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Developing Transparent Concrete Geometry Media Using the 4D Model for Junior High School Surface Area Learning

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This study aims to develop transparent concrete learning media for spatial geometry and evaluate its feasibility, practicality, and effectiveness in supporting students' understanding of surface area concepts. This development applies the 4D model (Definition, Design, Development, and Dissemination) and involves one media expert, one subject matter expert, and 30 ninth-grade students during the limited dissemination phase. The uniqueness of this study lies in the use of a transparent acrylic model that allows students to clearly observe the relationships among planes, edges, and angles, providing a concrete, visually accessible representation of geometric structures. The research procedure included a student needs analysis, prototype design and production, product validation through expert review, and limited classroom deployment supported by pre- and post-test assessments. Media experts rated the product at 80% (acceptable), while subject matter experts rated it at 87.5% (highly acceptable). Students' conceptual understanding improved significantly, with the average pre-test score of 81.43 increasing to 100 on the post-test, resulting in an N-Gain of 1.00 (very high). The student response rate reached 66.9% (very practical). These findings indicate that transparent concrete geometric media are feasible, practical, and effective, offering pedagogical advantages for enhancing students' conceptual understanding through realistic, transparent geometric representations.

Keywords: 4D Model Concrete Media Development Geometry Surface Area

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1.

INTRODUCTION

Understanding three-dimensional space remains one of the most challenging concepts in mathematics for students. Many students struggle to connect real objects with abstract representations of solid figures, especially when determining surface area [1]. This difficulty is often caused by a predominantly symbolic and procedural approach to learning, which gives students little opportunity to visualize how the surfaces of a solid figure relate

to each other. As a result, students' mathematical representation skills are weak, and they often fail to generalize concepts to new situations [2]. Concrete manipulatives have been widely recognized as effective tools for supporting conceptual understanding in geometry. By allowing students to physically hold and manipulate objects, these tools help bridge the gap between abstract ideas and real-world experiences [3]. Evidence from systematic reviews indicates that concrete media can improve learning outcomes, student engagement, and conceptual understanding across various geometry topics [4]. However, most existing manipulatives remain limited to flat, two-dimensional models, and research on three-dimensional models that can be physically manipulated and are specifically designed for surface area exploration remains scarce [5]. This problem becomes more critical in contexts where teachers rely heavily on textbook illustrations due to limited access to visual and tactile learning resources [6]. The constructivist perspective emphasizes that meaningful understanding develops through practical activities and reflective exploration. Three-dimensional models that can be opened, reassembled, and explored in detail provide learners with the opportunity to understand how individual faces form a complete spatial figure, thereby strengthening spatial reasoning [7]. Transparent media offer the added advantage of allowing students to observe internal structures and overlaps. This clarity helps reduce misunderstandings that often arise when non-transparent models obscure important geometric relationships. Previous studies have shown that such learning aids can significantly improve spatial visualization and fluency of representation [8]. Based on these theoretical and empirical insights, this study developed transparent solid geometry media specifically designed for learning surface area. This media consists of several geometric shapes, including cubes, blocks, pyramids, and prisms, made of colored transparent acrylic. Each model can be opened to reveal its net and is supported by real-life context connections. This design encourages exploration, discovery, and motivation while helping students build a deeper understanding of geometric concepts. The uniqueness of this study lies in the development and validation of a physically manipulable, transparent three-dimensional model, specifically designed for learning surface area. Existing studies rarely focus on transparent acrylic models that allow students to clearly see geometric relationships, and many rely on digital or two-dimensional representations [9]. Therefore, this research contributes both theoretically and practically by offering empirically tested, concrete learning tools that support students' conceptual understanding through realistic and accessible visual representations. This study aims to: (1) develop concrete, transparent solid geometry media for surface area learning, (2) evaluate its feasibility through expert validation, (3) analyze its practicality based on student responses, and (4) determine its effectiveness in improving students' conceptual understanding. 2. METHOD This study employs a research and development (R&D) design based on the 4D model (Define, Design, Develop, Disseminate), formulated by Thiagarajan and Semmel. This model was chosen because it provides a structured and systematic framework for

https://doi.org/10.58421/misro.v4i4.815 1467 producing educational products that are suitable and practical for mathematics learning [10]. The 4D framework is often applied in the development of mathematics learning media because it facilitates the alignment of product characteristics with student needs and instructional content [11]. The products developed in this study were transparent 8 concrete models of solid figures, including cubes, rectangular prisms, prisms, and pyramids, designed to support ninth-grade students' understanding of surface area concepts [12]. The define stage involved analyzing student needs and identifying conceptual difficulties in surface-area learning [13]. 6 The design stage included preparing visual specifications, selecting materials, and planning the details of the transparent acrylic and thick cardboard components to ensure clear visibility of the geometric relationships. The development stage included product construction and validation by experts. Two experts were involved: a mathematics education lecturer as a media expert and a mathematics teacher as a subject matter expert. Both experts evaluated the product using a validation rubric comprising two core dimensions: feasibility and practicality. Feasibility was assessed in terms of content accuracy, clarity of representation, and alignment with curriculum standards, while practicality was evaluated based on durability, ease of use, and classroom implementation. After revisions were made based on expert feedback, the product proceeded to limited testing at the dissemination stage [14], [15]. Figure 1. 4-D Research Stages The research subjects were 30 ninth-grade students from SMPIT Al-Mubarok in Serang City, selected using random sampling. This technique was chosen for its practicality and affordability in a school context, making it suitable for development studies that require real classroom conditions. However, random sampling has limitations, particularly in terms of limited generalizability and susceptibility to selection bias. These limitations are acknowledged as part of the study's limitations [16], [17]. Ethical procedures were fully adhered to. Official permission was obtained from the school, and written consent was collected from participating students. Participants were informed that the data would be used exclusively for academic purposes and that all personal information would remain confidential. Data collection techniques included observation, interviews, expert validation, questionnaires, and pre- and post-test assessments. Quantitative data were obtained from expert validation scores and student test results, while qualitative data were collected through classroom observation and semi-structured interviews during the pilot implementation. Quantitative data were analyzed descriptively through mean scores to determine the feasibility and practicality of the media. 12 The effectiveness of the media was measured using the N-gain formula to evaluate improvements in students' conceptual understanding [18]. Qualitative data were analyzed through a thematic analysis, which involved coding responses, grouping them into categories, and interpreting the emerging themes. These

https://doi.org/10.58421/misro.v4i4.815 1468 qualitative findings were used to enrich the quantitative results by providing contextual insights into the usefulness of the media, student engagement, and the learning process. 3. RESULTS AND DISCUSSION 3.1. Results Define Stage 13 The first step in conducting this research was to interview a mathematics teacher at SMPIT Al-Mubarok. The purpose of this interview was to identify problems related to teaching materials and learning media for mathematics, particularly in the subject of surface area of solid figures. The interview was conducted on Monday, September 15, 2025, with a ninth-grade mathematics teacher. 3 Based on the interview results, it was found that most students still struggled to understand the relationship between two-dimensional and threedimensional shapes. Students tend to memorize 11 surface area formulas without understanding their origins and the relationship between these formulas and the shapes of three-dimensional figures. The teacher also said that the learning process so far has still relied on print media, such as textbooks, without using concrete media that allow students to observe the shapes of three-dimensional figures directly. This condition aligns with research indicating that learning abstract geometry can limit students' understanding [19]. Based on the results of these observations and interviews, the researcher conducted a further analysis of the Learning Achievements and Learning Objective Flow in the ninthgrade mathematics curriculum. The aim was 12 to ensure that the media developed aligned with the expected competencies. The analysis showed that students were expected to be able to identify, explain, and calculate the surface area of cubes, blocks, prisms, and pyramids, as well as to explain the relationship between net shapes and solid shapes. However, in reality, many students only mastered procedural skills, namely calculating, without understanding the concepts behind the calculations. Therefore, in this defining stage, it was determined that the learning media developed must encourage conceptual understanding [20]. In response to field problems, researchers sought to update the 10 geometry learning media by developing transparent concrete media made of acrylic and thick, colored cardboard. This media was designed to enable students to dismantle and reassemble spatial shapes, allowing them to observe the relationship between their constituent sides directly. Through these manipulative activities, students are expected to gain a deeper understanding of the meaning of surface area formulas rather than simply memorizing them. This aligns with findings that the use of concrete and manipulative media can enhance students' conceptual thinking skills and facilitate the transition from concrete to abstract understanding in geometry learning [21]. Design 6 Stage The Design stage produces media based on student needs. The media is designed as a spatial structure that can be broken down into its constituent parts, or nets. The primary materials selected are transparent acrylic (for the body of the spatial structure) and thick cardboard (for the nets), which are connected by a separate acrylic side for easy assembly and disassembly. Important elements in the design include: (1) Side visualization: The sides

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of the spatial structure are given colored cardboard images to help students visually identify that 9 the Surface Area is the sum of all its constituent sides. (2) Concrete-Abstract Connection: The cardboard nets can be flattened on a table, allowing students to see the geometric relationship between the 3D shape and its 2D form, which is the basis for discovering the surface area formula. (3) Geometric shapes: The prototypes include cubes, blocks, 8 prisms, and pyramids, which are the main surface area materials in the Solid Shapes chapter at the junior high school level. Development Stage The realization of Concrete Space Geometry Media used transparent acrylic (for the body of the space structure) and thick cardboard (for the nets) as the main materials, both of which are easy to manipulate. Transparent acrylic was specifically chosen to address the visualization issues identified in the Define stage, enabling students to see the components of the spatial structure, represented by colored cardboard images. Despite using more specific materials (acrylic), the development process still maintains cost efficiency and ease of finding materials according to practicality criteria. The product is designed to provide an enactive (manipulative) experience through a mechanism of assembling and disassembling nets made of thick cardboard, which directly supports the discovery of 9 the Surface Area formula. The initial design of the media product was then reviewed and evaluated by 6 a team of validators, comprising one Media Expert and one Material Expert, who provided assessments using a 4-point rating scale. The results of 10 the final product of the Concrete Solid Geometry learning media are as follows. Figure 2. Application of Concrete Space Geometry Media Validation by media experts yielded an average of 95%, placing it in the Very Practical/Highly Feasible category. Media experts provided recommendations based on an assessment focused on media design, function, and efficiency. Based on Table 1, the input from media experts served as a guideline for improving Concrete Space Geometry Media. Media revisions were made in accordance with suggestions to improve practicality.

https://doi.org/10.58421/misro.v4i4.815 1470 Table 1. Media Expert Recommendations No. Type of Error Suggestion 1. The media's user manual is unclear. Add user instructions (in the form of a worksheet) for each model to prevent confusion among teachers and students. 2. The material's durability is suboptimal. The quality of the net materials (cardboard/plastic) should be improved to make them more durable and practical for repeated use. Subject matter experts also validated the learning media, focusing on conceptual accuracy and alignment with the curriculum. The validation results, obtained through averaging, showed a 87.5% score, which falls into the Very Practical/Very Feasible category, indicating that the media does not require substantial further revision of the concept. Table 2. Results of Content Expert Validation No. Expert V I II 1 4 4 1 2 1 2 0,167 3 4 4 1 4 3 3 0,67 5 3 3 0,67 6 4 4 1 7 4 4 1 8 4 4 1 9 4 3 0,833 10 4 4 1 Mean - - 0,833 From Table 2, it can be concluded that the validity level of the Concrete Space Geometry media developed by subject matter experts is overall in the "Valid" category, with a Mean V of 0.833. 3 Based on the verification results, the media's validity and feasibility have been assessed by media experts at 80%. Meanwhile, verification by two subject matter experts yielded a 87.5% agreement. From these two results, an average suitability score of 83.75% was obtained. Thus, this concrete manipulative-based media is declared valid and suitable for use in learning. The media application trial was conducted at a junior high school with ninth-grade A and B students in mathematics, focusing on Flat-Sided Shapes. The implementation was carried out through face-to-face learning, with two meetings. The first meeting introduced the media and conducted a pre-test; the second meeting involved learning activities using the Concrete Spatial Geometry media and a learning evaluation (post-test), followed by the distribution of a student response questionnaire. Table 3 presents the results of the media practicality questionnaire completed by students, with an average score of 2.676 (66.9%, 61% ≤ 80%). Concrete spatial geometry learning media fall into the Practical category. These results indicate [1] that students have a positive attitude toward the use of concrete media.

https://doi.org/10.58421/misro.v4i4.815 1471 Table 3. Student Response Results (practicality) Respond (N=29) Sum Maximum Scale Average Percentage (Students' Practicality Score) Mean 2.676 4.00 66.9% After completing the development and testing [13] stages of the learning media product, the researchers conducted an effectiveness test to assess improvements in student learning outcomes [1] related to the concept of Surface Area. This effectiveness test was conducted using pre-tests and post-tests, with the N-Gain test employed. However, before that, descriptive statistics were sought first. Table 4. Descriptive Statistics N Minimum Maximum Mean Std. Deviation Variance Pre-test 30 70 90 81.43 8.645 74.737 Post-test 30 100 100 100 0 0 Based on Table 4, the analysis [1] results show that the average pre-test score of 81.43 increased to 100 on the post-test. The standard deviation decreased from 8.645 to 0, which means that all students achieved perfect scores after using concrete media for spatial structures. These findings indicate that the media developed is very effective in improving students' understanding [8] of surface area concepts comprehensively and evenly. Table 5. N-Gain Test Results

Respond (1-30) $Spre$ $SPost$ Score N-Gain Mean 81.43 100 1.00 The N-Gain test results show an average score of 1.00 (100%), which falls into the high or effective category (1.00 ≥ 0.70). Based on these results, it can be concluded that the Concrete Space Geometry learning media is effective in improving student learning outcomes in the Surface Area material. Disseminate Stage The researchers carried out this stage through limited distribution due to time and resource constraints. They distributed the final products, consisting of completed Concrete Space Geometry physical model sets and Student Worksheets (LKS), to mathematics teachers at SMPIT Al-Mubarok. The distribution was carried out by handing over this set of teaching aids to teachers, who then integrated them into Flat Surface Building learning activities in the classroom. This limited distribution was intended to enable educators to use the media as an alternative visual and manipulative tool to enhance students' understanding of surface area concepts. 3.2. Discussion The validation results obtained from the media expert and the subject matter expert indicate that the Concrete Space Geometry media meets high feasibility criteria with an overall score of 83.75 percent. This demonstrates that the product has met the essential criteria for content accuracy, representational clarity, and instructional relevance, which

align with the feasibility standards referenced in Ref [22]. Systematic development frameworks, such as the 4D model, enhance feasibility by incorporating iterative refinement based on expert evaluation, as also emphasized by Ulyani and Qohar [23]. The expert assessments in this study affirm that the media are suitable for supporting geometry instruction. In terms of practicality, student responses averaged 66.9 percent, placing the media in the practical category. This result indicates that students found the media engaging, intuitive, and helpful for connecting two-dimensional nets to three-dimensional structures, consistent with the practicality indicators discussed in Ref [24]. The use of transparent acrylic also supports visual clarity, a crucial factor highlighted by Nati et al. [25] in helping students develop accurate spatial representations. In this study, classroom observations revealed that students could independently manipulate the models and collaborate effectively, demonstrating that the media functioned smoothly within regular classroom routines. The effectiveness test produced an N Gain value of 1.00, which falls into the very high category. Such an extreme score indicates a substantial improvement in learning outcomes, likely due to the influence of several factors. First, the media provided direct and concrete visualization of geometric relationships, reducing misconceptions about surface area. Second, the test items were aligned with the instructional content, which may have supported strong learning transfer. Third, the students had already demonstrated moderate prior knowledge, so the media served as a tool for conceptual strengthening. Muflikhah et al. [26] note that interactive media facilitate deeper connections between two-dimensional and three-dimensional understanding, while Risdiyanti et al. [27] explain that learning through direct experience often yields significant short-term gains. Although the high N Gain reflects substantial progress, it may also indicate a ceiling effect, as the post-test score reached a perfect score. Observations during implementation further support these findings. Students displayed higher levels of engagement, asked more analytical questions, and independently explained surface area formulas. These results align with Aditya and Hiltrimartin [28], who state that manipulative learning encourages self-discovery and enhances logical reasoning. Studies such as Lusiyana et al. [29] demonstrate that geometric media can enhance spatial and representational accuracy, while Wibawa and Nurhikmayati [30] emphasize that contextual and concrete exploration strengthens conceptual connections. The present study supports these perspectives: the hands-on models helped students shift from procedural calculation to conceptual reasoning. A broader pedagogical comparison with digital and augmented reality-based geometry tools is also relevant. Digital tools provide dynamic manipulation and automated visual feedback, while concrete models offer tactile engagement and physical exploration. Both have strengths depending on learners' needs. Concrete media are especially useful for building a foundational understanding, as they allow students to match nets to threedimensional structures physically. Digital tools, on the other hand, help extend learning by providing animations and transformations that are difficult to replicate manually. Combining both approaches could offer a more comprehensive learning experience.

https://doi.org/10.58421/misro.v4i4.815 1473 This study has several limitations. First, the implementation was conducted within a limited time frame, so long-term retention and transfer were not measured. Second, the research involved only one school and a relatively small sample of 30 students, limiting generalizability. Third, although random sampling was used, contextual [3] characteristics of the school may still influence the results. Fourth, the dissemination stage involved only a limited classroom trial, so broader adoption has not been evaluated. These limitations should be considered when interpreting the findings. Several practical recommendations can be proposed for teachers. Teachers are encouraged to use guiding questions that help students map each part of [9] the net to its corresponding surface. Facilitating group discussions can help students articulate their reasoning, thereby enhancing their conceptual understanding. Integrating the concrete media with simple digital animations may help students transition from concrete to abstract representation. Teachers may also assign comparison tasks between different nets of the same shape to strengthen spatial flexibility. Overall, the Concrete Space Geometry media developed using [7] the 4D model proved feasible, practical, and effective in enhancing students' understanding of surface-area concepts. These findings reinforce previous evidence suggesting that concrete manipulativebased learning can improve both conceptual clarity and student engagement. With further development and wider dissemination, this media has the potential to support studentcentered mathematics instruction [14] in line with the Merdeka Curriculum. 4. CONCLUSION This study successfully fulfilled its objectives of developing transparent concrete solid geometry media, validating their feasibility, evaluating their practicality, and assessing their effectiveness in supporting students' conceptual understanding [8] of surface area. The resulting media aligns with curriculum needs and provides clear visual access to geometric relationships, allowing students to observe how each face contributes to the overall structure. Expert judgments, student responses, and learning improvements collectively indicate that the media serves as an effective support for conceptual learning. The findings offer important implications for educational practice. For teachers, the media offers a concrete and engaging alternative to abstract explanations, encouraging exploratory, student-centered activities in geometry learning. For schools and curriculum developers, the study emphasizes the need to provide manipulatives that can bridge symbolic concepts and real-world representations. For researchers, the development process reinforces the utility of structured models, such as 4D, in producing learning media that meet both pedagogical and technical standards. Although the results are promising, the study has limitations. The implementation was conducted in a single school with a limited sample, and the trial period was relatively short, so long-term retention was not examined. Further research is recommended to test the media in broader classroom settings, apply it at different educational levels, and integrate it with digital or interactive technologies to enhance students' spatial reasoning and create richer geometry learning experiences.

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