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Developing Scratch-Based Learning Media to Improve Junior High School Students' Understanding of Curved-Sided Geometric Concepts

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Abstract

The abstract nature of curved-surface solid geometry often creates learning barriers for students. However, the integration of visual programming platforms such as Scratch into mathematics learning can provide dynamic visualizations that make concepts more concrete and easier to understand. This study aimed to develop Scratch-based mathematics learning media that meets the criteria of validity and practicality for curved-surface solids. The study employed a research and development approach using the ADDIE model, limited to the analyze, design, and development stages. The sample consisted of 2 mathematics teachers and 9 students. Research instruments included media and material expert validation questionnaires, as well as teacher and student response questionnaires. The results showed that the media expert evaluation reached 86.9% and the material expert evaluation reached 83.6%, both categorized as highly valid. The practicality of the media was indicated by teacher responses of 85% and student responses of 98.46%, both categorized as highly practical. Therefore, the Scratch-based learning media was considered valid and practical for stimulating students' conceptual understanding of curved-surface solid geometry. Future studies are recommended to examine its effectiveness using larger samples and different mathematics topics.

Keywords: instructional media, conceptual understanding, curved solid geometry, scratch

Pengembangan Media Pendidikan Berbasis Scratch untuk Meningkatkan Pemahaman Konsep Geometri Bangun Ruang Sisi Lengkung

Abstrak

Sifat abstrak pada materi bangun ruang sisi lengkung sering kali menimbulkan hambatan belajar bagi siswa. Namun, integrasi platform pemrograman visual seperti Scratch dalam pembelajaran matematika dapat memberikan visualisasi dinamis sehingga konsep menjadi lebih konkret dan mudah dipahami. Penelitian ini bertujuan untuk mengembangkan media pembelajaran matematika berbasis Scratch yang memenuhi kriteria valid dan praktis pada materi bangun ruang sisi lengkung. Penelitian ini menggunakan pendekatan penelitian dan pengembangan dengan model ADDIE yang dibatasi pada tahap analyze, design, dan development. Sampel penelitian terdiri atas 2 guru matematika dan 9 siswa. Instrumen penelitian meliputi angket validasi ahli media dan ahli materi, serta angket respons guru dan

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siswa. Hasil penelitian menunjukkan bahwa penilaian ahli media memperoleh persentase sebesar 86,9% dan penilaian ahli materi sebesar 83,6%, yang keduanya termasuk dalam kategori sangat valid. Kepraktisan media ditunjukkan melalui respons guru sebesar 85% dan respons siswa sebesar 98,46%, yang keduanya termasuk dalam kategori sangat praktis. Oleh karena itu, media pembelajaran berbasis Scratch dinyatakan valid dan praktis untuk menstimulasi pemahaman konsep siswa pada materi bangun ruang sisi lengkung. Penelitian selanjutnya disarankan untuk menguji efektivitas media dengan melibatkan sampel yang lebih luas dan materi matematika yang berbeda.

Kata kunci : Media pembelajaran, pemahaman konseptual, geometri sisi lengkung, scratch

INTRODUCTION

Conceptual understanding plays a crucial role in mathematics learning. It represents a fundamental ability that students must acquire in order to master more advanced mathematical concepts (Aledya, 2019). According to PISA (OECD, 2022), mathematical literacy involves the capacity to reason systematically and apply conceptual understanding in various real-life contexts. Therefore, conceptual understanding is not merely procedural knowledge but a critical foundation for meaningful mathematics learning.

Mathematics learning plays an important role in developing students' logical, analytical, and problem-solving skills (Syaiful et el., 2021; Christidamayani & Kristanto, 2020). One of the essential branches of mathematics is geometry, which requires students to understand abstract concepts through visualization and spatial reasoning (Almubarak et al., 2025; Medina Herrera et al., 2024). However, geometry learning is often considered difficult because many concepts cannot be directly observed in concrete form. One of the important concepts in geometry is curved solid figures, which students often find challenging. Such difficulties are generally caused by the dominance of procedural approaches in instruction, where students are directed to memorize formulas without understanding their meaning and origins conceptually (Khoirunnisa et al., 2020). Research by Jo and Hong (2020) revealed that students tend to have incomplete understanding of spatial concepts, both in identifying and generating them independently. Similarly, Pauweni et al. (2019) reported that students' conceptual understanding of curved solid figures was at a moderate level, indicating that the teaching methods employed were not fully effective in building strong conceptual

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foundation. This is consistent with interview results obtained from a junior high school in Yogyakarta, which revealed that mathematics learning still relied heavily on conventional methods and lacked the integration of technology-based instructional media. Consequently, students' understanding and interest in learning mathematics, particularly in geometry, remain limited.

To address this issue, the teaching of curved solid figures must be effectively designed to support students' success in mastering the material (Marasabessy et al., 2021). This requires innovative, interactive, and effective instructional media. Beyond effective pedagogical models, appropriate media are essential to help students grasp abstract content, particularly through technology-based solutions (Rahmawati et al., 2024). Resti et al. (2024) highlighted that educational technology can address students' individual learning needs, while Putra and Rahmawati (2022) showed that interactive media enhances conceptual understanding through visualization and interactive simulations.

Innovative and interactive media are those that can enhance students' interest in learning mathematics. Interactive instructional media serve as technological tools that facilitate communication and enable active interaction during learning (Choir & Abdullah, 2021). In line with this, Cahdriyana and Richardo (2016) emphasized that effective instructional media should be interactive, motivating, and stimulating, thereby promoting student engagement, feedback, and reinforcement (Rochaendi & Sholihah, 2024). One promising solution is the development of Scratch-based instructional media to overcome the limitations of existing approaches, particularly in teaching curved solid geometry. Azizul et al. (2024) stated that Scratch offers innovative teaching techniques to improve students' skills and understanding in the learning process. Similarly, Puteri and Farhurrohman (2024) found that delivering content through Scratch-based media using animations provides students with interactive and enjoyable learning experiences, strengthening their conceptual understanding through visualization and direct interaction.

Previous studies have demonstrated the effectiveness of technology-assisted media in mathematics learning, such as augmented reality for curved solid geometry (Agung, 2023), and Macromedia Flash-based learning media (Fadillah et.al., 2023). However, these studies mainly focused on general learning outcomes and visualization

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aspects, while limited attention has been given to the development of interactive Scratch-based media specifically designed to stimulate students' conceptual understanding of curved solid geometry. In addition, Scratch-based learning for curved solid figures has mostly been implemented in the form of e-modules, limiting students' opportunities for dynamic interaction and exploration. Therefore, this study offers a novelty by developing interactive Scratch-based instructional media oriented toward students' conceptual understanding of curved solid geometry. Accordingly, the purpose of this study is to develop a Scratch-based instructional media product for curved solid figures and to examine its validity and Practicality facilitating students' conceptual understanding of this topic.

RESEARCH METHODS

This study employed a Research and Development (R&D) design. Research and Development is a method used to produce a specific product and to test its effectiveness (Sugiyono, 2016; Afrijal et al., 2021). The data collection techniques and instruments used in this study included interviews and questionnaires. The interview was conducted in person on October 31, 2024, with a mathematics teacher at a junior high school in Yogyakarta to gather information regarding learning needs and characteristics. Meanwhile, the questionnaires were administered to two media experts, two content experts, two mathematics teachers, and nine students.

The involvement of two mathematics teachers and nine students was considered representative of a small-group trial intended to gather initial user feedback on the developed media. In development research, small-group trials commonly involve approximately 6–12 participants, which is considered sufficient to identify the usability, practicality, and quality of instructional media before large-scale implementation (Dick et al., 2015). The questionnaires were employed to evaluate the validity and practicality of the Scratch-based instructional media developed in this study. Accordingly, this study aimed to develop instructional media that meets the criteria of validity and practicality in facilitating students' conceptual understanding of curved solid geometry.

The development process followed the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The analyze stage was conducted through interviews and literature reviews consisting of needs analysis, material analysis, and technology analysis. The needs analysis identified

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several problems in mathematics learning, including students' difficulties in understanding curved solid geometry, the continued use of conventional teaching methods, and the availability of supporting facilities such as Wi-Fi, projectors, and facility of ICT others. The material analysis involved reviewing mathematics textbooks, journals, the Independent Curriculum, and learning outcomes related to curved solid geometry. Meanwhile, the technology analysis focused on selecting appropriate devices and systems for developing the instructional media.

The design stage included preparing instructional materials, designing flowcharts and storyboards, and determining strategies for presenting the content through animations, videos, audio, and quizzes. The development stage consisted of pre-production, production, and post-production activities. The pre-production stage involved preparing materials, creating scripts, and selecting media components such as images, animations, sounds, and videos. The production stage focused on developing the Scratch-based instructional media. Finally, in the post-production stage, the developed media was validated by media experts and material experts and subsequently revised based on the validation results. However, this study was limited to three stages, namely analysis, design, and development. The stages carried out in this study are described as follows:

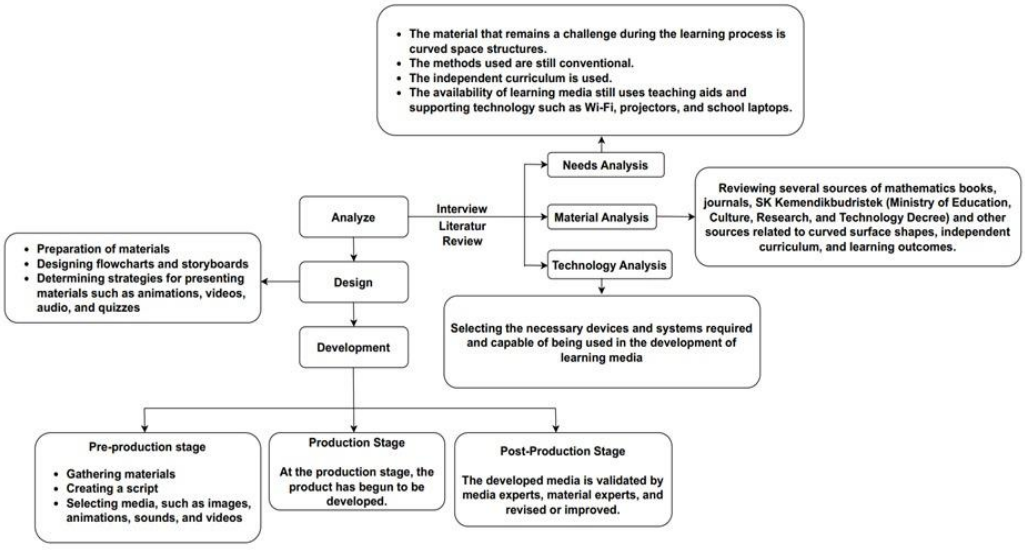


Figure 1. Development Procedure

In line with the stated objectives, this study aimed to examine the validity and practicality of the developed instructional media. The validity was assessed through expert evaluation involving a media expert and a subject-matter expert. The practicality

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test was conducted with two mathematics teachers and three ninth-grade students from one of public junior high school in yogyakarta, who were selected based on their level of mathematical ability (low, medium, and high). This selection was intended to evaluate the practicality of the product when used by students with diverse characteristics. Once the media was considered practical, it could be further tested in broader classroom settings involving students with various ability levels.

The instruments employed in this study consisted of a media expert validation questionnaire, a subject-matter expert validation questionnaire, a teacher practicality questionnaire, and a student practicality questionnaire. Data analysis techniques included both qualitative and quantitative descriptive analysis. Qualitative data were obtained from comments, suggestions, and feedback provided by the validators. Quantitative data were derived from Likert-scale ratings (1–5), where a score of 1 indicated "Strongly Disagree," a score of 2 "Disagree," a score of 3 "Somewhat Disagree," a score of 4 "Agree," and a score of 5 "Strongly Agree". Which were analyzed to determine the validity and practicality of the product using the following formula.

$$P = \frac{Total\ Score\ Obtained}{Maximum\ Score} \times 100\%$$

where P represents the average percentage score. The maximum score is determined by multiplying the total number of items by the highest possible score on the Likert scale. The level of validity was determined based on the validation sheet and categorized as follows

Table 1. Validity Criteria

Average Score (%)	Criteria
0-20	Invalid
21-40	Less Valid
41-60	Fairly Valid
61-80	Valid
81-100	Very Valid

The criteria for the practicality of the media products produced are stated in the following categories

Table 2. Practicality Criteria

Average Score (%)	Criteria
0-20	Inpractical
21-40	Less practical

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41-60	Fairly practical
61-80	Practical
81-100	Very practical

In this study, indicators of mathematical concept understanding are based on Bloom's Taxonomy, which encompasses three main aspects: (1) translation, which refers to students' ability to transform or translate an idea into another form, such as converting abstract concepts into symbolic models to facilitate the understanding process; (2) interpretation is the students' ability to interpret the meaning of an idea, including interpreting various data, symbols, and concepts to solve mathematical problems, (3) extrapolation is the students' ability to apply a concept or idea to solve problems and to be able to summarize what has been done or learned using their own words (Ubaidillah et al., 2025).

RESULTS AND DISCUSSION

The needs analysis indicated that students continued to experience difficulties in learning topics related to three-dimensional curved-surface solids because they found the concepts abstract and challenging to visualize. This aligns with research by Aprilia (2024), which finds that students face challenges in areas such as visualizing three-dimensional forms, understanding the components of these shapes, and connecting concepts to formulas for surface area and volume.

Furthermore, a content analysis was carried out to determine the scope of the curved-surface solid geometry material, ensure its alignment with the Merdeka Curriculum, and formulate the intended learning outcomes and indicators. The learning outcomes were established based on the Decree of the Head of the Agency for Standards, Curriculum, and Educational Assessment, Ministry of Education, Culture, Research, and Technology, Number 33 of 2024 (Kemendikbudristek, 2024). The learning outcomes are presented in Table 3.

Table 3. Learning Outcomes

Learning Outcomes	Learning Outcomes Indicators
Determining the nets of curved-sided solids (cylinders, cones, and spheres)	➢ Determine the nets and shapes of cylindrical solids. ➢ Determine the nets and shapes of conical solids. ➢ Determine the nets and shapes of spherical solids.

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Determining the surface area and volume of curved-sided shapes (cylinders, cones, and spheres)	➢ Determine the surface area and volume of a cylinder. ➢ Determine the surface area and volume of a cone. ➢ Determine the surface area and volume of a sphere.

Based on Table 3, a technology analysis was conducted to determine the hardware and software requirements for developing Scratch-based learning media. This analysis ensures that the media can be effectively developed and implemented within the intended learning environment.

The second stage is the design stage, which involves planning the instructional media to be developed. At this stage, the researcher prepared the essential components of the subject matter to be included in the media, such as definitions, properties, formulas, nets, and derivations of volume formulas. Furthermore, the researcher designed a flowchart and storyboard, as well as determined strategies for presenting the material, including the use of animations, videos, audio, and quizzes to enhance the understanding of concepts. In line with Amedia et al. (2023), it is shown that the use of animated videos combined with team quiz activities is effective in improving the mastery of concepts.

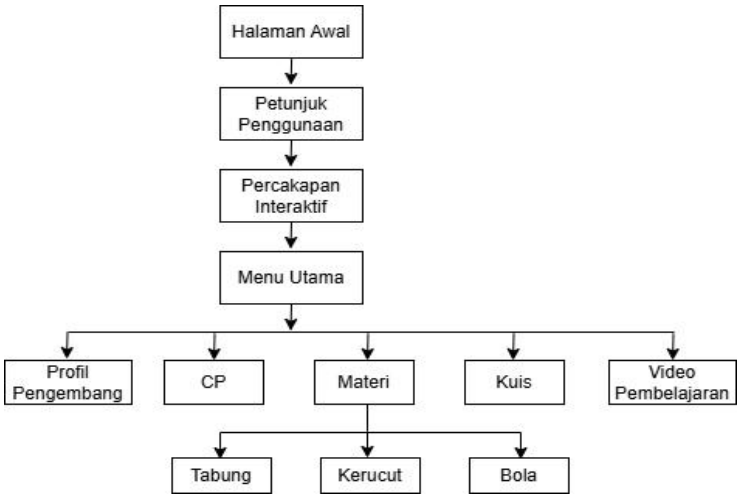


Figure 2. Flowchart

Figure 2 illustrates the flowchart of the Scratch-based instructional media developed in this study. The learning process begins with the home page, followed by the user guide and an interactive conversation designed to familiarize students with the navigation and features of the media before entering the main menu. From the main

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menu, users can access five primary sections: the developer profile, learning outcomes (CP), learning materials, quizzes, and instructional videos. The learning materials are further organized into three subtopics, namely cylinders, cones, and spheres, allowing students to explore each concept systematically. This hierarchical navigation structure was designed to provide a clear and user-friendly learning pathway, enabling students to access instructional content, multimedia resources, and formative assessments in an integrated learning environment.

As part of the design phase, a storyboard was prepared to provide a detailed description of each interface and its corresponding functionality within the instructional media. The storyboard served as a blueprint for the media development process by outlining the layout, learning content, navigation, multimedia elements, and user interactions for each screen. Following the completion of the storyboard, the instructional media was implemented using the Scratch programming platform. At this stage, each storyboard component was translated into a functional interactive application by integrating visual elements, animations, navigation controls, audio, and programming scripts. An example of the media development interface in Scratch is presented in Figure 3.

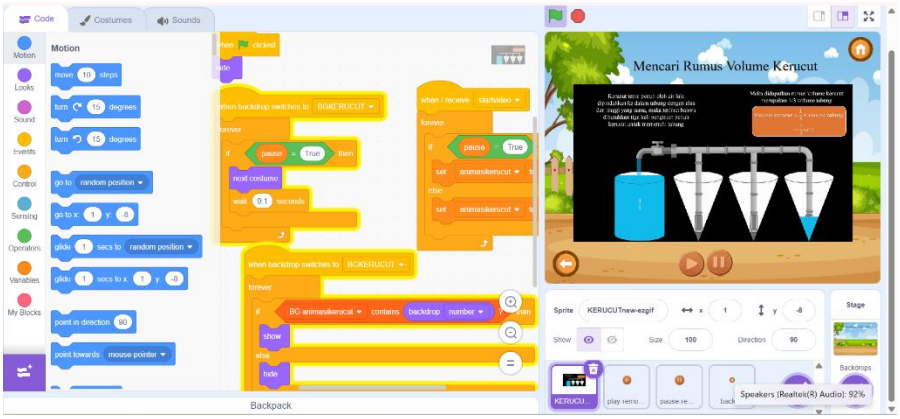


Figure 3. Designing Learning Media Using Scratch

Figure 3 illustrates the development of the instructional media using the Scratch programming environment. The left section of the interface displays the programming blocks used to define the media's functionality and interactive behaviors, including navigation, animation control, and user interaction. The right section presents the visual appearance of the instructional media, which integrates learning materials, animations, interactive simulations, and multimedia elements. By combining visual programming

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with multimedia features, Scratch facilitates the development of an engaging instructional medium that enables students to actively explore mathematical concepts related to curved-surface solids. As noted by Calder (2018), the use of Scratch can foster students' mathematical thinking, including in activities involving geometry and problem-solving.

The third stage was the development phase, which comprised three sequential processes: pre-production, production, and post-production. At this stage, the interface, navigation system, programming scripts, animations, and multimedia features were implemented and integrated into a functional instructional medium in accordance with the storyboard and flowchart prepared during the design phase. The production process resulted in a fully functional Scratch-based instructional medium consisting of several interconnected interfaces, each designed to support specific learning activities. A summary of the main displays and their respective functions is presented in Table 4.

Table 4. Learning Media Display

Display	Description
Splash Screen 	The splash screen is the initial display of media accompanied by loading..
First Page 	The home page displays the title ‘Bangun Ruang Sisi Lengkung’ (Building Curved Spaces), an animated teacher icon, and a start navigation button to begin accessing the media..
Instructions for Use 	Instructions for Use The instructions for use page contains guidelines for using learning media.
Interactive Conversation 	The display contains a conversation between animated teachers with added sound, and users will type in the answers that have been explained previously on the instructions page.
Main Menu 	This page contains several main navigation buttons, such as developer profile, learning outcomes (LO), materials, quizzes, and learning videos.

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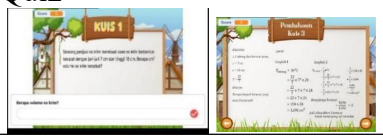
Learning Outcomes 	The learning outcomes display contains information related to learning outcomes and learning objectives to be achieved..
Main Menu tube material 	This page will contain three pages consisting of tubes, cones, and spheres.
	The tube display contains several explanations related to the definition of a tube, the properties of a tube, the formula for a tube, the net of a tube, and the calculation of the volume of a tube.
Quiz 	The quiz page contains instructions, quiz questions with answer columns, scores, and question explanations.

Table 4 presents the main interfaces of the Scratch-based instructional media and their respective functions. The media was designed with a sequential navigation structure that guides students from the introductory pages to the learning materials and assessment activities, thereby providing a systematic learning experience. A well-organized navigation structure can reduce learners' cognitive load and help them focus on essential learning content (Mayer & Fiorella, 2021).

The instructional materials are organized into three topics cylinders, cones, and spheres—and each topic integrates textual explanations, illustrations, animations, interactive simulations, and worked examples. The integration of multiple multimedia elements is consistent with the Cognitive Theory of Multimedia Learning, which suggests that combining verbal and visual representations can improve students' conceptual understanding (Mayer & Fiorella, 2021). Furthermore, the quiz feature provides immediate feedback through scores and answer explanations, enabling students to monitor their understanding and identify misconceptions. Immediate feedback has been shown to enhance learning achievement and self-regulated learning (Hattie & Timperley, 2007). Overall, the integration of multimedia resources and interactive

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features creates an engaging learning environment that promotes active participation and meaningful learning.

The final process in the development stage was post-production, during which the developed instructional media underwent expert validation and subsequent revisions to ensure its quality and suitability for classroom use. The validation process involved two groups of experts: media experts, who evaluated the technical and visual aspects of the instructional media, and subject matter experts, who assessed the accuracy, relevance, and appropriateness of the learning content. Feedback and recommendations from both groups of experts were used to refine and improve the instructional media before implementation. The results of the expert validation are presented in the following table 5 and table 6

Table 5. Validation Results by Media Experts

No.	Aspect	Score	P (%)	Validity Category
1.	Visual	35	87,5%	Very Valid
2.	Audio Visual	25	83,3%	Very Valid
3.	Text	35	87,5%	Very Valid
4.	Animation	18	90%	Very Valid
Total		113	86,9%	Very Valid

Table 5 shows that the Scratch-based mathematics learning media that has been developed obtained an overall percentage of with a category of highly valid. The improvement suggestions given by the media expert validator are that a play and pause button needs to be added to the animation for finding the volume formula, and the media expert validator stated that the Scratch-based learning media product for curved surface material is suitable for use with minor revisions.

Table 6. Validation Results by Subject Matter Experts

No.	Aspect	Score	P (%)	Validity Category
1.	Presentation	26	86,6%	Very Valid
2.	Contents	49	81,6%	Very Valid
3.	Questions	17	85%	Very Valid
Total		92	83,6%	Very Valid

Table 6 shows that the Scratch-based learning media that has been developed obtained an overall percentage of with the category of highly valid. The suggestions for improvement given by the subject matter experts are as follows: (1) Write down the learning outcomes and learning objectives in full, (2) include the titles of the main menu

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and material menu, (3) it would be better if the quizzes were made into contextual questions. The subject matter expert validator stated that the Scratch-based learning media product for curved-sided spaces is suitable for use with minor revisions.

Table 7. Revised by Media Experts

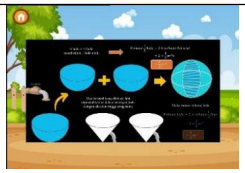
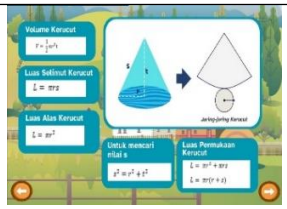
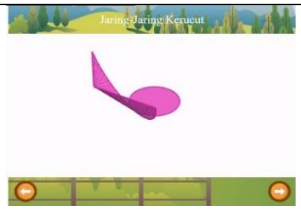
Recommendations	Before Revision	After Revision
A play and pause button needs to be added to the animation for finding the volume formula.		

Table 8. Revised by Media Experts

Before Revision	Before Revision	After Revision
It is recommended that the nets be made into their own backdrops and animated.		
It would be better if the quiz was replaced with contextual questions and all answers were changed to fill-in-the-blank questions.		

. Table 5 and 6 shows that the validation results indicated that the Scratch-based learning media achieved a very high validity level across all evaluated aspects, including visual design (87.5%), audio-visual integration (83.3%), text readability (87.5%), animation quality (90%), presentation (86.6%), content accuracy (81.6%), and assessment questions (85%). These findings suggest that the developed media was able to present curved-sided geometric concepts in a clear, engaging, and understandable manner for junior high school students. This result is consistent with Mayer & Fiorella (2021) Cognitive Theory of Multimedia Learning (CTML), which states that learning becomes more effective when information is presented through a combination of text, images, audio, and animation. The high scores obtained for the animation and visual

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aspects indicate that the Scratch-based media successfully helped students visualize abstract geometric objects, thereby facilitating the construction of mental representations. Furthermore, the integration of audio, text, and visual elements supports Mayer's multimedia, signaling, and modality principles, which can enhance students' attention and conceptual understanding.

From the perspective of Baddeley's Working Memory Theory (2000, 2012), the high validity scores also indicate that the learning media effectively optimized students' information-processing mechanisms within working memory. The visualizations and animations embedded in the media support the function of the visuospatial sketchpad, which processes visual and spatial information, while the textual and audio components facilitate the operation of the phonological loop, which processes verbal information. In addition, the systematic presentation of learning materials and the interactive assessment activities enable the central executive to allocate attention and coordinate information processing more efficiently, while the episodic buffer integrates newly acquired knowledge with information stored in long-term memory. Therefore, the combination of Mayer's multimedia learning principles and Baddeley's working memory theory provides a strong explanation for the effectiveness of the Scratch-based learning media in reducing cognitive load, enhancing information retention, and supporting meaningful understanding of curved-sided geometric concepts

After revisions and improvements were made by media and material experts, the next stage was to conduct practical tests with teachers and students. The practical tests were conducted by two mathematics teachers and students. The following are the results of the practical tests conducted by teachers and students.

Table 9. Practicality Test Results by Teachers

No.	Aspect	Score	P (%)	Practicality Category
1.	Presentation of Material	35	87,5%	Very practical
2.	Accuracy of Material	34	85%	Very practical
3.	Technical Quality and Appearance	33	82,5%	Very practical
Total		102	85%	Very practical

Table 9 shows that the Scratch-based mathematics learning media developed

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obtained an overall percentage in the very practical category. Several teachers responded that this media was very interesting and helpful in explaining curved surface material, and could make students learn more enthusiastically and understand concepts that were previously quite abstract. In addition, the media was very flexible, allowing students to learn from home, anywhere and anytime.

Table 10. Results of Practicality Tests by Students

No.	Aspect	Score	P (%)	Practicality Category
1.	Presentation of Material	57	95%	Very practical
2.	Accuracy of Material	60	100%	Very practical
3.	Technical Quality and Appearance	75	100%	Very practical
Total		192	98,46%	Very practical

Table 10 shows that the Scratch-based mathematics learning media developed obtained an overall percentage result in the very practical category. Several student responses related to the learning media said that the media display was attractive, exciting, and not boring. There were interactive conversations and animations that made students more enthusiastic about learning and improved their understanding of the concepts related to the material. The practicality findings based on the evaluations from both teachers and students indicate that the developed learning media is easy to use, easy to understand, and feasible for implementation in classroom learning activities. The highest score was obtained in the presentation aspect, suggesting that students perceived the learning flow and media navigation as clear and well-structured. This finding can be explained through the Technology Acceptance Model (TAM) proposed by Davis (1989), which states that users are more likely to accept and utilize a technology when it is perceived as useful and easy to use. Similarly, a study conducted by Saltan & Kara (2024) on the use of Scratch in geometry learning found that students' interest and intention to use Scratch were strongly influenced by their perceptions of its ease of use and usefulness. Furthermore, Venkatesh et al. (2003) argued that technology acceptance is influenced by performance expectancy and effort expectancy, which are reflected in learning environments that provide intuitive navigation and encourage

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active student participation. These characteristics are evident in the developed media through the integration of interactive activities, visual demonstrations, and structured learning sequences, which help students better understand curved-sided geometric concepts.

The material accuracy, technical quality, and appearance aspects indicate that the media not only delivers appropriate mathematical content but also provides a positive learning experience for students. From a usability perspective, Hornbæk (2006) emphasized that educational technologies with clear and user-friendly interfaces are more likely to be accepted and effectively utilized by learners. In line with this, O'Brien and Toms (2008) stated that attractive visual design, system responsiveness, and interactivity are important factors that enhance user engagement. In the context of mathematics education, Malik & Agarwal (2012), Siswanah (2017), Rahmawati et.al., (2024) found that interactive multimedia can improve students' motivation and conceptual understanding by transforming abstract mathematical concepts into more concrete and meaningful learning experiences. Research on Scratch-based learning environments has also shown that the interactive features available can promote learner autonomy and exploration, thereby increasing the practicality of the media and user satisfaction (Resnick et al., 2009). Therefore, the Scratch-based learning media developed in this study can provide a meaningful learning experience for students while minimizing barriers to the use of technology in mathematics education.

Beyond its validity and practicality, the effectiveness of the developed Scratch-based learning media can also be explained through its pedagogical design. The learning of curved-surface solids, including cylinders, cones, and spheres, should not merely emphasize the memorization of formulas but should facilitate students in constructing their own understandng of volume concepts through exploration and guided activities. This approach is consistent with Vygotsky's Zone of Proximal Development (ZPD) theory, which emphasizes that learners can achieve higher levels of understanding when supported by teachers, peers, or instructional media that provide appropriate scaffolding (Vygotsky & Cole, 1978; Arina et al., 2020). In the developed media, students are guided through a sequence of observations, explorations, and interactive activities that allow them to discover relationships among geometric concepts before arriving at formal volume formulas. Such learning experiences encourage active knowledge

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construction rather than passive reception of information, thereby supporting deeper conceptual understanding.

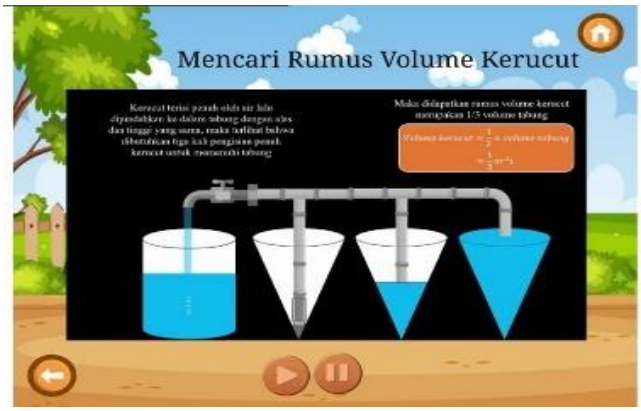


Figure 3. of the Discovery of the Volume of a Cone

The findings of the expert validation further support the pedagogical appropriateness of the developed media. The overall validation score from media experts reached 86.9%, while material experts awarded an overall score of 83.6%, both categorized as "very valid". The numerical results, the validators highlighted the appropriateness of visual design elements, including color selection, navigation buttons, audio quality, animation resolution, and font readability. These findings are consistent with previous studies indicating that technology-based learning media should integrate attractive visual layouts and high-quality multimedia elements to enhance learning experiences (Nadzif et al., 2022; Nicolaou, 2021). Furthermore, material experts noted that the learning content was presented systematically and was supported by animations illustrating the process of deriving volume formulas. This reflects the principles of Bruner's Discovery Learning Theory, which emphasizes that concepts should be introduced in a structured and hierarchical manner, enabling students to construct knowledge through discovery and direct experience (Jiang & Perkins, 2013; Goulet-Lyle, 2020). Such an approach is particularly important in mathematics, where conceptual understanding develops through recognizing relationships among interconnected ideas (Vohns, 2016).

The practicality results obtained from teachers and students also reinforce the suitability of the developed media for classroom implementation. The overall practicality score reached 86.15% from teachers and 98.46% from students, both categorized as "very practical." These findings indicate that the media is not only pedagogically appropriate but also accessible and convenient for users. Consistent with

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the findings of Lenggogeni and Roqoyyah (2021), the integration of animations within Scratch-based learning environments can increase students' interest and facilitate their understanding of mathematical concepts. In addition, the media provides flexibility for independent learning, allowing students to access instructional materials anytime and anywhere. Such flexibility is considered an important indicator of practicality because effective learning media should support ease of use and independent learning opportunities (Annisa et al., 2020; Nurhasanah et al., 2023).

One notable strength of the developed media lies in the systematic organization of learning content, beginning with definitions and properties of curved-surface solids, followed by guided activities for deriving volume formulas, and concluding with exercises and visualizations of geometric nets. The inclusion of animations that illustrate the process of discovering volume formulas helps students understand not only procedural calculations but also the underlying mathematical concepts. This finding supports Bruner's view that meaningful learning occurs when students actively construct knowledge through discovery and experience rather than simply receiving information from the teacher (Aduko & Armah, 2022). Therefore, the combination of Scratch-based interactivity, guided discovery activities, and systematic content organization provides a strong foundation for promoting students' conceptual understanding of curved-surface geometric solids.

The findings of this study are consistent with previous research demonstrating the potential of Scratch-based learning media in mathematics education. Azizul et al. (2024) reported that Scratch provides innovative instructional strategies that enhance students' understanding and engagement, while Puteri and Farhurrohman (2024) found that Scratch-based animations create interactive learning experiences that strengthen conceptual understanding. Similarly, the results support the findings of Agung (2023), Fadillah et.al., (2023), which showed that technology-assisted learning environments improve students' learning experiences and mathematical understanding. The high validity and practicality of the developed media further confirm the effectiveness of interactive technology in supporting geometry learning

CONCLUSION

Based on the findings, the development of Scratch-based instructional media to enhance students' conceptual understanding of curved-surface solids was successfully

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conducted through the Analyze, Design, and Development phases of the ADDIE model. The media achieved a validity score of 86.9% from media experts and 83.6% from subject-matter experts, both categorized as very valid, while the practicality assessments yielded scores of 85% from teachers and 98.46% from students, both categorized as very practical. These results indicate that the developed media is feasible and practical for supporting interactive mathematics learning. However, this study was limited to three phases of the ADDIE model, involved a relatively small sample, and focused only on curved-surface solid geometry, which may limit the generalizability of the findings. Nevertheless, the study highlights the potential of Scratch-based media to support technology-enhanced mathematics learning and suggests that future research should extend the development to the implementation and evaluation phases, involve larger and more diverse samples, and examine its effectiveness across different mathematical topics and broader learning outcomes, such as motivation, critical thinking, creativity, and conceptual understanding.

DECLARATION:

Phenomenon: Jurnal Pendidikan MIPA was selected as the target journal for the publication of our paper because this journal strives to promote the implementation of high-quality mathematics and science education at all educational levels, an objective that aligns with the aims and scope of this internationally reputable journal. We confirm that both authors have approved the manuscript for publication in your journal.

Availability of Data and Materials: The data supporting the study was classified according to the institutions' authorities; therefore, the participants only agreed to participate in the study based on anonymity, and a confidentiality agreement was reached. The data can therefore not be divulged to any third party without official permission granted from the institutions which can either be accepted or declined.

Competing interests: The authors declare that they have no conflicting interests in the publication of the paper in your journal.

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Authors' contributions: Rifqotul Azizah, Rino Richard, Robiatul Adawiya contributed to this article by identifying the research problem, conducting interviews, distributing questionnaires to participants, and drafting the entire manuscript. Robiatul Adawiya, Rino Richard played a key role in overseeing the drafting process, performing final proofreading, editing the manuscript, and conducting data analysis.

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