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Development of 3D Visualization Media Using Assemblr Studio for Learning Polyhedral Geometry

Nur Riski Hasanah
Indonesia University of Education

Turmudi Turmudi
Indonesia University of Education

Dadang Juandi
Indonesia University of Education

Wahyudin Wahyudin
Indonesia University of Education

Abstract: The integration of technology in education has significantly transformed the teaching and learning process, especially in subjects like geometry, which heavily rely on spatial visualization. Students' understanding of polyhedral geometry concepts is often hindered by the limitations of two-dimensional representations found in textbooks. Recent technological advancements have enabled 3D visualization to become an innovative solution for enhancing conceptual understanding in geometry. This study employs the Plomp development model, which consists of three phases. In the preliminary research phase, it was found that students struggle to understand polyhedral geometry due to limitations in visual representation. In the prototyping phase, an interactive and engaging 3D visualization medium was developed. In the assessment phase, media feasibility testing was conducted, focusing on expert validation and practical testing with students. The validation was carried out by three experts: a media expert, a subject matter expert, and an educational expert. The validation results indicated that the developed 3D visualization media achieved a very high level of validity, with an average score of 90.7%. Furthermore, the average practicality score was 79%, categorized as practical. The findings of this study demonstrate that the use of 3D visualization media based on Assemblr Studio is feasible for teaching polyhedral geometry.

Keywords: 3D visualization, Assemblr Studio, Polyhedral geometry, Media development, Plomp model

Introduction

The integration of technology in education has significantly transformed the teaching and learning process, especially in subjects that heavily rely on spatial visualization, such as geometry (Dalgarno & Lee, 2010; Hwang & Tsai, 2011; Fowler, 2015; Jian & Abu Bakar, 2024). Geometry plays a crucial role in developing students' spatial reasoning and problem-solving skills. However, many students struggle to understand three-dimensional (3D) geometry concepts due to the limitations of two-dimensional (2D) representations in textbooks that are not supported by interactive media (Lowrie et al., 2016; Fujita et al., 2017; Rich & Brendefur, 2019; Fujita et al., 2020).

Advancements in digital technology, such as Augmented Reality (AR), have emerged as an innovative solutions to enhance students' understanding of geometric concepts in mathematics education, one of the core components of STEM education (Bacca et al., 2014; Ibáñez & Delgado-Kloos, 2018; Gargrish et al., 2020; Wang et al., 2024;

Jiang et al., 2025). One AR-based platform that can be used in learning is Assemblr Studio, which allows students to interact with 3D models to improve their spatial understanding (Huang & Lin, 2017; Šafhalter et al., 2020; Surynkova, 2020).

Several studies have shown that students continue to struggle with polyhedral geometry, highlighting the need for learning aids and the integration of interactive technology (Yegambaram, 2013; Jones & Tzekaki, 2016; Fazira & Qohar, 2021; Izzati et al., 2023; Nuratiqoh & Qohar, 2024). Traditional teaching methods that rely on static 3D represebtations in textbooks often fail to provide the dynamic and immersive learning experiences needed to enhance students' spatial ability (Kinshuk et al., 2016; Chikha et al., 2021). Moreover, technology-based learning media must address the complexity of usage and ensure user-friendliness for students while aligning with curriculum standards in this digital age (Scanlon, 2021; Twining et al., 2021). Therefore, there is a need for 3D visualization media that is not only easily accessible and student-friendly but also designed to meet the learning objectives of polyhedral geometry.

A growing body of research has explored the role of technology in geometry learning. For instance, research has shown that AR-based geometry applications can significantly enhance students' spatial abilities (Gecü-Parmaksız, 2017; Gun & Atasoy, 2017; Danakorn Nincarean et al., 2019; del Cerro Velázquez & Morales Méndez, 2021; Ozcakir & Cakiroglu, 2021; Supli & Yan, 2024). Additionally, other studies have indicated that interactive 3D models are more effective in helping students grasp complex geometric relationships compared to traditional teaching methods that lack 3D visualization (Ng et al., 2020; Schmid & Korenova, 2024). The novelty of this research is lies in its bibliometric analysis using VOSviewer on internationally recognized journals, focusing on the keywords 3D Visualization, Assemblr Studio, Polyhedral Geometry, and Media Development. The network visualization resulting from this bibliometric analysis is presented in Figure 1.

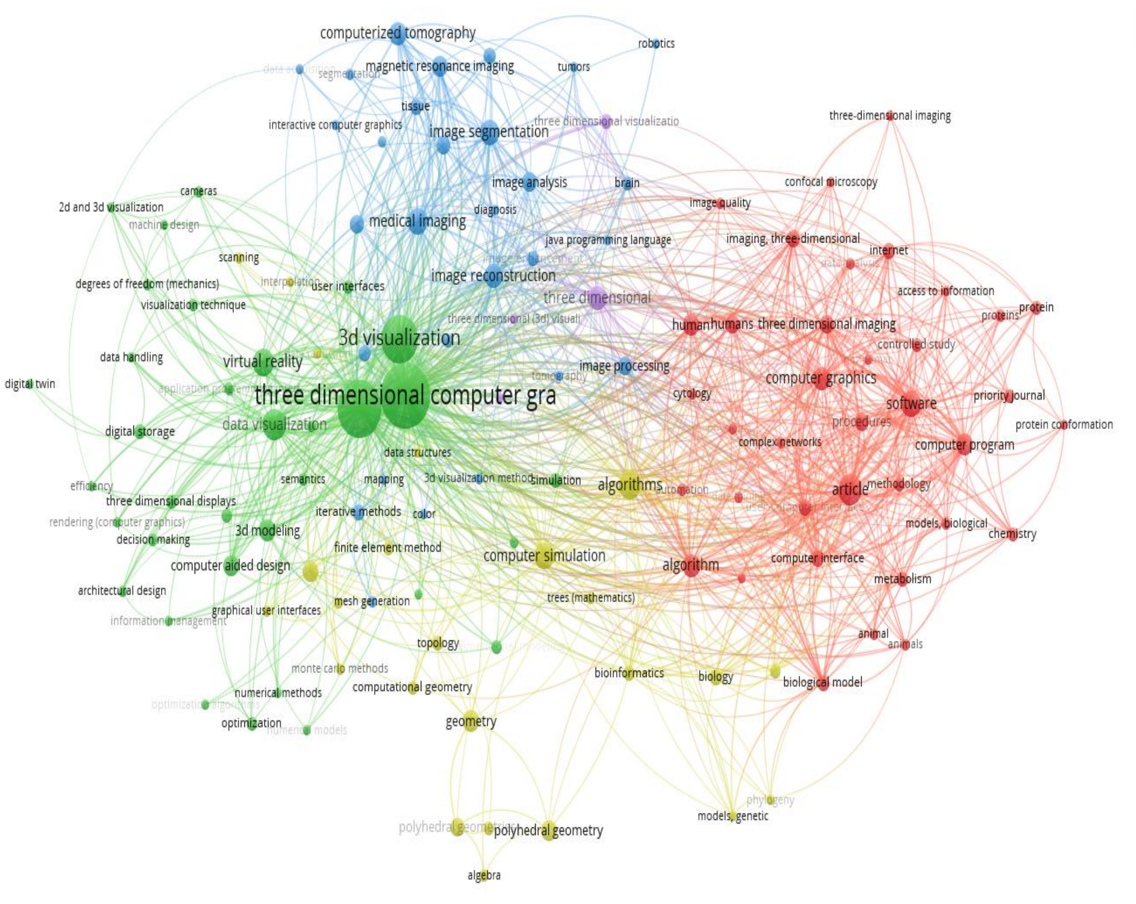

Figure 1. Network visualization

Based on the bibliometric analysis in the network visualization, the keyword “polyhedral geometry” has not yet been linked to “3D visualization”. Additionally, there are no existing connections to the keywords “Assemblr Studio” and “media development’. While numerous studies have discussed the benefits of digital visualization in geometry learning, no research has systematically investigated the development process of 3D visualization media using Assemblr Studio for learning polyhedral geometry, particularly through the Plomp development model.

Moreover, there are still limitations in research that examines this development with validation and practicality tests in polyhedral geometry. Most 3D visualization or modeling-based learning media that have been developed either lack empirical validation from experts and practicality test. This study addresses these gaps by applying the Plomp development model to design and evaluate 3D visualization media using Assemblr Studio for learning polyhedral geometry.

Additionally, this study provides empirical validation from experts to ensure the feasibility of the developed media for classroom use. Recognizing the importance of 3D visualization media, this study aims to: 1) design 3D visualization media using Assemblr Studio based on the Plomp development model for learning polyhedral geometry; 2) evaluate the validity of the developed media through expert validation; 3) evaluate the practicality of the developed media through practicality tests to students.

Method

This study employs developmental research, focusing on the design, validation (Tracey, 2009), and practicality testing of 3D visualization media for learning polyhedral geometry. This media is designed to support the understanding of shapes, dimensions, and relationships between different parts of polyhedral geometry. The Plomp development model is used, with its phase modified into three main phases: preliminary research, prototyping phase, and assessment phase (Nieveen & Folmer, 2013).

Subjects (Participants)

The participants in this study include three experts responsible for media validation: a media expert who evaluates the technical aspects of 3D visualization, a subject matter expert who evaluates content alignment with geometry learning objectives, and an educational expert who evaluates the instructional aspects of the developed media. The research subjects consist of a small group of 25 junior high school students from Indonesia. These students participated in the needs analysis and practicality testing to assess the usability of the media.

Data Collection Techniques

Data collection was conducted through several activities: 1) a literature review to analyze previous studies on the use of digital media, challenges in geometry learning, and the potential of 3D visualization media; 2) interviews and observations with teachers and students to identify challenges and learning needs in polyhedral geometry; 3) validation by three experts, who evaluated the media based on feasibility of materials, feasibility of media, feasibility of instruction manual language using validation sheets. Practicality testing was conducted with a small group of students using the developed media, followed by a questionnaire to evaluate its practicality in learning.

Data Analysis Techniques

The data analysis techniques used in this study include: 1) needs analysis, processed through coding using MAXQDA 24; 2) media validation, analyzed based on the percentage score to determine its level of validity; 3) media practicality testing, assessed using the percentage score to determine the practicality level. The analysis follows a Likert scale (1-5). The validity criteria in this study are based on a minimum validity score of $4 \leq Va < 5$ on the Likert scale or $80\% \leq Va < 100\%$, indicating that the developed media is feasible for use (Mustami et al., 2019). The validation score criteria for all validators are presented in Table 1.

Table 1. Validity criteria

Validity score	Category
85,01-100,00%	Very valid
70,01-85,00%	Valid
55,01-70,00%	Moderately valid
37,01-55,00%	Less valid
20,00-37,00%	Not valid

Criteria for determining the practicality test score for all students based on the percentage of their assessment (Dahal et al., 2023) are presented in Table 2.

Table 2. Practicality criteria

Practicality score	Category
0 – 59 %	Not practical
60 – 65 %	Little practical
66 – 70%	Pretty practical
71 – 81 %	Practical
82 – 100%	Very practical

Results and Discussion

Preliminary Research

The needs analysis was conducted by identifying challenges in learning polyhedral geometry and exploring potential solutions. During the preliminary research phase, interviews and classroom observations were carried out. The needs analysis of qualitative data from interviews and observations was analyzed using creative coding with MAXQDA 24 application and are presented in Figure 2.

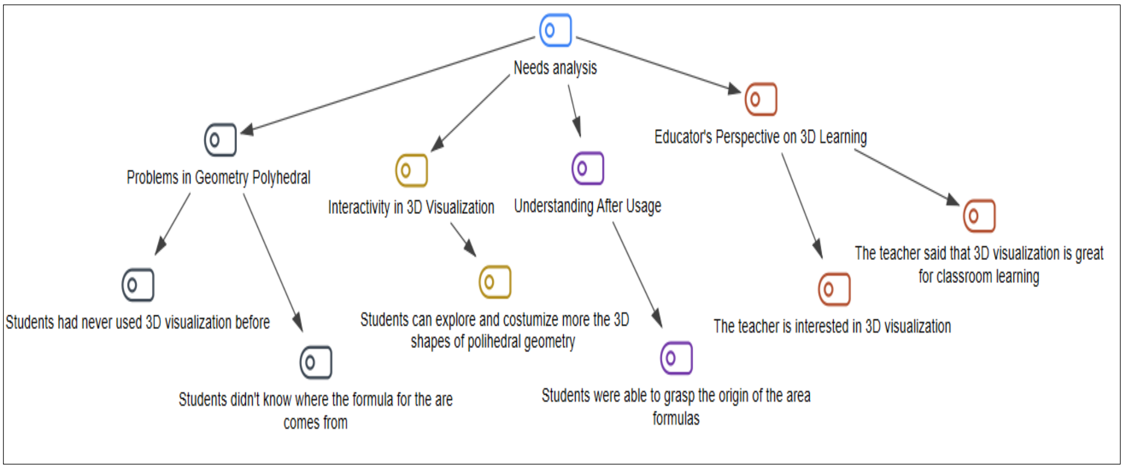

Figure 2. Needs analysis through creative coding

Based on the coding of interview and observation results, as shown in Figure 2, it was found that students had never used 3D visualization media in polyhedral geometry learning in the classroom. Additionally, students struggled to understand polyhedral geometry concepts, such as the derivation of surface area formulas they had learned. This difficulty was caused by the limited visual representations available in textbooks and two-dimensional images. These findings align with previous research by Lowrie et al. (2016), Fujita et al. (2017), Rich and Brendefur (2019), and Fujita et al. (2020). Discussions with the teacher revealed that she was interested in 3D visualization media for polyhedral geometry because she had never used such media in her classroom instruction. According to the teacher, using this media could make students more active in learning and help them better understand polyhedral geometry concepts. A literature review of previous studies has shown that technology-based visualization can aid in understanding geometry concepts (Žakelj & Klancar, 2022; Mjenda, 2023; Schoenherr et al., 2024; Suparman et al., 2024; Medina Herrera et al., 2024). Furthermore, interactive and digital learning media have the potential to enhance students' learning motivation and engagement in the learning process (Liu & Moeller, 2019; Li et al., 2024). The findings from this preliminary research serve as the foundation for designing 3D visualization media tailored to students' learning needs.

Prototyping Phase

In the prototyping phase, the 3D visualization media was designed with an interactive and engaging interface to enhance students' learning experiences. This media was developed using the Assemblr Studio platform, which allows students to view and interact with 3D models. The development process involved designing the initial layout and creating visualizations that support the learning of polyhedral geometry concepts. An example of a polyhedral geometry concept that has been visualized is a prism. Figure 3 illustrates the 3D visualization of triangular prism.

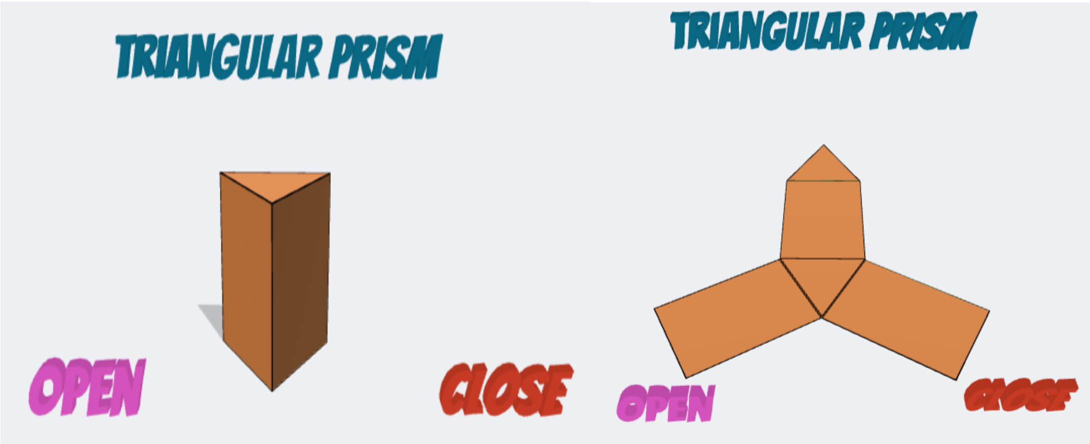

Figure 3. 3D visualization of a triangular prism

The 3D visualization of the triangular prism in Figure 3 displays both the front view and the internal structure of the shape. This visualization allows students to explore the 3D form from various angles. Students can rotate, zoom in, zoom out, and view the nets of the polyhedral geometric shapes. Other polyhedral geometry included in the media are cubes, rectangular prism, and triangular pyramid. Each 3D shape can be explored by scanning its respective barcode. These barcodes can be scanned using a mobile phone. The barcodes for the 3D visualization are shown in Figure 4.

(a) (b)

(c) (d)

Figure 4. (a), (b), (c), (d) Barcodes for each polyhedral geometric shape

Each barcode in Figure 4 represents the 3D visualization of different polyhedral geometry shapes. Figure 2(a) corresponds to a triangular prism, Figure 2(b) to a triangular pyramid, Figure 2(c) to a cube, and Figure 2(d) to a cuboid.

Some of the most suitable topics for using this 3D visualization include: 1) understanding the characteristics of polyhedral shapes, such as identifying the number of faces, edges, and vertices, as well as recognizing the shapes of their constituent faces; 2) exploring the nets of polyhedral geometric shapes and relating them to their 3D counterparts to better understand their construction; 3) helping students grasp that surface area is the sum of all face areas by exploring the nets of polyhedral geometric shapes.

Assessment Phase

At the assessment phase, the developed media was evaluated by three experts: a media expert, a subject matter expert, and an educational expert. The validation test was conducted to evaluate the feasibility of the media. The validation results from the three experts for each assessment aspect are presented in Table 3.

Table 3. Validity test

Aspect	Number of indicators	Total score	Maximu m score	Percentage	Criteria
Feasibility of materials	5	68	75	90,7	Very valid
Feasibility of media	11	149	165	90,3	Very valid
Feasibility of instruction manual language	2	28	30	93,3	Very valid
Total	18	245	270	90,7	Very valid

The expert validation results indicate that the media has a very high level of validity, with an average validation score of 90.7%. This percentage demonstrates that the 3D visualization media for learning polyhedral geometry meets feasibility standards in terms of content, visual presentation, and the appropriateness of instructional language for learning.

Table 4. Practicality test

Aspect	Number of indicators	Total score	Maximum score	Percentage	Criteria
Usefulness	3	60,204	75	80,272%	Practical
Convenience	5	106	125	84,8%	Practical
Satisfication	2	35,8	50	71,6%	Practical
Total	10	245	270	78,891%	Practical

In addition to expert validation, the practicality test was carried out on students to find out the extent to which this media can be implemented properly in learning. The results of the practicality test for each assessment aspect by students are presented in Table 4. The practicality test results in Table 4 indicate that the media obtained an average score of 79%, categorized as practical. This score indicates that the developed 3D visualization media is practically applicable for classroom learning.

The findings of this study show that the use of 3D visualization media based on Assemblr Studio is feasible for use in learning polyhedral geometry, as evidenced by validity and practicality tests. This aligns with the studies of Schindler et al. (2017), and D'Angelo (2018). With clearer and more interactive visual representations, students can more easily grasp geometric concepts that were previously difficult to understand without using this media. This is consistent with the research of Schoenherr et al. (2024), Parame-Decin (2023), Medina Herrera et al. (2024); and Žakelj and Klancar (2022), which highlight visualization as a powerful tool to support mathematics learning.

Conclusion

The integration of 3D visualization media in mathematics education has demonstrated its potential to enhance students' understanding of polyhedral geometry. This study, which employs the Plomp development model, has produced 3D visualization media using Assemblr Studio that have been validated and tested for practicality. Expert validation results indicate that the developed 3D visualization media have a very high validity level, with an average score of 90.7%. Additionally, student practicality testing yielded an average score of 79%, categorizing the media as practical. The findings reveal that students often struggle with understanding polyhedral geometry due to the limitations of two-dimensional representations in textbooks, which are presented without the aid of media. The developed media addresses these challenges by providing interactive and engaging visualizations that support polyhedral geometry learning.

Recommendations

This study has the advantage of providing a strong foundation for the development of technology-based learning media through expert validation and practicality testing. Although it has not yet included an effectiveness test on student learning outcomes, the validation conducted ensures that this media meets quality standards for use. To maximize its benefits, further research can focus on testing its effectiveness in significantly improving students' understanding. Additionally, further development is needed to make this media more flexible and adaptive, allowing it to be used in various learning scenarios.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in the EPESS journal belongs to the authors. This study does not require ethics committee approval as it focuses on the development of 3D visualization media without involving human subjects in experimental research.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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Author(s) Information

Nur Riski Hasanah
Indonesia University of Education
Jalan Dr. Setiabudhi 229 Bandung, Jawa Barat, 40154
Indonesia
Contact e-mail: *nurriskihasanah@upi.edu*

Turmudi Turmudi
Indonesia University of Education
Jalan Dr. Setiabudhi 229 Bandung, Jawa Barat, 40154
Indonesia

Dadang Juandi
Indonesia University of Education
Jalan Dr. Setiabudhi 229 Bandung, Jawa Barat, 40154
Indonesia

Wahyudin Wahyudin
Indonesia University of Education,Indonesia Jalan Dr. Setiabudhi 229 Bandung, Jawa Barat, 40154
Indonesia

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