

Research Article

Designing Pop-Up Mathematics Books to Enhance Understanding of Cubes and Cuboids

Pratiwi Dwi Warih Sitaresmi^{1*}, Nuryami¹, Diaya Ud Deen Al Zitawi²

¹ Department of Mathematics Education, Institut Ahmad Dahlan, Kedopok, Probolinggo, Indonesia

² Department of Social Sciences and Humanities, Universiti Teknologi Malaysia (UTM), Johor, Malaysia

*Corresponding Author: pratiwidws23.math@gmail.com | Phone: +6285258614008

ABSTRACT

This study aimed to develop a Pop-Up Mathematics Book to improve eighth grade students' understanding of cubes and cuboids. The main objective of this study was to create an engaging and interactive learning tool to improve students' problem-solving skills and conceptual understanding. The development process used the ADDIE model and included a comprehensive literature review and pilot testing to identify common challenges in geometry learning. The content and design of the book were rigorously evaluated by content and design experts to ensure its quality and effectiveness. Implementation was carried out by actively involving students, and its effectiveness was measured through pre-test and post-test scores, student feedback, and teacher observations. The results showed significant improvements, with a 25% increase in post-test scores, indicating a better understanding of geometry concepts. Students reported high levels of engagement, while teachers noted improvements in learning delivery and student participation. These findings demonstrate the potential of the Pop-Up Mathematics Book as an effective tool in geometry learning. However, the limited scope of the study to one topic and a specific group of students requires further research to evaluate the effectiveness of this tool on a more diverse student population, other academic subjects, and various educational contexts.

Keywords: learning media; pop-up book; mathematics; cubes; cuboids

1. INTRODUCTION

Mathematics is a fundamental discipline in education, playing a vital role in developing students' logical reasoning, analytical skills, and problem-solving abilities (Szabo et al., 2020; Xu et al., 2021; Zhou et al., 2023). A strong foundation in mathematics also supports progress in various fields, including science, technology, and economics. Integrating learning media in mathematics education has significantly improved students' understanding and engagement, especially for complex subjects such as geometry. Traditional teaching methods often struggle to maintain students' interest, leading to low engagement and less effective learning outcomes. Incorporating interactive learning tools, including digital technologies, has emerged as an effective strategy.

Innovative learning media are essential to improving students' understanding of geometry, including important topics such as cubes and cuboids. Geometry provides students with a conceptual framework for shape, size, and spatial relationships, which is the foundation for practical applications in everyday life and engineering (Gurmu et al., 2024; Jablonski & Ludwig, 2023; Wardhani et al., 2023). Cubes and cuboids, as fundamental three-dimensional shapes, are essential for building a basic understanding of geometry. While a cube has six identical square faces, a cuboid has six rectangular faces of varying dimensions. Mastering the volume and surface area calculation for these shapes is an essential skill in geometry (Baah-Duodu et al., 2020; Kuzniak & Nechache, 2021).

Visual and interactive media, such as pop-up books, can provide a more immersive and engaging learning experience. Research shows innovative learning media increase students' motivation and interest, leading to deeper conceptual understanding (Charline et al., 2023; Vijayalakshmi & Reddy, 2020). Visual-based media, such as pop-up books, allow students to interact directly with three-dimensional shapes, especially in geometry, where spatial understanding is key. Interactive media transforms students from passive recipients of information to active participants in the learning process. Studies show that students who engage with interactive media achieve significantly higher levels of understanding than traditional methods (El-Sabagh, 2021; Tuma, 2021). Specifically, visual and interactive media such as pop-up books allow students to grasp complex concepts more easily in geometry. These media allow students to explore and interact with geometric shapes, strengthening their understanding of the unique properties of cubes and cuboids. Research shows that interactive learning experiences increase information retention and foster long-term conceptual understanding (Bizimana et al., 2022; Sarwar et al., 2024). For this reason, educators need to integrate innovative learning media into the curriculum, especially for subjects that require strong visual understanding, such as geometry. Students often face challenges with conventional methods when learning the concept of cubes and cuboids. These challenges can include conceptual understanding, application of formulas, and critical thinking skills. One common difficulty is understanding the

fundamental properties of cubes and cuboids. Research shows that many students experience confusion when identifying geometric attributes, such as the number of sides, types of angles, and dimensional relationships (Gee & Harefa, 2021; Ibili et al., 2020; Mudhefi et al., 2024). This lack of basic understanding can hinder students as they progress to more complex topics (Mi et al., 2020; Paige et al., 2019; Strong et al., 2024).

Students often struggle to apply the concepts learned to real-world scenarios or more challenging problems (Dixon & Brown, 2012; Larson et al., 2018). Difficulty in applying formulas is another significant barrier. Many students rely on rote memorization without understanding the context or practical use of formulas, which often leads to difficulties applying them effectively (Legarde, 2022; Liu et al., 2023). Studies have revealed that students often cannot explain their solution steps, indicating a shallow understanding of the underlying concepts (Maryanah et al., 2018; Mutia, 2017). Furthermore, traditional teaching methods relying heavily on lectures without visual engagement can exacerbate students' difficulties. When teachers primarily use a lecture-based approach without engaging students in hands-on activities or visualizations, students tend to lose interest and motivation (Mariappan, 2024; Tang, 2023; Vansadiya et al., 2023).

To address these challenges, this study proposes the development of a Math Pop-Up Book as a learning aid. Math Pop-Up Books include three-dimensional elements that appear when the page is opened, providing students with a realistic and interactive experience. Visualization of attractive geometric shapes such as cubes and cuboids. This tool accurately represents abstract mathematical concepts, encouraging experiential learning. Visually engaging and interactive, this tool allows students to manipulate three-dimensional shapes, enhancing their understanding. Studies by (Kwok et al., 2016; Liono et al., 2021) show that interactive learning media can help students understand complex concepts more effectively than static and traditional materials. Studies Lasher & Denzer (2020) found that pop-up books increase students' focus and engagement, making them a valuable educational tool. Similarly, (Abbazio et al., 2023; Nkosinkulu, 2024) showed that pop-up books enhance knowledge retention and engagement more effectively than other media, such as posters. These findings suggest that pop-up books' tactile and visual nature provides an immersive experience that supports a deeper understanding of complex concepts, especially three-dimensional shapes, that static images cannot achieve.

The novelty of this study lies in the specific application of pop-up books to teaching cubes and cuboids. Compared to previous studies, this study focuses on geometry topics that have not been widely explored in the context of pop-up books. For example, (Mohamed & Kandeel, 2023; Nor'a et al., 2024; Zhu et al., 2023) found pop-up book media effective in general learning but did not focus on geometry. This study emphasizes the importance of interactive and engaging learning media, consistent with the findings by (Djus et al., 2024; Mohamed & Ali, 2024), which highlight that pop-up books can attract students' attention and improve classroom dynamics. Based on this background, it is necessary to conduct development research entitled "Designing Pop-Up Mathematics Books to Improve Understanding of Cubes and Blocks".

2. RESEARCH METHOD

This study employs a development research approach, focusing on creating instructional media. The pop-up book provides a visual aid for learning and realistic mathematics-based student worksheets. In addition, student worksheets were developed to complement the media and facilitate active learning. The participants in this study were 22 eighth-grade students and one teacher of Mathematics of MTs Miftahul Ulum, Probolinggo, selected through purposive sampling based on their willingness to participate and recommendations from their mathematics teachers. These students were considered appropriate for the study as they actively studied the concepts of cubes and cuboids within their mathematics curriculum. The selection ensured that the sample aligned with the research objectives and the context of the media being evaluated.

This study follows a development research design, specifically the ADDIE model, which includes the following steps: (1) The Analysis phase began with preliminary observations and interviews with mathematics teachers and students to identify challenges in teaching and understanding cubes and cuboids. This phase helped determine the specific needs of the instructional media; (2) the design phase, the concept for a math pop-up book, was created to address the challenges identified in the analysis phase. The design phase included establishing specific learning objectives and structuring the content to present cubes and cuboids in a visually engaging and interactive format; (3) the development phase, the pop-up book was produced based on the design specifications. Expert validators, including subject matter experts and instructional designers, reviewed the prototype to ensure its quality. The media validation was based on a set of criteria, and the feedback provided guided revisions to improve the media; (4) implementation phase, the media was implemented in the classroom with the students, who used the pop-up book along with accompanying worksheets. This phase involved observing students' interactions with the media and collecting feedback on its usability and effectiveness; (5) the evaluation phase involved evaluating the effectiveness and practicality of the media. Data were collected through student response questionnaires, cognitive tests (pre-test and post-test), and expert validation.

The data collection instruments in this study were observation, validation, questionnaires, and tests. First, the observation was used to write down all kinds of activities in learning and administration and describe all kinds of school conditions and situations. Things that need to be observed include student behavior and the process of teaching and learning cubes and blocks using the 8th-grade math pop-up book. Second, the validation sheet was used to test the quality of the product. For this reason, validation is arranged into two types adjusted to the respondents' needs: media and material. Media validation is carried out to measure the product from the media aspect. At the same time, material validation is carried out to measure the media from the learning and content aspects. The validation sheet is a closed questionnaire in the form of a checklist with a Likert scale, namely by preparing several questions regarding the developed media and respondents (material experts and media experts). Third, the questionnaire, namely the teacher and student questionnaire sheets. The student questionnaire sheet is used to find out students' responses to the media to be developed. Student responses can be used as a tool to measure the practicality of the mathematics pop-up book media. The response sheet is a closed questionnaire and a checklist with a Likert scale.

Table 1. Student Questionnaire Indicators

No	Indicators	Descriptions
1	Ease of Use	Assesses how easy it is for students to interact with the media.
2	Perceived Benefits for Learning	Measures students' perceptions of how the media helped them learn.
3	Overall Impression of the Media	Evaluates the general impression of students regarding the media.
4	Practicality for Everyday Use	Assesses whether students find the media practical for learning.

Meanwhile, the teacher fills out the teacher questionnaire sheet during the trial. The teacher assesses the learning media through the questionnaire and the media distributed. The questionnaire sheet is in the form of a closed questionnaire using a Likert scale.

Table 2. Teacher Questionnaire Indicators

No.	Indicators	Description
1	Ease of use	Evaluates how easily teachers can understand and use the media in teaching.
2	Alignment with curriculum	Assesses the alignment of the media content with the mathematics curriculum standards for grade 8.
3	Quality of Media Design	Evaluates the visual appeal, readability, and physical quality of the pop-up book.
4	Practicality in Teaching	Measures the flexibility and ease of using the media in different teaching methods and classroom settings.
5	Effectiveness in Enhancing Learning	Assesses the media's ability to improve students' understanding of cubes and cuboids.
6	Support for Interaction	Measures how well the media facilitates teacher-student and peer interactions during learning.
7	Teacher Readiness to Use the Media	Evaluates the teacher's willingness to use the media in future lessons and any need for additional training.

Fifth, test. The question test is an evaluation of student learning. Students are given a test to determine their understanding of cubes and blocks. The test sheet is in two forms, pre-test and post-test, and is given to students in the second trial. The evaluation sheet aims to measure the effectiveness of learning media on student learning outcomes using pop-up book media.

Table 3. Test Instrument Indicators

No	Indicators	Description
1	Understanding the Properties of Cubes and Cuboids	Assesses students' understanding of basic properties of cubes and cuboids, such as faces, edges, and angles.
2	Calculation of Volume and Surface Area	Evaluates students' ability to calculate the volume and surface area of cubes and cuboids.
3	Understanding of Spatial Relationships	Measures students' ability to understand the spatial relationships and orientation of three-dimensional objects.
4	Application of Cubes and Cuboids in Real-World Contexts	Assesses students' ability to relate the concepts of cubes and cuboids to real-life situations.
5	Problem-Solving with Cubes and Cuboids	Tests students' ability to solve contextual problems involving cubes and cuboids.
6	Identification of Real-World Objects as Cubes or Cuboids	Measures students' ability to identify real-world objects that are cubes or cuboids.

Proper data analysis techniques were employed to ensure the validity and reliability of the data collected. The analysis process included evaluating observation data, validation forms, questionnaires, and test results using appropriate quantitative and statistical methods. Data from validation forms, teacher questionnaires, and student questionnaires were analyzed using quantitative descriptive analysis, employing Likert scales to measure the levels of agreement with various criteria. The Likert scale ranged from 1 (Very Poor) to 5 (Very Good), allowing for a structured assessment of the media's validity, practicality, and effectiveness. In addition, data collected from observation sheets were analyzed qualitatively to identify patterns in student behavior, teacher-student interactions, and overall classroom dynamics during the implementation of the Math pop-up book. The percentage results from the Likert-scale responses were interpreted based on predefined validity criteria:

Table 4. Validity criteria

No.	Validity Criteria	Validity Percentage
1	Very Valid	81% – 100%
2	Valid	61% – 80%
3	Fairly Valid	41% – 60%
4	Less Valid	21% – 40%
5	Not Valid	< 20%

Based on **Table 4**, used to interpret the validation results of the instructional media. The percentage range indicates the level of alignment and quality of the media based on predefined standards. The aggregated results were converted into percentages for more explicit interpretation and classification. For the test data analysis, pre-test and post-test scores were processed to evaluate the effectiveness of the Math pop-up book in improving students' understanding of cubes and cuboids. The research design employed a one-group pre-test and post-test approach, where the same group of students was assessed before and after using the media. The difference in scores was analyzed quantitatively using a t-test. The significance of the

treatment effect was determined by comparing the empirical t-value (calculated from the data) with the theoretical t-value (from a t-distribution table). If the empirical t-value exceeded the theoretical t-value, the null hypothesis (H_0) was rejected, indicating a statistically significant improvement in student learning outcomes. Conversely, the null hypothesis was accepted if the empirical t-value was smaller. The success criteria for the media's validation, practicality, and effectiveness were defined as follows. First, the Math pop-up book was considered valid if the average percentage of validation scores achieved $\geq 61\%$, indicating alignment with accepted standards for educational media. Second, the media was deemed practical if more than 61% of questionnaire responses fell into the "very strong" or "strong" categories, demonstrating ease of use and applicability in classroom settings. Third, the media was considered adequate if post-test scores significantly improved compared to pre-test scores, confirming its impact on students' understanding of cubes and cuboids. This comprehensive data analysis framework ensured that the media's development was rigorously evaluated across multiple dimensions, providing reliable evidence of its validity, practicality, and effectiveness in enhancing mathematics learning outcomes.

3. RESULTS AND DISCUSSION

The primary objective of this study is to develop an educational tool—a Math Pop-Up Book—focused on the geometry topics of cubes and cuboids. This tool is specifically designed to enhance problem-solving skills among eighth-grade students at MTs Miftahul Ulum. The Pop-Up Book offers realistic two-dimensional and three-dimensional representations when opened, creating a more engaging and interactive learning experience. The problem-solving approach supported by this tool involves stages of understanding the problem, planning a solution, implementing the solution, and interpreting the results. The development process follows the ADDIE model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation.

3.1 Analysis

The initial phase of this study involved a comprehensive analysis of the learning process, aimed at identifying the specific needs related to the development of the educational medium. This needs analysis was carried out through a review of relevant literature and pilot trials conducted with junior high school students in Probolinggo City. The literature review identified several critical areas that require attention: (1) the importance of learning geometry, particularly concepts related to cubes and cuboids; (2) the common challenges students face in understanding these geometric concepts; (3) the need for innovative teaching media that can be effectively applied in the classroom; and (4) the effectiveness of pop-up books as an educational medium, as demonstrated by previous studies. The field analysis revealed that traditional teaching methods, which often rely on textbooks and blackboard illustrations of geometric shapes, have been insufficient in helping students fully grasp the material. Many students struggle with visualizing and understanding three-dimensional shapes when presented only in two dimensions. Based on the findings from the needs analysis and the literature review, including studies by (Chao et al., 2018; Fazira & Qohar, 2021; Nuratiqoh & Qohar, 2024), the Math Pop-Up book emerged as a promising tool for teaching geometric shapes. This medium is expected to improve student learning outcomes by providing realistic and interactive visualizations, thus promoting a deeper understanding of geometric concepts.

Furthermore, the analysis of the curriculum indicated that the material to be covered in the Math Pop-Up book is in line with the curriculum requirements for junior high school students, specifically the content on cubes and cuboids, which is part of the geometry section in the mathematics syllabus for grade 8th. The relevant competencies and learning objectives from the Merdeka Curriculum' and 2013 Curriculum include the ability to identify the properties of three-dimensional shapes and apply formulas for volume and surface area in contextual problem-solving. The Math Pop-Up book is designed to align with these competencies by helping students recognize the properties of cubes and cuboids, compute their volume and surface area, and apply these concepts to real-life scenarios. The inclusion of interactive, three-dimensional visuals aims to strengthen students' understanding and engagement with the subject matter, ensuring a more effective and meaningful learning experience.

In terms of content depth, the book will cover fundamental concepts such as the properties of cubes and cuboids, including the number of faces, edges, and vertices, as well as methods for calculating their volume and surface area. It will also provide contextual problem-solving tasks that relate the geometric concepts to everyday life, thus allowing students to see the practical applications of what they learn. By combining theoretical explanations with interactive and visual elements, the Math Pop-Up book addresses the needs of students who find it challenging to comprehend abstract geometric concepts in a traditional classroom setting. This design aims to facilitate a deeper understanding and mastery of the concepts of cubes and cuboids, contributing to the overall improvement of student learning outcomes in geometry.

3.2 Design

In the design phase, the focus shifts to conceptualizing the new educational media and establishing the framework for its creation and implementation ((Li & Cheong, 2023) This phase is essential for aligning the instructional media with the learning objectives, particularly in the context of developing the Math Pop-Up book. The design process begins by preparing the necessary materials, which include glue, scissors, double-sided tape, cutters, rulers, pencils, glossy A4 paper, manila paper, Asturo paper, sewing thread, and cardboard. These tools are selected to ensure the durability, interactivity, and aesthetic quality of the final product. A critical step in the design phase is the creation of a storyboard or prototype, which serves as a blueprint for the media. The storyboard outlines the structure, flow, and content of the Math Pop-Up book, ensuring that the instructional material is organized in a way that enhances both visual appeal and pedagogical

effectiveness. The storyboard is used to plan each section of the book, including its interaction design, content layout, and visual elements, before moving on to the actual development phase.

The Math Pop-Up Book is structured to include several key components aimed at maximizing student engagement and comprehension. These components are carefully organized across the media to ensure a logical progression of content. The layout includes a cover page, motivational quotes, a preface, a table of contents, core competencies (KI), basic competencies (KD), indicators, and nine additional pages featuring instructional content along with three-dimensional illustrations. The storyboard also includes detailed designs for the pop-up elements, showing how the 3D illustrations will unfold to demonstrate key concepts like the volume, surface area, and properties of cubes and cuboids. These interactive elements are strategically placed to maintain student interest and enhance their comprehension through hands-on learning.

Table 5. The Math Pop-Up Book Storyboard Layout

No	Contents	Visual/Interaction Design
1	Cover Page & Title	Eye-catching graphics with the title and subtitle.
2	Motivational Quote	Inspirational quote to engage students in the learning process.
3	Preface & Instructions	Brief introduction and guidelines for using the Pop-Up Book effectively.
4	Table of Contents	Organized listing of all sections and topics.
5	Core Competencies & Basic Competencies	Aligned with curriculum, showing learning objectives.
6	Cube Properties	Pop-up illustration of a cube with labels for faces, edges, and vertices.
7	Cuboid Properties	Pop-up illustration of a cuboid with labels and explanations.
8	Volume Calculation (Cube)	Interactive pop-up demonstrating the volume formula with visual aids.
9	Surface Area Calculation (Cuboid)	Pop-up demonstrating surface area formula and real-life applications.
10	Practice Problems	Example problems and exercises to apply learning.

The design phase thus establishes a clear visual and instructional structure for the Math Pop-Up Book, ensuring that the final product is both engaging and effective in promoting a deep understanding of geometric concepts among students. The storyboard serves as a foundational guide, ensuring that all content is presented in a visually appealing, interactive, and pedagogically sound manner. This step is critical to guarantee the media's alignment with both the curriculum and the specific learning needs of the target audience.

3.3 Development

The development stage of this research focuses on transforming the conceptual design into a tangible and functional educational tool, while also creating assessment instruments to evaluate its effectiveness (Li & Cheong, 2023). In this phase, the findings from the analysis and design stages are integrated to develop the Math Pop-Up book, ensuring it aligns with the predefined learning objectives and educational goals. Once the prototype of the Math Pop-Up Book is completed, validation tests are conducted by experts to assess its feasibility, effectiveness, and alignment with the intended learning outcomes. During the validation process, the Math Pop-Up Book was evaluated based on multiple criteria, including content accuracy, media effectiveness, clarity, and design quality. The evaluators, who are experts in educational media, provided feedback and suggestions for improvement.

The validation process evaluated the Math Pop-Up Book from material and media perspectives. The material validation focused on feasibility and content, assessing alignment with the curriculum, including basic competencies, indicators, objectives, and evaluation components. The feasibility aspect achieved an average score of 4.6, with a percentage of 92%, while the content aspect scored an average of 4.25, yielding 85%. Overall, the material validation achieved an average score of 4.38 and a percentage of 87.69%, both categorized as Very Good. Media validation assessed communication, technical design, and packaging format. Communication and technical design achieved average scores of 4.25 and 4.29, corresponding to percentages of 85% and 85.71%, respectively, categorized as Very Good. The packaging format achieved an average score of 4.0, with a percentage of 80%, categorized as Good. Overall, the media validation achieved an average score of 4.2, with a percentage of 84%, categorized as Very Good. These results indicate that the Math Pop-Up Book is of high quality, meeting the standards for effective educational media, and is deemed suitable for classroom use. The specific feedback from the media experts revealed areas that required revision, especially concerning the clarity of the instructions for using the pop-up features and the integration of these instructions with the student worksheets.

In response to the feedback, revisions were implemented to improve the clarity and usability of the Math Pop-Up Book. The instructions for using the pop-up book were refined to include more detailed and explicit guidance, ensuring students could effectively engage with the pop-up elements. These instructions were also integrated with the student worksheets to provide a seamless and cohesive learning experience. Additionally, the validators recommended including essential information in the student worksheets, such as learning objectives, basic competencies, and specific indicators, to enhance students' comprehension of the learning goals and expected outcomes. The experts subsequently re-evaluated the revised version of the Math Pop-Up Book and confirmed that it aligned with curriculum standards and was suitable for classroom implementation. The content and interactive features of the media were deemed engaging and well-suited for the target students, ensuring its effectiveness in facilitating the learning process. Below are images of the final version of the developed media, showcasing key interactive elements that contribute to its educational impact.



Figure 1. Final Product Revision Results

3.4 Implementation

The implementation stage of this research aims to assess the practicality and effectiveness of the Mathematics Pop-Up Book as a learning medium for grade VIII students of MTs Miftahul Ulum. The main objective of this stage is to convey the practicality of the media through student responses and observing teachers, with a particular focus on its impact on students' understanding of geometric concepts such as cuboids and cubes (Alnajdi, 2018). The student response questionnaire was administered to assess student engagement with the Mathematics Pop-Up Book. The questionnaire was designed to broadcast two main aspects: material presentation and language and media display. The results of the student response analysis showed that the Mathematics Pop-Up Book received a very positive score, with an overall score of 80.4%. These results indicate that the media was well-received, interesting, and effective in facilitating student understanding.

Regarding material presentation, students rated the media's ease of use very high, with an average score of 4. They also considered the media useful, with a score of 3.5. Students showed moderate interest in learning after using the media, with a score of 3, and reported a positive attitude toward mathematics, also scoring 3. Similarly, their motivation toward mathematics increased after using the media, with a score of 3. In terms of language and appearance, students rated the clarity of writing and the appearance of the media with a score of 3. These results collectively reflect that students felt that the media helped them understand the material and that the information was fun to use. These findings are in line with previous studies (Mohamed & Kandeel, 2023; Nuratiqoh & Qohar, 2024), which showed that interactive learning media, such as the Math Pop-Up Book, fostered positive attitudes and motivation toward learning mathematics. In addition to student evaluations, teacher observations were conducted to assess the practicality and usefulness of the media in the classroom. Teachers assessed the media's ease of use, the time required to explain the material and the level of student engagement during learning. These observations indicate that the Math Pop-Up Book was considered very practical, with a score of 90% for ease of use and effectiveness in maintaining student engagement. Teachers noted that the media helped facilitate smoother lesson delivery so students could better understand geometry concepts more engagingly and interactively.

In this study, the effectiveness of the Pop-Up Mathematics Book was assessed through student learning outcomes, activities, and the ability to understand concepts. Learning media is considered adequate if the post-test score is higher than the pre-test score, student activities align with the predetermined indicators, and the test significantly increases the understanding of concepts. The test results showed a significant increase in student learning outcomes. The average pre-test score of third-grade elementary school students was 62.72, while the post-test score increased to 88, reflecting an increase of 25%. This shows that the learning media effectively improves students' understanding of cube and cuboid material. A t-test was conducted to test the significance of these results, with the hypotheses $H_0 = \mu_1 \geq \mu_2$ and $H_1 = \mu_1 < \mu_2$. Based on the sample distribution and a significance level of 5%, the calculated t_{value} confirmed a statistically significant increase in student performance after using the media. These findings indicate that the Pop-Up Mathematics Book effectively improves students' understanding of cubes and cuboids and encourages meaningful engagement in the learning process.

3.5 Evaluation

After the initial product trial and obtaining very valid and practical media results, the final product trial was conducted on 22 8th-grade students of MTs Miftahul Ulum, Probolinggo. The trial aims to assess the effectiveness of learning media in learning in a real environment, namely 8th-grade students. A t-test was conducted to measure this, and the results showed that H_0 was rejected and H_1 was accepted. This shows a significant difference between the learning outcomes of exposition

before and after the implementation of interactive learning media in writing learning for 8th-grade students.

The final stage is when the media has been tested in the field. The Mathematics pop-up book learning media is ready to be distributed to surrounding junior high schools/MTs. There are many advantages in the interactive learning media that are produced, namely: 1) the media is designed in such a way that the delivery of the material becomes interesting, 2) the media can provide stimulus to students before starting to solve cube and block problems, 3) the media is engaging so that it can attract attention, interest, and improve memory. This increase indicates that the Math Pop-Up Book is effective in helping students comprehend the geometric concepts of cubes and cuboids (Mohamed & Kandeel, 2023; Wardani et al., 2019). The realistic visualization provided by the book enables students to grasp the taught concepts more easily, thereby enhancing their problem-solving abilities. Additionally, the use of the Math Pop-Up Book enhances student engagement and enthusiasm in the learning process. Students become more active and participative in learning activities, contributing to the improvement of their learning outcomes. Overall, the evaluation shows that the Math Pop-Up Book is a valid, practical, and effective learning medium for mathematics education, particularly for the topic of geometric shapes such as cuboids and cubes. This medium not only enhances concept comprehension but also boosts student motivation and participation in learning.

4. CONCLUSION

This study successfully developed an innovative educational tool, the Math Pop-Up Book, focusing on the geometry topics of cubes and cuboids, designed for eighth-grade students at MTs Miftahul Ulum. Using the ADDIE model, the research demonstrated the tool's effectiveness in improving students' problem-solving skills, engagement, and understanding of geometric concepts. The findings showed a significant increase in students' learning outcomes, as evidenced by a notable improvement in test scores from pre-test to post-test. A key insight from this research is the value of integrating interactive, visually engaging media into mathematics education, which can bridge the gap between abstract concepts and practical understanding, thereby fostering more profound learning experiences. This study contributes to the academic field by providing a novel perspective on using interactive media, specifically pop-up books, as an effective method to teach geometry. It advances how three-dimensional visualization can enhance students' comprehension and problem-solving abilities, offering an alternative to traditional teaching methods. Moreover, this research introduces an innovative methodological approach to integrating curriculum-based competencies with interactive learning designs, thus paving the way for further exploration of hands-on educational tools in various disciplines. However, the study is not without limitations. Its scope is restricted to a specific group of students in a single location, focusing only on cubes and cuboids. It does not account for variations in gender, age, or broader demographics, nor does it explore the potential application of other instructional methods or topics. Future studies should address these gaps by including more diverse student populations, a wider range of geometric topics, and the application of mixed methods, such as surveys or longitudinal studies. Such comprehensive research would provide a deeper and more nuanced understanding of the effectiveness of interactive learning media, offering robust evidence to inform educational policies and practices for broader implementation.

ACKNOWLEDGEMENTS

The authors wish to express their profound gratitude to all those who contributed to the completion of this article, with particular thanks to our esteemed colleagues for their insightful contributions and unwavering support throughout the research and writing process. We are also immensely grateful to the students who participated in the study, sharing their perspectives and engaging enthusiastically in the learning activities. Additionally, we extend our profound gratitude to the faculty and staff of MTs Miftahul Ulum, Probolinggo, for their unwavering cooperation and invaluable assistance in facilitating this research. Their commitment to providing an optimal learning environment has been instrumental in achieving significant outcomes, exemplifying the collaborative spirit that underpins meaningful academic inquiry.

REFERENCES

- Abbazio, J. M., Majewicz, K., & Ultan, D. K. (2023). "The pop-up exhibitrary": collaborative library outreach for performing arts audiences. *Public Services Quarterly*, 19(3), 176–200. <https://doi.org/10.1080/15228959.2023.2181277>
- Baah-Duodu, S., Osei-Buabeng, V., Cornelius, E. F., & Hegan, J. E. (2020). Review of Literature on Teaching and Learning Geometry and Measurement: A Case of Ghanaian Standards Based Mathematics Curriculum. *International Journal of Advances in Scientific Research and Engineering (IJASRE)*, ISSN:2454-8006, DOI: 10.31695/IJASRE, 6(3), 103–124. <https://doi.org/10.31695/IJASRE.2020.33766>
- Bizimana, E., Mutangana, D., & Mwesigye, A. (2022). Fostering Students' Retention in Photosynthesis Using Concept Mapping and Cooperative Mastery Learning Instructional Strategies. *European Journal of Educational Research*, 11(1), 103–116.

- Chao, Q., Lu, T., Zhao, X., -, al, Guo, K., Tamirisa, P. A., Sheldon, B. W., Susilo, T., Sujadi, I., & Indriati, D. (2018). Developing A Media 'Visual Design of Pop Up Mathematics Book' as a Supporting Tool in Inquiry-Based Learning for Learning Three-Dimensional Figures. *Journal of Physics: Conference Series*, 1108(1), 012029. <https://doi.org/10.1088/1742-6596/1108/1/012029>
- Charline, C., Jo, S., & Frederic, E. (2023). Use of Learning Media to Increase Student Learning Motivation in Junior High Schools. *World Psychology*, 2(3), 176–189. <https://doi.org/10.55849/WP.V2I3.402>
- Dixon, R. A., & Brown, R. A. (2012). Transfer of learning: Connecting concepts during problem solving. *Journal of Technology Education*, 24(1), 2–17. <https://doi.org/10.21061/JTE.V24I1.A.1>
- El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, 18(1), 1–24. <https://doi.org/10.1186/S41239-021-00289-4/TABLES/4>
- Fazira, S. K., & Qohar, A. (2021). Development of Pop-up Book Mathematics Learning Media on Polyhedron Topics. *Journal of Physics: Conference Series*, 1957(1), 012005. <https://doi.org/10.1088/1742-6596/1957/1/012005>
- Gee, E., & Harefa, D. (2021). Analysis of Students' Mathematic Analisis Kemampuan Koneksi dan Pemahaman Konsep Matematis Siswa. *Musamus Journal of Primary Education*, 4(1), 1–11. <https://doi.org/10.35724/musjpe.v4i1.3475>
- Gurmu, F., Tuge, C., & Hunde, A. B. (2024). Effects of GeoGebra-assisted instructional methods on students' conceptual understanding of geometry. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2379745>
- İbili, E., Çat, M., Resnyansky, D., Şahin, S., & Billingham, M. (2020). 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(2), 224–246. <https://doi.org/10.1080/0020739X.2019.1583382>
- Jablonski, S., & Ludwig, M. (2023). Teaching and Learning of Geometry—A Literature Review on Current Developments in Theory and Practice. *Education Sciences* 2023, Vol. 13, Page 682, 13(7), 682. <https://doi.org/10.3390/EDUCSCI13070682>
- Kuzniak, A., & Nechache, A. (2021). On forms of geometric work: a study with pre-service teachers based on the theory of Mathematical Working Spaces. *Educational Studies in Mathematics*, 106(2), 271–289. <https://doi.org/10.1007/S10649-020-10011-2/METRICS>
- Kwok, K., Ghrear, S., Li, V., Haddock, T., Coleman, P., & Birch, S. A. J. (2016). Children can learn new facts equally well from interactive media versus face to face instruction. *Frontiers in Psychology*, 7(OCT), 220068. <https://doi.org/10.3389/FPSYG.2016.01603/BIBTEX>
- Larson, J. S., Farnsworth, K., Folkestad, L. S., Tirkolaie, H. K., Glazewski, K., & Savenye, W. (2018). Using Problem-Based Learning to Enable Application of Foundation Engineering Knowledge in a Real-World Problem. *Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018*, 500–506. <https://doi.org/10.1109/TALE.2018.8615329>
- Lasher, M., & Denzer, K. (2020). Just Popping In: Collections and Outreach Collaborations to Increase Student Engagement with Electronic Resources. *Serials Review*, 46(3), 201–208. <https://doi.org/10.1080/00987913.2020.1806649>
- Legarde, M. A. A. (2022). Working with Mathematical Problems: an Analysis Of Students Misconceptions and Its Impact on Mathematics Learning. *International Journal of Advanced Research*, 10(03), 25–33. <https://doi.org/10.21474/IJAR01/14358>
- Li, H., & Cheong, J. P. G. (2023). Using the ADDIE model to design and develop physical education lessons incorporated with a functional training component. *Frontiers in Public Health*, 11, 1201228. <https://doi.org/10.3389/FPUBH.2023.1201228/BIBTEX>
- Liono, R. A., Amanda, N., Pratiwi, A., & Gunawan, A. A. S. (2021). A Systematic Literature Review: Learning with Visual by The Help of Augmented Reality Helps Students Learn Better. *Procedia Computer Science*, 179, 144–152. <https://doi.org/10.1016/J.PROCS.2020.12.019>
- Liu, J., Huang, Z., Ma, Z., Liu, Q., Chen, E., Su, T., & Liu, H. (2023). Guiding Mathematical Reasoning via Mastering Commonsense Formula Knowledge. *Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 1477–1488. <https://doi.org/10.1145/3580305.3599375>
- Mariappan, L. (2024). From Boredom to Excitement: Transforming Classroom Activities with Realia-Based Games. *Journal of Electrical Systems*, 20(5s), 1607–1613. <https://doi.org/10.52783/JES.2494>
- Maryanih, M., Rohaeti, E. E., & Afrilianto, M. (2018). ANALISIS KESULITAN SISWA SMP DALAM MEMAHAMI KONSEP KUBUS BALOK. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, 1(4), 751. <https://doi.org/10.22460/jpmi.v1i4.p751-758>

- Mi, S., Lu, S., & Bi, H. (2020). Trends and foundations in research on students' conceptual understanding in science education: A method based on the structural topic model. *Journal of Baltic Science Education*, 19(4), 551–568. <https://doi.org/10.33225/JBSE/20.19.551>
- Mohamed, D. A., & Kandeel, M. M. (2023). Playful Learning: Teaching the Properties of Geometric Shapes through Pop-up Mechanisms for Kindergarten. *International Journal of Education in Mathematics*, 11(1), 179–197. <https://doi.org/10.46328/ijemst.2921>
- Mudhefi, F., Mabotja, K., & Muthelo, D. (2024). The use of Van Hiele's geometric thinking model to interpret Grade 12 learners' learning difficulties in Euclidean Geometry. *Perspectives in Education*, 42(2), 162–175. <https://doi.org/10.38140/PIE.V42I2.8350>
- Mutia, M. (2017). Analisis kesulitan siswa SMP dalam memahami konsep kubus balok dan alternatif pemecahannya. *Beta: Jurnal Tadris Matematika*, 10(1), 83–102. <https://doi.org/10.20414/betajtm.v10i1.107>
- Nkosinkulu, Z. (2024). Visualizing education: infographics and pop-up edutainment exhibitions. *Journal of Visual Literacy*, 43(3), 250–265. <https://doi.org/10.1080/1051144X.2024.2396253>
- Nuratiqoh, & Qohar, A. (2024). Development of Worksheets Using Pop-Up Books and GeoGebra in the Learning of Polyhedron Concepts. *AIP Conference Proceedings*, 3176(1). <https://doi.org/10.1063/5.0222512/3305402>
- Paige, D. D., Rupley, W. H., & Magpuri-Lavell, T. (2019). The lexile leap: Consequences for foundational skills and accountability achievement. *Universal Journal of Educational Research*, 7(9), 1882–1891. <https://doi.org/10.13189/UJER.2019.070906>
- Sarwar, M. N., Maqbool, M. A., Ullah, S., Rana, A. S., Khan, S. U., Ibrahim, A. A., Alam, K., Zafar, S., Ullah, Z., & Nazar, M. F. (2024). Fostering Conceptual Understanding of Photocatalysis for Sustainable Development: A Social Constructivism Flipped-Classroom Model. *Sustainability 2024, Vol. 16, Page 10324*, 16(23), 10324. <https://doi.org/10.3390/SU162310324>
- Strong, J. Z., Tortorelli, L. S., & Anderson, B. E. (2024). Read STOP Write: Teaching foundational skills in a multicomponent informational reading and writing intervention. *Journal of Adolescent and Adult Literacy*. <https://doi.org/10.1002/JAAL.1389>
- Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of Problem-Solving Strategies in Mathematics Education Supporting the Sustainability of 21st-Century Skills. *Sustainability 2020, Vol. 12, Page 10113*, 12(23), 10113. <https://doi.org/10.3390/SU122310113>
- Tang, H. (2023). The Effect of Different Teaching Styles of Shenzhen Teachers on Students Learning Motivation The Example of Seminar and Lecture Methods. *Lecture Notes in Education Psychology and Public Media*, 21(1), 273–282. <https://doi.org/10.54254/2753-7048/21/20230169>
- Tuma, F. (2021). The use of educational technology for interactive teaching in lectures. *Annals of Medicine and Surgery*, 62, 231–235. <https://doi.org/10.1016/J.AMSU.2021.01.051>
- Vansdadiya, R. P., Vasoya, N. H., & Gondaliya, P. R. (2023). Beyond the Classroom Walls: Activity based Learning for a Real-world Math Experience. *Asian Journal of Education and Social Studies*, 43(1), 1–9. <https://doi.org/10.9734/AJESS/2023/V43I1930>
- Vijayalakshmi, A., & Reddy, J. K. (2020). Role of Multimedia on Motivation and Knowledge Retention. *The International Journal of Analytical and Experimental Modal Analysis*, XII(IV).
- Wardani, I., Tolle, H., & Aknuranda, I. (2019). Evaluation of an educational media on cube nets based on learning effectiveness and gamification parameters. *International Journal of Emerging Technologies in Learning*, 14(14), 4. <https://doi.org/10.3991/IJET.V14I14.10505>
- Wardhani, I. S., Nusantara, T., Parta, I. N., & Permadi, H. (2023). The Model of Geometry Learning with Spatial Skills Features: Is It Possible? *Journal of Higher Education Theory and Practice*, 23(14), 225. <https://doi.org/10.33423/JHETP.V23I14.6397>
- Xu, C., Lafay, A., Douglas, H., Di Lonardo Burr, S., LeFevre, J. A., Osana, H. P., Skwarchuk, S. L., Wylie, J., Simms, V., & Maloney, E. A. (2021). The Role of Mathematical Language Skills in Arithmetic Fluency and Word-Problem Solving for First and Second-Language Learners. *Journal of Educational Psychology*, 114(3), 513–539. <https://doi.org/10.1037/EDU0000673>
- Zhou, D., Gomez, R., Davis, J., & Rittenbruch, M. (2023). Engaging solution-based design process for integrated STEM program development: an exploratory study through autoethnographic design practice. *International Journal of Technology and Design Education*, 33(2), 717–748. <https://doi.org/10.1007/S10798-022-09745-2/TABLES/3>