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THE USE OF FORMATIVE EVALUATION IN THE DEVELOPMENT OF SPATIAL BUILDINGS FOR ELEMENTARY SCHOOL STUDENTS BASED ON AUGMENTED REALITY

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ABSTRACT

Learning media for elementary school students is an important tool that has developed in line with technological advances. Therefore, this study aims to evaluate learning media development on building space materials using Augmented Reality (AR) technology. Formative evaluation consists of initial analysis and stages. In addition, this study used 15 SDIT students, Alam Nurul Islam and Yogyakarta. The questionnaires distributed were related to the respondents' attitudes and responses. The results showed that students reacted positively to the development of AR learning media, and validation from experts obtained a feasibility percentage of 85.34% with valid criteria. Meanwhile, student responses expressed a sense of pleasure when the teacher explained the use of AR learning media. Mathematics material is easy to understand because geometry objects are realized as 3D objects through AR learning media. In addition, students are more active in learning by using AR learning media.

Keywords: augmented reality; evaluation formative; learning media; spatial buildings

INTRODUCTION

Mathematics education continues to develop along with rapid technological advances.[1] Technology in mathematics teaching has become increasingly important, as technology provides various tools and resources to enhance learning, facilitate understanding of concepts, and expand the scope of mathematics learning beyond the classroom.[2] Technology integration in mathematics education is a phenomenon that has been around for a while.[3] With the increasingly rapid development of technology, the role of technology in mathematics learning is becoming increasingly significant.[4]

[1] F. P. Rachmavita, "Interactive Media-Based Video Animation and Student Learning Motivation in Mathematics," *Journal of Physics: Conference Series* 1663, no. 1 (October 2020): 012040, https://doi.org/10.1088/1742-6596/1663/1/012040.

[2] Mailizar and Lianghuo Fan, "Indonesian Teachers' Knowledge of ICT and the Use of ICT in Secondary Mathematics Teaching," *Eurasia Journal of Mathematics, Science and Technology Education* 16, no. 1 (September 11, 2019): em1799, https://doi.org/10.29333/ejmste/110352.

[3] Olga Viberg, Åke Grönlund, and Annika Andersson, "Integrating Digital Technology in Mathematics Education: A Swedish Case Study," *Interactive Learning Environments* 31, no. 1 (January 2, 2023): 232–43, https://doi.org/10.1080/10494820.2020.1770801.

[4] Viberg, Grönlund, and Andersson.

The main aspect of using technology is the adoption of mathematical software.[5] Geogebra, Mathematica, and Augmented Reality (AR) have become popular tools for teachers to visually show concepts, facilitate exploration, and develop a deeper understanding. For example, teachers can show dynamic visualizations of more realistic mathematical functions in three-dimensional form, allowing students to interact directly with objects.[6]

Augmented Reality is a technology that combines the real world with digital elements generated by computers.[7] In this context, digital objects, such as images, sounds, or other information, are added to a natural environment that can be viewed through smartphones, tablets, or special AR glasses. The goal of AR is to enhance the user's perception and interaction with the natural world by inserting additional information that is useful or entertaining. The application is also quite familiar among students because it is often used in gameplay.[8]

Augmented Reality in Mathematics allows users to perform complex mathematical calculations quickly and accurately.[9] With Augmented Reality, teachers can show students how to apply mathematical concepts in real-world situations, such as scientific research or industrial problem-solving.[10] It helps students understand the relevance and application of mathematical concepts in various real-life contexts.

In addition, Augmented Reality has become an exciting and innovative tool in math education.[11] Augmented Reality allows teachers to show dynamic visualizations of

[5] Kaput, Hegedus, and Lesh, "Technology Becoming Infrastructural in Mathematics Education."

[6] Francisco del Cerro Velázquez and Ginés Morales Méndez, "Application in Augmented Reality for Learning Mathematical Functions: A Study for the Development of Spatial Intelligence in Secondary Education Students," *Mathematics* 9, no. 4 (January 2021): 369, https://doi.org/10.3390/math9040369.

[7] Shaveta Dargan et al., "Augmented Reality: A Comprehensive Review," *Archives of Computational Methods in Engineering* 30, no. 2 (March 1, 2023): 1057–80, https://doi.org/10.1007/s11831-022-09831-7.

[8] Maja Videnovik et al., "Increasing Quality of Learning Experience Using Augmented Reality Educational Games," *Multimedia Tools and Applications* 79, no. 33 (September 1, 2020): 23861–85, https://doi.org/10.1007/s11042-020-09046-7.

[9] Eleni Demitriadou, Kalliopi-Evangelia Stavroulia, and Andreas Lanitis, "Comparative Evaluation of Virtual and Augmented Reality for Teaching Mathematics in Primary Education," *Education and Information Technologies* 25, no. 1 (January 1, 2020): 381–401, https://doi.org/10.1007/s10639-019-09973-5.

[10] Su Cai et al., "Probability Learning in Mathematics Using Augmented Reality: Impact on Student's Learning Gains and Attitudes," *Interactive Learning Environments* 28, no. 5 (July 3, 2020): 560–73, https://doi.org/10.1080/10494820.2019.1696839.

[11] Timur Koparan et al., "Integrating Augmented Reality into Mathematics Teaching and Learning and Examining Its Effectiveness," *Thinking Skills and Creativity* 47 (March 1, 2023): 101245, https://doi.org/10.1016/j.tsc.2023.101245.

mathematical functions in a more realistic three-dimensional form. Using Augmented Reality devices, teachers can bring mathematical objects into the classroom's physical space, allowing students to interact directly with complex mathematical concepts. For example, a teacher can show students how to visualize volume integrals with Augmented Reality, providing a more immersive and intuitive experience than two-dimensional images or diagrams.[12,13]

The capacity to broaden the area of arithmetic learning outside of the classroom is a benefit of employing math software and other technology in math education. Students can access math tools anywhere, anytime, through mobile apps and internet resources. This enables students to study independently and delve deeper into mathematical ideas even when not in a formal learning setting.[14]

It is important to remember that the use of technology in mathematics education also poses some challenges. For example, not all students have the same access to technology or have the same skills in using it.[15] Therefore, educators need to ensure that the use of technology in mathematics learning does not increase access or skills gaps among students. Augmented Reality was chosen to develop media in this study because it is considered an inexpensive and friendly technology among students.[16] The number of students who have used mobile phones while attending school makes it very easy to use Augmented Reality in learning. The easy use of Augmented reality applications is also a reason for developing this learning application.[17]

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[12] Mailizar, Rahmah Johar, and Lainufar, "Designing Augmented Reality-Based Teaching Resource of Three Dimensional Geometry," *Journal of Physics: Conference Series* 1470, no. 1 (February 2020): 012061, https://doi.org/10.1088/1742-6596/1470/1/012061.

[13] Tetiana A. Vakaliuk, Larysa D. Shevchuk, and Borys V. Shevchuk, "Possibilities of Using AR and VR Technologies in Teaching Mathematics to High School Students," *Universal Journal of Educational Research* 8, no. 11B (November 2020): 6280–88, https://doi.org/10.13189/ujer.2020.082267.

[14] Julie Ducasse, "Augmented Reality for Outdoor Environmental Education," in *Augmented Reality in Education: A New Technology for Teaching and Learning*, ed. Vladimir Geroimenko (Cham: Springer International Publishing, 2020), 329–52, https://doi.org/10.1007/978-3-030-42156-4_17.

[15] Amy L. Gonzales, Jessica McCrory Calarco, and Teresa Lynch, "Technology Problems and Student Achievement Gaps: A Validation and Extension of the Technology Maintenance Construct," *Communication Research* 47, no. 5 (July 1, 2020): 750–70, https://doi.org/10.1177/0093650218796366.

[16] Afnan et al., "School of the Future: A Comprehensive Study on the Effectiveness of Augmented Reality as a Tool for Primary School Children's Education," *Applied Sciences* 11, no. 11 (January 2021): 5277, https://doi.org/10.3390/app11115277.

[17] Savita Yadav et al., "Interaction of Children with an Augmented Reality Smartphone App," *International Journal of Information Technology* 12, no. 3 (September 1, 2020): 711–16, https://doi.org/10.1007/s41870-020-00460-6.

Spatial material about nets and ribs in mathematics lessons at elementary school requires a high imagination. Many teachers need help to explain the material due to the limited learning media.[18] For this reason, the development of augmented Reality is expected to help teachers provide better explanations and visual illustrations to students when learning the material of webs and ribs in building space.

Hardware is as essential to using technology in mathematics instruction as software. Using graphical calculators and tablets in mathematics learning allows students to quickly perform complex computations, access mathematical references, and interact directly with the material through touch screens.[19] In addition, using the internet and online learning platforms has opened access to unlimited math resources for students and teachers. On the online learning platform, students can access learning videos, interactive exercises, and group discussions that extend their learning experience beyond the traditional classroom.[20]

Although technology in mathematics education offers many benefits, it will not be separated from challenges and obstacles. One of them is the integration of technology into the existing mathematics curriculum. A careful and integrated approach is needed to use technology as an additional tool and an integral part of the learning process. Teachers' roles are crucial regarding technology usage in mathematics instruction. Teachers must also know how to utilize this technology efficiently and incorporate it into their lesson plans. In this sense, the secret to effectively integrating technology into mathematics instruction is providing teachers with the necessary training and assistance.[21]

One of the technologies that teachers can use is Augmented Reality, especially in building space learning. The Augmented Reality approach to building space teaching

[18] Endah Budi Rahaju, Dwi Iriyani, and Ahmad Wachidul Kohar, "Features of Teaching Supplements Designed to Help Primary Teachers Reduce Student Misconceptions in Mathematics," *Jurnal Elemen* 9, no. 2 (July 31, 2023): 403–23, https://doi.org/10.29408/jel.v9i2.12274.

[19] Catherine Attard and Kathryn Holmes, "An Exploration of Teacher and Student Perceptions of Blended Learning in Four Secondary Mathematics Classrooms," *Mathematics Education Research Journal* 34, no. 4 (December 1, 2022): 719–40, https://doi.org/10.1007/s13394-020-00359-2.

[20] Frederik Dilling and Amelie Vogler, "Pre-Service Teachers' Reflections on Attitudes Towards Teaching and Learning Mathematics with Online Platforms at School: A Case Study in the Context of a University Online Training," *Technology, Knowledge and Learning* 28, no. 3 (September 1, 2023): 1401–24, https://doi.org/10.1007/s10758-022-09602-0.

[21] Theodosia Prodromou and Zsolt Lavicza, "Integrating Technology into Mathematics Education in an Entire Educational System – Reaching a Critical Mass of Teachers and Schools," *International Journal for Technology in Mathematics Education* 24, no. 3 (September 1, 2017): 129–35, https://doi.org/10.1564/tme_v24.3.04.

promises exciting innovations in mathematics learning.[22] By blending real-world and digital elements, Augmented Reality allows students to experience geometry concepts firsthand, significantly improving their understanding. In the classroom, using Augmented Reality brings the space of textbooks to life. Students can view and interact with geometric objects in a vivid 3D environment.[23] For example, through Augmented Reality applications, students can scan QR codes on their textbooks or cards that have been provided. Following this, students can see the actual space-built projection on their desks. They can rotate, zoom in, or shrink the object, allowing them to understand its geometric properties better.[24]

The main advantage of the Augmented Reality approach to learning is that it increases student engagement in learning.[25] Compared to traditional teaching methods that rely solely on two-dimensional images, Augmented Reality provides a more immersive and enjoyable experience. Students become not only spectators but also actors in their learning. In addition, using Augmented Reality can help solve challenges some students face in understanding abstract concepts.[26] By looking at space in a more tangible and customizable context, students who need additional help can more easily relate theory to practical applications.

RESEARCH METHODS

This research was conducted using formative evaluation.[27] This study is conducted in two phases: namely, the preliminary study stage and the formative evaluation phase, which involves self-evaluation, expert reviews, one-on-one, small-

[22] Prodromou and Lavicza.

[23] Maria Fakih, "Step into a New Dimension with Augmented Reality. Can Augmented Reality (AR) Replicate the Tactile Experience in a Virtual Mathematics Classroom and What Is the Impact on Engagement and Deeper Understanding?," *Research in Post-Compulsory Education* 28, no. 2 (April 3, 2023): 226–40, https://doi.org/10.1080/13596748.2023.2206707.

[24] Emin İbili et al., "An Assessment of Geometry Teaching Supported with Augmented Reality Teaching Materials to Enhance Students' 3D Geometry Thinking Skills," *International Journal of Mathematical Education in Science and Technology* 51, no. 2 (February 17, 2020): 224–46, https://doi.org/10.1080/0020739X.2019.1583382.

[25] Neven Drljević, Ivica Botički, and Lung-Hsiang Wong, "Investigating the Different Facets of Student Engagement during Augmented Reality Use in Primary School," *British Journal of Educational Technology* 53, no. 5 (2022): 1361–88, https://doi.org/10.1111/bjet.13197.

[26] Alex Mazzuco et al., "A Systematic Review of Augmented Reality in Chemistry Education," *British Educational Research Association*, 2021, https://doi.org/10.1002/rev3.3325.

[27] Tessmer and Martin, *Planning and Conducting Formative Evaluations* (London: Routledge, 1993), https://doi.org/10.4324/9780203061978.

group, and field tests.[28] This research aims to apply augmented reality to the material of spatial buildings.

At the preliminary study stage, student needs related to mathematics learning in Spatial Buildings are identified, especially for the material of nets and ribs in Spatial Buildings. After the preliminary study stage, the formative evaluation stage is carried out. Various tasks are conducted during the formative assessment, including field tests and self-evaluation.

In self-evaluation activities, the focus is to design the Augmented Reality Spatial Buildings application by paying attention to the content of the material and the ease of use of the application. Regarding the content of the material in this Augmented Reality application, it adjusts to the curriculum contained in elementary schools regarding nets and ribs in Spatial Buildings. Based on the content of the existing material, Augmented Reality applications began to be developed.

In prototyping activities, the results of Augmented Reality design are then submitted to experts and students for review. The experts selected for expert reviews are three experts in mathematics education, computers, and educational technology. The students selected for a one-to-one test learned the material of nets and ribs in spatial buildings. The input results from expert reviews and one-to-one tests are used to provide revisions to the developed prototype Augmented Reality application.

The results of revising the existing prototype were then tested on a limited basis by five students studying the material of nets and ribs in Spatial Buildings. This trial is given to students who were not sampled in this study. The results of this trial will produce a prototype, which is the result of revision and is declared the third prototype.

The final activity is to conduct a field test. At the stage of field test activities, Augmented Reality applications that have been developed are given to research samples to be used in learning. The research sample consisted of SDIT Alam Nurul Islam students, Sleman Regency, Yogyakarta. The focus of this trial is to determine the effectiveness of the Augmented Reality Spatial Buildings application that has been developed.

Research data was obtained through walkthroughs, interviews, and tests. The data analysis technique used in this study consists of two analytical techniques, namely qualitative and quantitative analysis, with the main aim of analyzing the validity,

[28] Tessmer and Martin.

practicality, and effectiveness of the Augmented Reality application that has been developed. Qualitative analysis analyzes comments and suggestions from expert reviews and one-to-one tests. In comparison, quantitative data is analyzed based on the field test results.

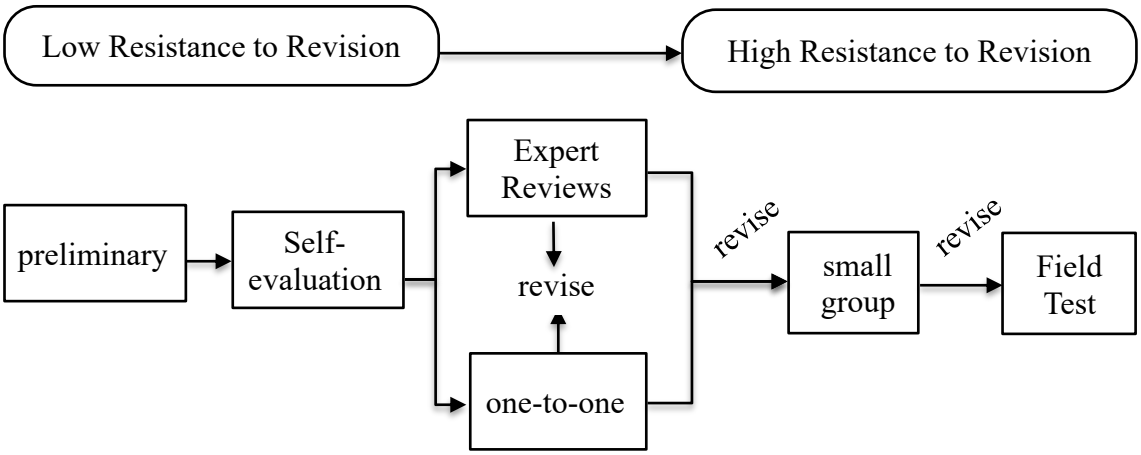

Figure 1
Research Design Flow[29]
Source: Personal Document

The final activity is to conduct a field test. At the stage of field test activities, Augmented Reality applications developed and validated by experts are given to research samples for use in learning. The research sample was 15 SDIT Alam Nurul Islam students from Sleman Regency, Yogyakarta. This trial focuses on determining the effectiveness of the developed Augmented Reality Spatial Buildings application. The instrument used in this study was a questionnaire given to the respondents, which was to the attitudes and responses of the respondents to the Augmented Reality application developed.

[29] Tessmer and Martin.

RESULT AND DISCUSSION

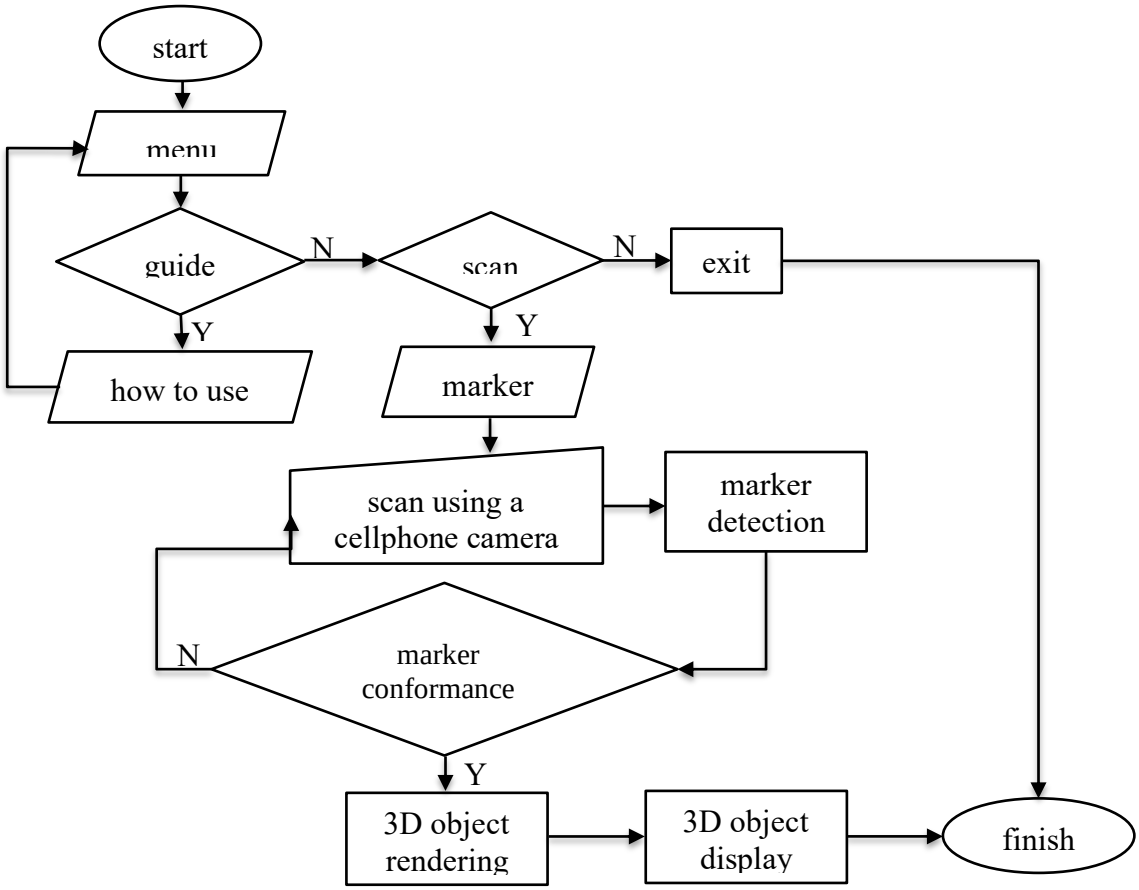

Figure 2
Application Flowchart
Source: Personal Document

The Augmented Reality Spatial Buildings application developed was evaluated using the formative evaluation method in two main stages: the preliminary study stage and the formative evaluation stage. The preliminary study stage aims to collect initial information regarding user needs and technical characteristics required for application development. Meanwhile, the formative evaluation stage is conducted to test the application prototype and obtain user feedback directly, allowing for adjustments and improvements before the application is widely implemented. With this evaluation, the development of the Build Space Augmented Reality application can be more targeted and effective in supporting interactive and fun mathematics learning.

In the preliminary study, a needs analysis of students' needs in spatial building materials was first conducted. This needs analysis aims to test and obtain findings on implementing mathematics learning on spatial building materials. The needs analysis was conducted by interviewing 40 elementary school students who had studied spatial

building materials from several schools. After being analyzed, several answers were obtained that were the same between one student and another, that is students who have learned and understood about building flats and building space, build the spaces they have learned, including cubes, beams, tubes, cones, prisms, and pyramids, students need help learning the material for Spatial Buildings in class, especially for nets, the area of various building spaces, and volumes of prisms and pyramids, some students revealed that the existing media needs to be improved, so learning sometimes fails.

When answering a question about the need to use Augmented Reality-based learning media in teaching geometry, all students said that the media is indispensable. The reason is that augmented reality-based media is very much in line with the times when students were more interested in digital media.[30] They also stated that Augmented Reality media can help visualize abstract concepts for the understanding and structure of objects of an object, especially spatial space.[31] And structure of objects of an object, especially spatial space.[32]

After obtaining preliminary data through a preliminary study, the next step is designing the Augmented Reality Spatial Buildings application. There are two essential things to note when designing the augmented reality application: the application's design and the material content presented in the application. The development of material content in this Augmented Reality application is based on the essential competencies in the curriculum related to nets and space-building ribs, as listed in Table 1.

[30] I. Nyoman Sudirman, Ni Komang Pitri Ani, and Putu Diah Utari, "Analisis Kebutuhan Siswa Terhadap Pengembangan Media Ajar Digital Pendidikan IPS," *Jurnal Elementary:Kajian Teori Dan Hasil Penelitian Pendidikan Sekolah Dasar* 6, no. 1 (January 20, 2023): 51–54, https://doi.org/10.31764/elementary.v6i1.11519.

[31] Nafisat A. Adedokun-Shittu et al., "Augmented Reality Instructional Tool in Enhancing Geography Learners Academic Performance and Retention in Osun State Nigeria," *Education and Information Technologies* 25, no. 4 (July 1, 2020): 3021–33, https://doi.org/10.1007/s10639-020-10099-2.

[32] Adedokun-Shittu et al.

Table 1
Core Competencies and Basic Competencies

Core Competencies	Basic Competencies
Gain an understanding of factual and conceptual knowledge by asking questions, observing, and attempting things out of curiosity about God, himself, his creations, and the things that one comes into contact with at home, school, and on the playground.	Explain and find webs of building simple spaces (cubes and blocks)
Communicate factual and conceptual knowledge through artistic works, movements that depict healthy children, and behaviors that model the conduct of young people of faith and noble character. Also, provide your knowledge in clear, methodical, logical, and critical language.	Making webs build simple spaces (cubes and blocks)

Source: Minister of Education and Culture Regulation Number 37 of 2018[33]

In developing an Augmented Reality application design using 3D modeling Unity software with augmented reality, the Augmented Reality Wake application's material content is designed on a storyboard. This storyboard was created to facilitate augmented reality application development, and its material is unbiased. Furthermore, a marker card is integral to this Augmented Reality application. This card functions as object detection that will be carried out by Augmented Reality applications so that Augmented Reality applications will take 3D on the smartphone screen.

The self-evaluation stage is carried out after the Augmented Reality application has been developed. At this stage, the researcher evaluates the prototype independently before being submitted to the validator. At this stage, improvements are made to Augmented Reality applications, especially in 3D displays. The result of this cell evaluation is called the prototype.

The results of the prototype developed in the form of an Augmented Reality application were then given to three reviewers and three students. The three reviewers are experts in mathematics, computers, and educational technology. In comparison, the students required this one-to-one test to study the building space material.

The validation results of mathematics education experts obtained a percentage of eligibility of 85.34% with valid criteria, as listed in Table 2. Reviewers provided

[33] Kemendikbud, *Permendikbud Nomor 37 Tahun 2018 Tentang Perubahan Atas Permendikbud Nomor 24 Tahun 2016 Tentang Kompetensi Dasar Pelajaran Pada Kurikulum 2013 Pada Pendidikan Dasar Dan Pendidikan Menengah* (Jakarta, Indonesia: Kementerian Pendidikan dan Kebudayaan, 2018).

comments to pay more attention to the theory of tube ribs. Because many students need clarification about tube ribs, the research results by Dahlan et al. (2022) found that 78.33% of respondents experienced misconceptions about tube ribs.[34] Students only memorize formulas without understanding existing concepts.[35] In addition, the reviewer gave suggestions so that the side borders on each wake are visible on the 3D display.

Table 2
The Results of Validation by Mathematics Education Experts

ASPECTS	AVERAGE VALUE
Fill Eligibility	3.1
Delivery	3.3
Graphics	3.0
AVERAGE	**3.13**
PRESENTED	**78.33%**
CRITERION	**VERY VALID**

Source: Personal Document

The validation results by Computer experts on the Augmented Reality Build Space application are categorized as valid, but the learning model can be used with minor revisions. The comments of computer experts are given to simplify the application's systematics further so that users are more familiar with its use. This is conveyed because several Augmented Reality-specific learning applications must familiarize themselves with their use.[36] Computer expert assessments are set out in Table 3.

Table 3
The Results of Validation by Computer Experts

ASPECTS	AVERAGE VALUE
Fill Eligibility	3.00
Design	3.25
Graphics	3.15
Language	3.40
AVERAGE	**3.20**
PRESENTED	**80.0%**
CRITERION	**VALID**

Source: Personal Document

[34] M. Dahlan and Ika Kurniasari, "Identifikasi Miskonsepsi Siswa Smp Pada Materi Bangun Ruang Sisi Lengkung Menggunakan Three Tier-Test," *MATHEdunesa* 11, no. 2 (May 20, 2022): 499–512, https://doi.org/10.26740/mathedunesa.v11n2.p499-512.

[35] Dewi Hamidah et al., "Penerapan Pendekatan PMR Dalam Menemukan Konsep Luas Permukaan Dan Volume Tabung Pada Siswa SMP," *Jurnal Ilmiah Pendidikan Matematika Al Qalasadi* 5, no. 2 (December 21, 2021): 179–88, https://doi.org/10.32505/qalasadi.v5i2.3305.

[36] Rahmi Faradisya Ekapti and Marzni Mohamed Mokhtar, "Persepsi Mahasiswa Indonesia Dan Malaysia Tentang Penerapan Augmented Reality Pada Pembelajaran: Studi Pendahuluan," *Jurnal Tadris IPA Indonesia* 3, no. 3 (November 30, 2023): 327–35, https://doi.org/10.21154/jtii.v3i3.2610.

The results of validation by Educational Technology experts on Augmented Reality applications Spatial Buildings are categorized as valid, but learning models can be used with minor revisions. Educational Technology experts commented that the model syntax must be more convincing so that the learning model can be appropriately implemented based on the designed work steps. The assessment of educational technology experts is presented in Table 4.

Table 4
The Results of Validation by Educational Technology Experts

ASPECTS	AVERAGE VALUE
Rational Model	3.3
Model Supporting Theory	3.3
Syntax	3.1
Social System	3.5
Reaction principle	3.0
Support System	3.2
Impact of Implementation	3.0
AVERAGE	**3.20**
PRESENTED	**80.00%**
CRITERION	**VALID**

Source: Personal Document

A one-to-one trial was carried out after obtaining the data from expert validation. One-to-one trials were carried out with subjects as many as three students. The one-to-one trial aims to get responses and information from students about the Augmented Reality applications developed. Three things will be given a response by students to the Augmented Reality application developed. The three things are clarity of presentation, suitability of media in learning, quality of appearance, and design. Data obtained from one-to-one trials on student responses to clarity of presentation can be seen in Table 5. In Table 5, the maximum score is 145. The average score of the three responses was 123.67, so it can be concluded that the percentage of eligibility is 85.28% with very valid criteria.

Table 5
One-To-One Trial Results

ASPECTS	RESPONDENT'S SCORE		
	1	2	3
Student response to clarity of presentation	29	29	30
Student response to media suitability in learning	44	47	42
Student response to the quality of look and design	50	50	50
TOTAL SCORE	**123**	**126**	**122**
PRESENTED	**84.83%**	**86.90%**	**84.13%**
CRITERION	**VERY VALID**	**VERY VALID**	**VERY VALID**

Source: Personal Document

In addition to responding to the developed media, the three students also commented as follows:

Respondent 1: The media developed is very useful in improving the learning process and student interest so that later, it can impact student grades.

Respondent 2: The developed media is especially interesting for me, even though I have studied these subjects in class. The necessary improvement is that the layer size needs to be bigger.

Respondent 3: The developed media is instrumental and exciting. This kind of media can also be developed in other materials and subjects. Just a little media display that is too large and cannot be reduced. Hopefully, it can be improved.

Augmented Reality applications that have received input at the expert review stage and one-to-one tests are revised and, from now on, referred to as prototype two. Prototype two was tested again in small groups. The small group stage was carried out to see the practicality of the Augmented Reality applications developed. In this stage, six students were asked to use Augmented Reality applications to understand the shapes of webs and ribs in building space. The six students were selected based on the criteria of two students, each with low, medium, and high levels of cognitive ability. Furthermore, the six students were asked to provide input regarding difficulties and shortcomings by writing on the comment sheet. All students in the small group stage stated that the Augmented Reality application builds space that is easy to use and understand.

After obtaining a valid and practical third prototype, proceed to the field test stage. This is the last stage in evaluating Augmented Reality application development for Spatial

Buildings. At this stage, the Augmented Reality application built a room to test the third prototype for the research subject, namely class VIB students of SDIT Alam Nurul Islam, Yogyakarta, consisting of 15 students. Researchers conducted a questionnaire to determine how students' attitudes or responses to the Augmented Reality application-built space had been developed. The results of the questionnaire of all students gave a positive response to the Augmented Reality application for Spatial Buildings developed. The study subjects also commented on the Augmented Reality applications they used. The comments they gave were as follows: (1) other subjects should also use Augmented Reality applications, (2) learning atmosphere such as playing games, and (3) learning becomes more exciting.

Table 6
Field Test Stage Questionnaire Results

QUESTION	NUMBER OF SUBJECTS	
	AGREE	DISAGREE
Does the way teachers deliver material with the Spatial Buildings Augmented Reality app capture your attention	15	0
Are you happy with learning by using the Augmented Reality app Spatial Buildings	15	0
Do you understand the explanation of the subject matter with the Augmenter Reality Spatial Buildings app	14	1
Does learning with the Spatial Buildings Augmented Reality app increase your interest in learning	13	2
Does learning with the Spatial Buildings Augmented Reality app make it easier for you to understand the subject matter	14	1
Does learning with the Spatial Buildings Augmented Reality app make you more active in learning	15	0
Does the Augmented Reality Spatial Buildings app keep you motivated to learn more	14	1
Is the Augmented Reality Spatial Buildings app easy to use	15	0
Does learning with the Augmented Reality app Spatial Buildings make building space look more real	15	0
Does learning with the Augmented Reality app Spatial Buildings help you in illustrating the webs and ribs of Spatial Buildings	15	0

Source: Personal Document

From the results of the questionnaire data, the use of augmented reality applications makes learning more interesting and fun; this is also true of Liono's research

(2021).[37] Using Augmented Reality applications that have been developed can help students understand the nets and ribs of building space. Understanding the webs and ribs of space is very important. This is because both materials will be needed to understand the material further. As well as the volume and surface area of the spatial builds.[38] Students can more readily absorb lectures using 3D learning media by utilizing Augmented Reality. The learning process takes place more enjoyably and uses IT advancements well.[39] In this case, students are enthusiastic about learning because the 3D model displayed by Augmented Reality makes spatial builds more real.

The developed augmented reality application has more complete 3D views related to nets and ribs spatial builds than existing augmented reality applications. In addition, this application presents more forms of building space. So, students can use this Augmented Reality application for many forms of nets and ribs. Applications related to volume and off-surface materials of spatial builds can also still be developed.

The Augmented Reality application development results are presented carefully to facilitate students' understanding. A simple interface design was chosen so students feel safe the first time they use it. This is important because the home screen is a valuable guide for users to explore the app's features in more detail. Additionally, only basic features shown in the first test are included. This is intended to prevent information overload, which can cause students to become vulnerable. It is hoped that the tutorial on the application is provided so that students can quickly understand how the AR application works and feel comfortable using it.

[37] Erica L Zippert and Bethany Rittle-Johnson, "The Home Math Environment: More than Numeracy," *Early Childhood Research Quarterly*, Parents supporting early mathematical thinking, 50 (January 1, 2020): 4–15, https://doi.org/10.1016/j.ecresq.2018.07.009.

[38] Fajar Witdanarko, Wiryanto Wiryanto, and Neni Mariana, "Analysis of the Basic Abilities of Grade V Students in Working on Volume of Space Building Problems," *International Journal of Emerging Research and Review* 2, no. 2 (May 11, 2024): 000068–000068, https://doi.org/10.56707/ijoerar.v2i2.68.

[39] Oskah Dakhi et al., "Blended Learning: A 21St Century Learning Model at College," *INTERNATIONAL JOURNAL OF MULTI SCIENCE* 1, no. 08 (November 14, 2020): 50–65.

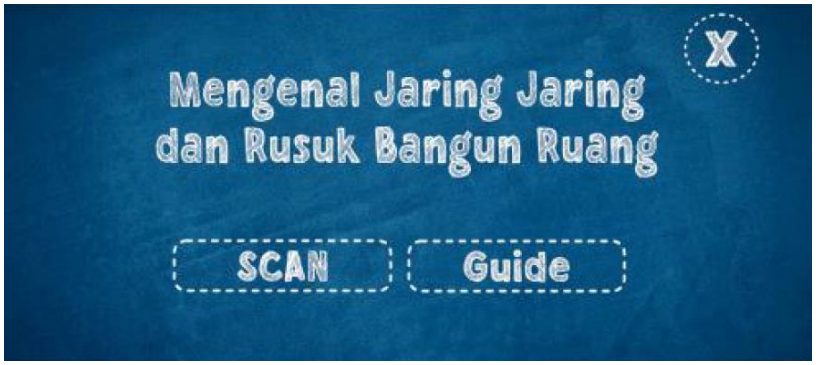

Figure 3
Main Page
Source: Personal Document

Using cards in Augmented Reality means they are cheaper and easier to produce. Augmented Reality enables high 3D detail and vivid colors, thus creating exciting and stunning visual effects. Good quality 3D results are essential to give students a professional and attractive impression. A gorgeous 3D display can attract attention and increase the effectiveness of the message it wants to convey.

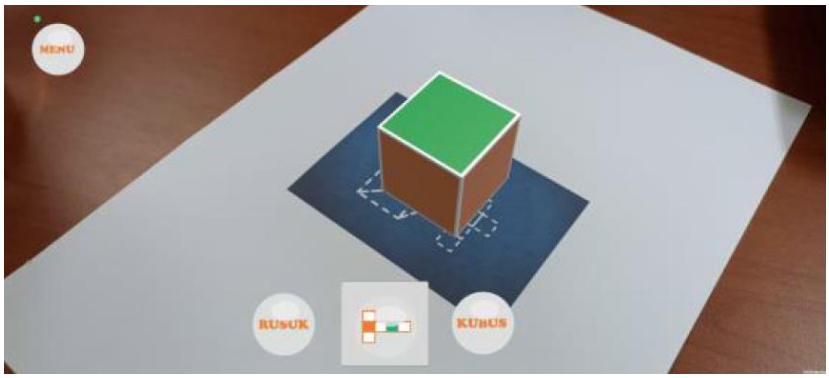

Figure 4
Scan Display on the Card
Source: Personal Document

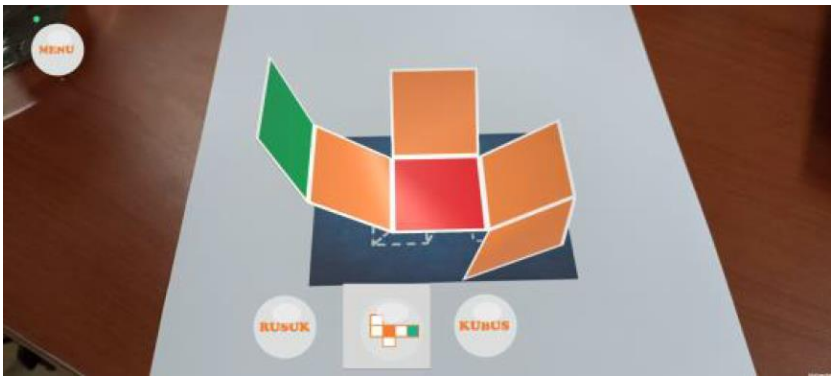

Figure 5
3D Object Display for Net Shape
Source: Personal Document

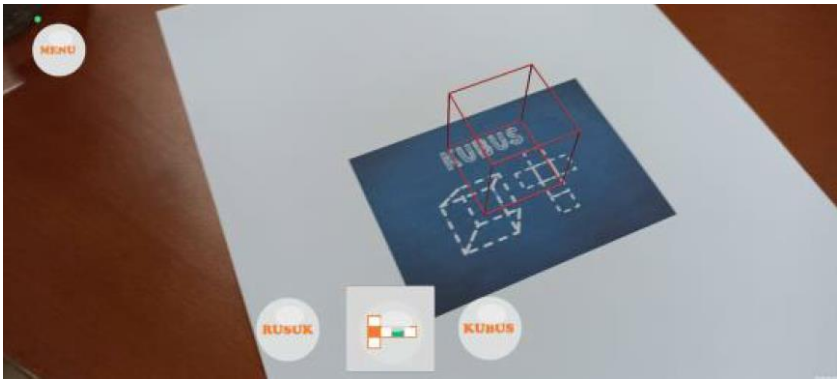

Figure 6
3D Object Display for Rib Shape
Source: Personal Document

CONCLUSION

This research has produced a learning media about the material of the ultimately and ribs of space-based Augmented reality applications. This Augmented Reality application presents the build space, including cubes, beams, pyramids, prisms, and tubes. Evaluation of this Augmented Reality application has gone through all stages of the formative evaluation method. From the study results, it is concluded that this Augmented Reality application is feasible to use for learning. This is because using Augmented Reality applications in learning can make learning more fun. The 3D display of the resulting space makes it easier for students to illustrate the nets and ribs in the space. This research can still be developed using different materials or broader subjects on Augmented Reality applications.

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DECLARATION OF CONFLICTING INTERESTS

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