based design were all part of the design stage. The modules' structure, interaction strategies, and evaluation formats were decided by this design (Adiguna et al., 2025). The process of turning the design into a prototype textbook that integrated GeoGebra AR was known as the development stage. At this point, subject matter, media, and language experts produced material, processed visual media, and conducted validation. According to Buchori et al. (2023), the verified GeoGebra AR-based prototype had a 90% level of validity and practicality. The GeoGebra AR textbook was tested in actual classrooms during the implementation stage to evaluate its usefulness and efficiency. The product was improved with input from instructors and students (Sarah et al., 2025). Formative assessment throughout the development phase and summative assessment following implementation were both included in the last stage, evaluation. Through data analysis tools like N-gain (Buchori et al., 2023) and user evaluations, this assessment sought to gauge the product's validity, usefulness, and efficacy (Sarah et al., 2025).

Data for this study was gathered using learning outcome test sheets, teacher practicality questionnaires, and student practicality questionnaires. Using a four-point Likert scale (1 being extremely terrible and 4 being very good), the media validation questionnaire was created to evaluate the GeoGebra AR textbook's look, content completeness, and language clarity. Students and instructors in the Algorithm and Programming course were given realistic surveys using the same Likert scale to assess the course's usability, content comprehension, and media's ability to enhance learning. Two knowledgeable lecturers evaluated the questionnaires' validity using their professional judgment, and internal consistency analysis was used to determine their dependability. The purpose of the learning outcome test sheets was to assess both conceptual knowledge and algorithmic application skills. During the development stage, students and lecturers were given practicality questionnaires to complete, and media validation

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questionnaires filled out by the validators were used to evaluate the learning media's validity. The efficiency of the GeoGebra AR textbook was evaluated during the installation phase in the classroom of the Algorithm and Programming course.

## Results and Discussion

This section discusses the research findings. The findings discussed the ADDIE development process for producing GeoGebra AR based math teaching resources. The ADDIE model analysis, design, development, implementation, and evaluation was adhered to during the development phases. In order to create the instructional materials, the researchers started with the analysis step. Interviews and observations made during the Algorithm and Programming course's instruction were used to conduct this step. The development of a mathematics textbook utilizing the GeoGebra program and Augmented Reality capabilities was determined to be crucial following an examination of the needs, content, and learning environment at the analysis stage. Students may benefit from this textbook's ability to relate mathematical concepts to actual items. Both school-level mathematics and material from the Algorithm and Programming course were included in the textbook.

According to the Design stage's findings, the relationship between angles, the surface area of two-dimensional shapes, transformations, nets of three-dimensional objects, integrals, and the volume of three-dimensional objects were among the mathematical topics appropriate for use with Augmented Reality tools. These subjects were covered in the textbook by using GeoGebra AR to illustrate the concepts with examples from real-world situations. Making a flowchart was the next step. The purpose of the flowchart was to make the researchers' work on the textbook easier. To assist the researchers in creating the textbook, the flowchart was created as seen in Figure 1.

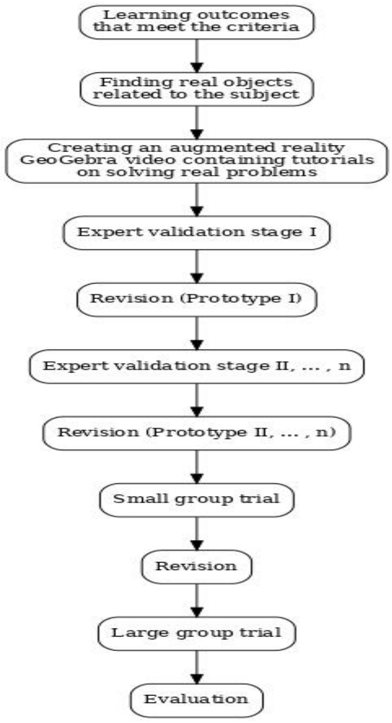


Figure 1. Research Flowchart

Figure 1 shows how the product development activities were conducted in a methodical manner according to the flowchart that was created. These activities included creating learning objectives, finding examples of real-life objects, creating videos, conducting validation stages 1 and 2, making revisions at these stages, conducting small group trials, revising again, and conducting large group trials. The material of the textbook complied with development requirements. This contained school-level mathematics that could be used with GeoGebra AR and content from the Algorithm and Programming course. Figure 2 shows the layout of the textbook that had been created.

Figure 2. Textbook Table of Contents

The components of the textbook table of contents design, which include an introduction to GeoGebra AR, three-dimensional and two-dimensional pictures, integrals, practice exercises, and references, are displayed in Figure 2 above. Additionally, the researchers used a few real-world objects to create GeoGebra AR films that were relevant to the subject matter. The following is an illustration of the GeoGebra AR application display:

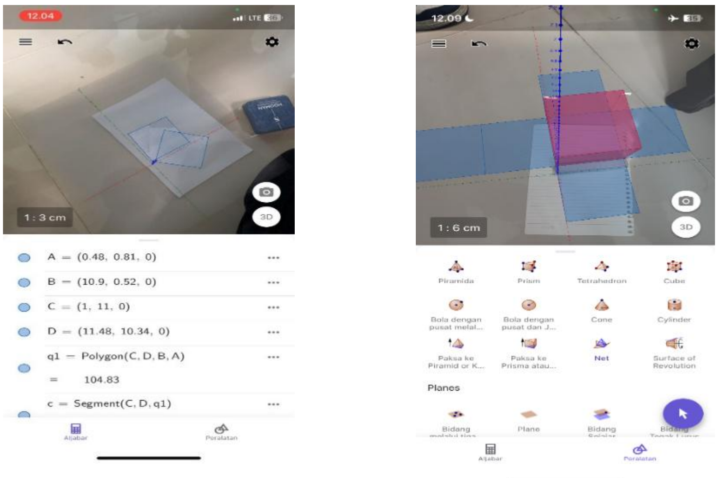

Figure 3. GeoGebra AR Application

A thorough examination of the topics covered in the Algorithm and Programming course as well as school-level mathematical subjects that might be

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incorporated using the GeoGebra AR platform was used to choose content that satisfied the development requirements. The following step strengthened the link between theoretical ideas and real-world applications by locating and mapping actual things that conceptually represented the content of the chosen material. As can be seen below, Table 1 offers a comprehensive list of actual things that correspond with each topic.

Table 1. Real Objects Used in GeoGebra AR Videos

| No. | Topic | Real Objects |
|---|---|---|
| 1 | Relationship between two angles | The surface of a circular powder container; intersection lines at a crossroads |
| 2 | Surface area of plane figures | Rubik's puzzle (pyramid) and powder box (cube) |
| 3 | Transformation | Student ID card surface (rotation) and hijab pin shaped like a pentagonal prism (dilation) |
| 4 | Nets of three-dimensional objects | Snack packaging shaped like a triangular prism; lipstick container (cylinder) |
| 5 | Volume of three-dimensional objects | Rubik's puzzle (pyramid) and powder box (cube) |
| 6 | Integral | Surface area of a leaf |

According to Table 1 above, GeoGebra AR was merged with six subjects. To make the product easier to use, a video tutorial on GeoGebra with Augmented Reality was included with each description of the content. Through barcodes connected to YouTube, students could access the tutorial videos included in this textbook and watch them as needed during lectures. These instructional films were created to complement the Algorithm and Programming course as well as school-level mathematics curriculum. To make sure the tutorial flow was suitable, the videos were edited using the CapCut program after being captured on mobile devices using a screen recording app.

The spherical surface of a powder container and the junction lines at a crossroads served as the actual items utilized in the "Relationship between Two Angles" topic. The produced movie claims that when a circle is subtended by the same arc, its central angle doubles in size. The calculation of the base area of a triangular Rubik's puzzle and one face of a powder box package was covered in the topic "Surface Area of Plane Figures." GeoGebra AR was used as the medium for this learning exercise, which could produce results like the ones in the following figure.

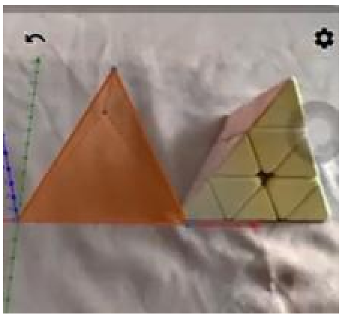

Figure 4. GeoGebra AR Visualization of a Rubik's Puzzle

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As seen in Figure 4, if you use the GeoGebra tool to generate a pyramid's net, you will notice that its base is triangular. The following formula is used to find the triangle's area.

Triangle area is equal to ½ × base × height (1)

A triangle's perimeter is determined by adding its sides together, specifically:

The total of the triangle's three sides is its perimeter (2)

A measuring device, such as a ruler, must be used to measure each side of the Rubik's base in order to apply the formula and get the answer. On the other hand, the area and perimeter of an object can be directly ascertained by using the GeoGebra AR program.

Following the completion of the GeoGebra AR movie editing process, the final result was assessed by professionals. At the Faculty of Science and Technology, UIN Sulthan Thaha Saifuddin Jambi, the evaluation was carried out by lecturers who taught Discrete Mathematics and Logic in the Information Systems Program and Algorithm and Programming in the Mathematics Education Program. The validators evaluated the product using four primary components: language, textbook presentation, content or subject matter, and usability.

This textbook received an average validation percentage of 90.53%, according to the validation results, meaning that it could be used with only minor changes. Validator I's average percentage was 88.42%, while Validator II's was 92.63%. At this validation stage, students' detailed quantitative data showed that the media/technology component scored 97.50%, the content component scored 88.33%, the language component scored 86.67%, and the practicality component scored 93.33%. The researchers moved on to the following phase, a small group trial to evaluate the generated textbook's usefulness, with the validators' consent. Ten students from the Mathematics Education Program participated in the small group trial. According to the results, the students were really happy with the textbook and hoped it would be used in the classroom soon, especially for the subjects it already covered. Additionally, the utilization of real-world object examples that are frequently encountered in daily life and the simplicity of the GeoGebra AR application which required users to click on the relevant features rather than conduct calculations by hand fueled their enthusiasm.

Through a Google Form created by the researchers, the students who took part in this study also answered questions about the product's usefulness. With a 93% practicality score, the questionnaire was deemed "very practical" and no changes were needed. Furthermore, the professors' practicality questionnaire yielded a score of 92.50%, which is likewise classified as "very practical" with no adjustments required. The researchers were able to move on to the next phase of development because to these findings. The researchers described the goals, subject matter, and additional value of the created textbook to the small group trial participants. Because the researchers stressed that the textbook used Augmented Reality techniques and included real-world objects from everyday life, all of the students were extremely excited during the trial. Additionally, because it was a component of mathematics courses, the researchers said that the textbook's content was very significant to them.

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Given the content previously covered in the textbook, the researchers discovered that students had a significant expectation that it will be issued shortly and used in lectures. The small group trial's findings demonstrated that the students strongly supported the researchers. They were excited by the usage of real-world object examples that they frequently saw and the fact that users merely needed to click on the appropriate features in the GeoGebra Augmented Reality (AR) application rather than doing manual computations.

The step of implementation, which included a large-scale group trial, came next. Students from the Mathematics Education Program participated in this experiment. Following an explanation of the textbook's goals, substance, and benefits by the researchers, the participating students were given evaluation tasks to finish. These tasks were designed to assess the effectiveness of the created GeoGebra AR textbook. Instead of completing tasks by hand on paper, the students were able to practice directly by utilizing the GeoGebra AR program. They might also use a screen-recording app on their phones to capture the findings of their evaluation. The following actions were taken during the implementation phase:

1) The researchers explained the textbook product that had been developed

The researchers first gave the chosen students an explanation of the generated textbook product during this big group trial stage. The researchers demonstrated the GeoGebra Augmented Reality (AR) textbook, as illustrated in Figure 5, explaining its elements, the motivations or goals behind its creation, its advantages, and usage guidelines so that students could comprehend and immediately utilize it.

Figure 5. Explanation of the GeoGebra Augmented Reality (AR) Textbook

Direct and active involvement with the pupils was a part of this two way explanation. As soon as the researchers demonstrated how to utilize the textbook, they told the students to scan the barcode that was shown on the screen. The following was the barcode that was scanned:

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Figure 6. Barcode for GeoGebra AR on Calculating the Base Area and Perimeter of a Pyramid and a Cube

The students were taken straight to a video of one of the subjects connected to actual objects after scanning the barcode, as illustrated in Figure 6, where GeoGebra Augmented Reality (AR) was used to illustrate the problem-solving procedure. For instance, the video demonstrated how to determine the area of one side of a powder box package and the base area of a Rubik's puzzle in the shape of a triangular pyramid when discussing the issue of calculating the surface area of plane figures.

2) The researchers provided the students with an opportunity to ask questions

Following their explanation of the textbook, the researchers let the students to ask questions, make ideas, or leave comments. A number of pupils expressed concerns about the GeoGebra Augmented Reality (AR) application's technological functionality and connection to mathematics, including: 1)Does this software work with any kind of mobile device?; 2) Will the findings produced by GeoGebra Augmented Reality (AR) be reliable when compared to computations done by hand?; 3) What is the process for installing this app on a mobile device?; 4) Should we as students grasp mathematical ideas, or is it enough to learn how to use mathematical apps like GeoGebra Augmented Reality (AR) for the future?; 5) What obstacles to mathematical advancement does the introduction of GeoGebra Augmented Reality (AR) technology present?

By offering helpful information and criticism, these questions assisted the research team in creating a textbook that satisfied the demands of the students. They also provided the team with assessment data to help them create suggestions for more study. The kids' favorable responses to the questions also showed that they understood how intimately mathematics related to their daily lives. Since the material they had previously learned was remained abstract, the contextual approach taken in the textbook's construction encouraged pupils to study mathematics.

The pupils were also able to identify nearby objects using GeoGebra Augmented Reality (AR) to ascertain their area, shape, and transformation outcomes. They had about twenty minutes to investigate, according to the research team.

3) The researchers administered evaluation tasks to assess the effectiveness of the product

The students were then given evaluation tasks to complete in order to gauge how well the created textbook worked. The researchers gave the students

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items like a lipstick bottle, a powder box, and a Rubik's puzzle to practice GeoGebra Augmented Reality (AR). Finding the net of the Rubik's cube, figuring out the net of the lipstick box that resembled a rectangular prism, and showing the rotation result of the powder box with a square base were among the tasks that were assigned. Working in the previously designated groups, the students had thirty minutes to finish these assignments. In accordance with the guidelines in the assigned assignments, each group chose a single item to practice.

4) The researchers conducted a reflection session and collected the students' completed answers

To see how each group responded to the questions, the research team took pictures and videos after the students finished the activities they were given. The following were the tasks' documented outcomes:
a) Group 1

Group 1 was tasked with figuring out a Rubik's cube's net. They chose the 3D Calculator mode on the application's main screen after installing and launching the GeoGebra Augmented Reality (AR) program successfully. As seen in Figure 7 below, they then navigated to the 3D view located in the top right corner of the screen.

Figure 7. AR Space Calibration Process on the Rubik's Puzzle by Group 1

One of Group 1's members is seen in Figure 7 pointing the iPhone camera at a level surface the classroom floor and identifying the chosen object, a Rubik's cube. They changed the Cartesian grid position until they got the right proportions by carefully moving it around the flat surface. They were able to effectively display the Rubik's cube visualization by following the instructions in the movie, as seen in Figure 8.

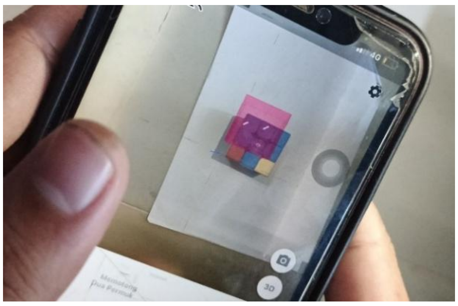

Figure 8. Visualization Display of the Rubik's Puzzle by Group 1

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Using the GeoGebra Augmented Reality (AR) program, Group 1 was able to correctly perceive the Rubik's problem, presenting it as a cube (Figure 8). They had not yet been able to present the Rubik's cube net, though.

b) Group 2

They were tasked with figuring out a lipstick box's net. They chose the 3D Calculator mode on the application's main screen after installing and launching the GeoGebra Augmented Reality (AR) program successfully. As seen in the graphic below, they then had access to the clear 3D view.

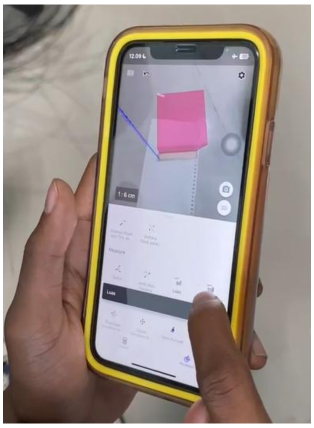

Figure 9. Visualization Display of the Lipstick Box by Group 2

One of Group 2's members is seen in Figure 9 directing the iPhone camera at a level surface the classroom floor and identifying the chosen object the lipstick box that resembles a rectangular prism. The lipstick box was visualized as a rectangular prism after they achieved the Cartesian grid location with a 1:6 ratio by slowly dragging it along the flat surface. By clicking the "net" symbol as directed in the previously viewed video, Group 2 was able to properly present the lipstick box's net. As seen in Figure 10, this instantly exhibited the rectangular prism's net.

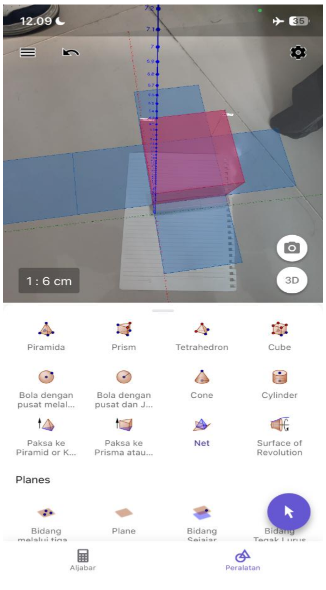


Figure 10. Net Display of the Lipstick Box in the Form of a Rectangular Prism

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The net of a rectangular prism is depicted in Figure 10 and is made up of six rectangle-shaped plane figures: the bottom side with the top side, the right side with the left side, and the front side with the back side.

c) Group 3

Displaying the rotation result of a powder box with a square base was the task that this group worked on. The GeoGebra Augmented Reality (AR) app was successfully installed and launched. On the application's main screen, they then chose the 3D Calculator mode. Then, as illustrated in Figure 11, they accessed the 3D view and turned on the AR mode, which is situated in the top right corner of the screen.

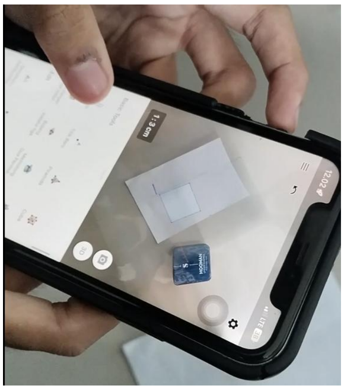

Figure 11. Visualization Display of the Powder Box by Group 3

One of the Group 3 members is shown in Figure 11 directing the iPhone camera at a level surface the classroom floor and identifying the chosen object the square-based powder box. The powder box with a square base was visualized when they achieved the Cartesian grid location with a 1:3 ratio by slowly sliding it along the level surface. Group 3 successfully demonstrated the powder box's rotation outcome with a square base by modifying the rotation's degree and direction in accordance with the guidelines in the previously shown video.

d) Group 4

They worked on figuring out the net of a lipstick box that was shaped like a rectangular prism. The GeoGebra Augmented Reality (AR) app was successfully installed and launched. On the application's main screen, they then chose the 3D Calculator mode. They then accessed the 3D view and turned on the AR mode, which is situated in the top right corner of the screen.

Figure 12. AR Space Calibration Process on the Lipstick Box by Group 4

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One of Group 4's members is seen in Figure 12 directing the iPhone camera at a level surface the classroom floor and identifying the chosen object the lipstick box shaped like a rectangular prism. They tried to get the Cartesian grid position by slowly moving it around the flat surface, but the lipstick box representation was still not visible. Group 4 had not yet been successful in modifying the correct positional ratio, but they were able to display the coordinate points using the GeoGebra Augmented Reality (AR) application. As a result, they couldn't see the lipstick packaging.

5) The researchers conducted an evaluation of the implementation stage that had been carried out

The following findings were reached when Groups 1, 2, 3, and 4 finished their tasks: 1) For smooth AR surface detection which some groups had trouble with a well lit environment is necessary. 2) Because AR features use a lot of power, the iPhone battery needs to be enough. 3) Downloading the GeoGebra Augmented Reality (AR) app requires a steady internet connection. 4) Two groups were able to finish half of the activities, while two groups were able to finish all of the tasks flawlessly up until the last step.

Overall, though, every group was successful in the preliminary setup phase (installing the GeoGebra Augmented Reality (AR) program and turning on the AR camera). They frequently ran into trouble modifying the positioning ratio during the usage procedures. In terms of using the application's tools, some of them were already able to make use of its capabilities, like choosing the tools needed for the jobs and taking screenshots or recording videos.

The outcomes of the trials and validation demonstrated that the GeoGebra AR-based textbook was not only viable and useful, but also offered a novel educational experience in contrast to traditional media. By combining GeoGebra with Augmented Reality technology, pupils were able to see geometric objects in real-world settings, which helped them create more organized and distinct mental images. When it came to abstract subjects like linear programming and nets of three-dimensional figures, spatial visualization integrated into authentic learning settings assisted in lowering cognitive burden. Students could now see and work with the things directly rather than only imagining the shapes. This accounted for the high degree of practicality attained and the fact that multiple groups were successful in finishing the assignments completely. However, several groups were unable to complete the tasks flawlessly due to technical issues including poor illumination and challenges with AR calibration. These results were consistent with earlier research that highlighted the beneficial role that 3D visualization plays in mathematical problem solving (Herrera et al., 2024; Li et al., 2025) and validated the idea that spatial abilities may be improved (Parkinson & Margulieux, 2025). Therefore, this study offered a novel approach in that the use of GeoGebra AR in textbooks guided students toward more efficient thinking techniques for resolving challenging algorithmic problems in addition to aiding conceptual knowledge.

In the last step, evaluation, a comprehensive assessment was carried out from the start of the procedure to its conclusion. Following the completion of the study, a number of factors were assessed, one of which was the necessity of

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incorporating usage guidelines and instructions for the GeoGebra Augmented Reality (AR) application. These additions were incorporated into Chapter 1 of the developed book by the authors who revised the textbook. Additionally, it was made clearer that GeoGebra Augmented Reality (AR) must be used to finish the tasks that were given to them. The purpose of this clarification was to make sure that the instructions would not be unclear to the students.

## Conclusion and Suggestion

With a content validation percentage of 88.33%, a language validation percentage of 86.67%, and a media validation percentage of 97.50%, the research findings demonstrated the validity of the mathematics textbook based on GeoGebra AR. Additionally, questionnaires were used to evaluate the textbook's usefulness, and the findings showed that 90% of lecturers and 93.33% of students agreed. As a result, the textbook turned out to be practical and advantageous for use in math education. As a result, this textbook for the course on algorithms and programming presents a fresh approach to making mathematical ideas more tangible and approachable for students. Naturally, the development of textbooks for additional courses that cover abstract mathematical ideas is anticipated to carry on this study. Thus, our study's contribution is to offer learning materials that are not only legitimate and useful, but also able to support students' spatial visualization techniques through engaging educational experiences. The capacity of GeoGebra AR to close the gap between concrete representations and abstract ideas is one of the new features provided. Additionally, this could raise the standard of mathematics instruction in postsecondary institutions.

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