

DEVELOPMENT OF MONOPOLY BOARD GAMIFICATION MEDIA BASED ON PROJECT-BASED LEARNING TO IMPROVE MATHEMATICAL CONCEPT UNDERSTANDING

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ABSTRACT

This study aims to develop a gamification board monopoly media based on Project Based Learning (PjBL) to improve mathematical concept understanding of elementary school students on solid geometry material. This research and development used the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The study was conducted at SDN Jatian 01 Jember with 25 fifth-grade students as subjects. The research instruments included material and media validation questionnaires using the Learning Object Review Instrument (LORI), a User Experience Questionnaire (UEQ) for teachers and students, and concept understanding tests (pretest–posttest). Results showed that the Polymath Space board monopoly media achieved a material validity score of 4.7 (95%, very valid) and media validity of 4.7 (93%, very valid). The UEQ practicality assessment from three teachers showed excellent ratings in attractiveness (2.06), efficiency (1.92), stimulation (2.00), and novelty (2.00). Students also rated the media positively, with excellent scores in clarity (2.07), appropriateness (2.02), stimulation (1.86), and novelty (2.04). The mean pretest score was 62.30 and posttest was 82.20. The Shapiro-Wilk normality test showed both data sets were normally distributed (sig. 0.620 and 0.697 > 0.05). The Levene homogeneity test indicated homogeneous variances (sig. 0.082 > 0.05). The paired sample t-test showed a significant improvement (sig. 0.000 < 0.05). The Cohen's d effect size was 1.65 (large effect). Learning mastery based on KKM (score ≥ 75) reached 92%, categorized as very effective. This media is valid, practical, and effective in improving mathematical concept understanding.

Keywords: board monopoly; concept understanding; gamification; project-based learning; solid geometry.

ABSTRAK

Penelitian ini bertujuan mengembangkan media gamifikasi board monopoly berbasis Project Based Learning (PjBL) untuk meningkatkan pemahaman konsep matematika siswa sekolah dasar pada materi bangun ruang sisi datar. Penelitian pengembangan ini menggunakan model ADDIE (Analysis, Design, Development, Implementation, Evaluation). Penelitian dilaksanakan di SDN Jatian 01 Jember dengan subjek 25 siswa kelas V. Instrumen penelitian meliputi angket validasi materi dan media menggunakan Learning Object Review Instrument (LORI), User Experience Questionnaire (UEQ) untuk guru dan siswa, serta tes pemahaman konsep (pretest–posttest). Hasil penelitian menunjukkan media board monopoly Polymath Space memperoleh skor validitas materi 4,7 (95%, sangat valid) dan validitas media 4,7 (93%, sangat valid). Penilaian kepraktisan UEQ dari tiga guru menunjukkan kategori excellent pada daya tarik (2,06), efisiensi (1,92), stimulasi (2,00), dan kebaruan (2,00). Siswa juga menilai positif dengan kategori excellent pada kejelasan (2,07), ketepatan (2,02), stimulasi (1,86), dan kebaruan (2,04). Rata-rata pretest sebesar 62,30 dan posttest sebesar 82,20. Uji normalitas Shapiro-Wilk menunjukkan kedua data berdistribusi normal (sig. 0,620 dan 0,697 > 0,05). Uji homogenitas Levene menunjukkan varians homogen (sig. 0,082 > 0,05). Uji paired sample t-test menunjukkan peningkatan signifikan (sig. 0,000 < 0,05). Nilai effect size Cohen's d sebesar 1,65 (efek

besar). Ketuntasan belajar berdasarkan KKM (≥ 75) mencapai 92% dengan kategori sangat efektif. Media ini terbukti valid, praktis, dan efektif dalam meningkatkan pemahaman konsep matematika.
Kata kunci: bangun ruang, gamifikasi, pemahaman konsep, project based learning, board monopoly.



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Introduction

Educational technology plays an important role in designing and developing learning media that support meaningful learning experiences (Alam & Mohanty, 2023). In the 21st century, learning media should encourage students' active participation, critical thinking, collaboration, and problem-solving skills (Kalyani, 2024). Meaningful learning environments are expected to facilitate students' active construction of knowledge through interaction with learning resources (Saleem et al., 2021). In mathematics learning, one of the persistent challenges is students' low conceptual understanding, particularly in solid geometry topics (Azibah, 2025; Sa'adah et al., 2024).

Conceptual understanding refers to students' ability to understand mathematical ideas, recognize relationships among concepts, and apply them appropriately in different situations (Ncube & Luneta, 2025). Conceptual understanding is one of the five strands of mathematical proficiency that support successful mathematics learning (Pulles & Burns, 2022). According to Munaji et al., (2025), students with strong conceptual understanding are able to establish connections among mathematical concepts and use them flexibly in various contexts. Conversely, students who lack conceptual understanding tend to memorize formulas without understanding the underlying principles, resulting in difficulties when solving contextual problems (Puspitasari et al., 2021). Therefore, strengthening conceptual understanding is essential for developing students' reasoning and problem-solving abilities in mathematics (Naz & Qayyum, 2025). The development of digital teaching materials should be supported by authentic assessment that comprehensively evaluates students' cognitive, affective, and psychomotor domains. Such an approach enables learning to focus not only on learning outcomes but also on the development of practical skills and learning processes (Vahlia & Sholiha, 2023).

This issue is also reflected in broader educational contexts. International assessments such as PISA consistently indicate that many students experience difficulties in applying mathematical concepts to real-world situations. Similar conditions were identified in a preliminary study conducted at SDN Jatian 01 Jember in January 2025 through a diagnostic test consisting of two essay questions on the volume of rectangular prisms administered to 25 fifth-grade students. The results showed that 19 students (76%) answered incorrectly on the first question, while 16 students (64%) answered incorrectly on the second question. These findings indicate that students had difficulty identifying relevant information, understanding mathematical concepts, and applying them appropriately in problem-solving situations. Interviews with classroom teachers further revealed that learning

activities were still dominated by conventional methods using textbooks and worksheets, with limited use of interactive learning media.

To address this issue, researchers have increasingly explored gamification and Project-Based Learning (PjBL) as innovative approaches in mathematics education. Gamification incorporates game elements into learning activities to increase students' motivation and engagement, whereas PjBL facilitates active knowledge construction through authentic projects and collaborative problem-solving. Gamification-based teaching materials integrated with the Contextual Teaching and Learning (CTL) approach can increase students' learning motivation by presenting interactive illustrations, contextual activities, and engaging learning tasks that encourage active knowledge construction (Winarto et al., 2023). Previous studies have reported that gamification positively affects mathematics learning outcomes and student engagement (Huang et al., 2023; Pratama, 2020). Furthermore, Hermaya et al. (2025) found that gamification-based learning significantly improved students' mathematical conceptual understanding, while Muhammad & Lusiyana (2025) reported that educational games enhanced students' understanding of mathematical concepts through interactive learning experiences. The integration of Android-based learning media with the Project-Based Learning (PjBL) approach provides contextual, flexible, and interactive learning experiences that enhance students' competencies through authentic, real-world project activities (Suprihatin et al., 2025).

The integration of gamification and PjBL is theoretically relevant because both approaches complement each other in promoting conceptual understanding. Gamification encourages students to participate actively in learning activities through engaging game mechanics, while PjBL provides opportunities for students to investigate, discuss, and apply mathematical concepts in meaningful contexts. Consequently, the combination of both approaches is expected to foster higher engagement and deeper conceptual understanding.

Several studies have developed monopoly-based educational games and reported positive impacts on students' motivation, participation, and learning activities (Latief & Novalia, 2023; Rosyadi et al., 2025). Gamification-based learning has been shown to increase students' engagement and learning motivation through interactive activities (Huang et al., 2023). Educational games also provide opportunities for students to learn collaboratively and construct knowledge actively (Adipat et al., 2021). However, most previous studies focused primarily on motivation and classroom engagement rather than on mathematical conceptual (Hermaya et al., 2025). In addition, monopoly-based educational games were generally implemented as supplementary learning media without being integrated into a structured pedagogical model (Muhammad & Lusiyana, 2025). Therefore, limited evidence is available regarding the effectiveness of monopoly-based gamification media integrated with Project-Based Learning in improving students' mathematical conceptual understanding (Rosyadi et al., 2025).

Although digital learning media have become increasingly popular, their implementation is not always optimal because some schools still face limitations related to device availability and internet access (Alias, 2021). Offline learning media remain relevant because they are more accessible, practical, and cost-effective for classroom implementation (Adie et al., 2023). Furthermore, tangible

game media are considered suitable for elementary school students who are still in the concrete operational stage and require direct interaction with learning objects (Pellas, 2025)

Based on these considerations, this study develops Polymath Space, a board monopoly gamification media integrated with Project-Based Learning for fifth-grade students learning solid geometry. Unlike previous monopoly-based educational games, Polymath Space incorporates PjBL syntax into the gameplay structure, enabling students to engage in project-oriented exploration, discussion, and application of mathematical concepts (Wertz, 2025). The integration of gamification and PjBL is expected to support active knowledge construction in accordance with constructivist learning theory (Huang et al., 2023). Therefore, this integration represents the novelty of the study and is expected to contribute to improving students' mathematical conceptual understanding (Siregar, 2025).

This study aims to develop *Polymath Space* that is (1) valid according to material and media experts, (2) practical according to teachers and students, and (3) effective in improving students' mathematical conceptual understanding. Accordingly, the research questions are as follows:

1. How valid is the *Polymath Space* board monopoly gamification media based on Project-Based Learning according to material and media experts?
2. How practical is the developed media according to teachers and students?
3. How effective is the developed media in improving students' mathematical conceptual understanding of solid geometry material?

Research Methods

This study employed Research and Development (R&D) using the ADDIE model consisting of Analysis, Design, Development, Implementation, and Evaluation phases (Branch & Varank, 2009). To evaluate the effectiveness of the developed product, a One-Group Pretest-Posttest Design (O_1-X-O_2) was employed, where O_1 represents the pretest, X represents the implementation of Polymath Space, and O_2 represents the posttest. Although this design allows researchers to examine learning improvement before and after treatment, the absence of a control group limits causal inference.

The study was conducted at SDN Jatian 01 Jember. Participants consisted of 3 students in one-to-one evaluation, 9 students in small-group evaluation, and 25 fifth-grade students in field testing and effectiveness evaluation. The validation process involved two material experts, two media experts, and two practitioner teachers.

The research instruments included material and media validation questionnaires based on the Learning Object Review Instrument (LORI), one-to-one evaluation using cognitive walkthrough, small-group evaluation using heuristic evaluation (Nielsen et al., 2004), the User Experience Questionnaire (UEQ), and a mathematical conceptual understanding test consisting of 10 essay items. The UEQ was used to evaluate overall user experience, while heuristic evaluation was used to identify usability problems during product refinement; therefore, both instruments served different purposes.

Prior to implementation, the conceptual understanding test underwent content validation by mathematics education experts and practitioner teachers to

ensure alignment with learning objectives and conceptual understanding indicators. A scoring rubric ranging from 0 to 4 was applied to each essay item, with higher scores indicating better conceptual understanding. The revised instrument was piloted on 25 fifth-grade students at SDN Jatian 02 Jember. Results indicated that all items were valid ($r = 0.558-0.763$, $p < .01$) and reliable (Cronbach's $\alpha = 0.852$).

Validity data were analyzed using mean scores and interpreted according to the criteria proposed by Folger et al. (2023). Practicality data from the UEQ were interpreted using UEQ benchmark categories. Effectiveness was analyzed through descriptive statistics, Shapiro-Wilk normality testing ($p > .05$), Levene's homogeneity testing ($p > .05$), paired-sample t-test ($\alpha = .05$), Cohen's d effect size, and learning mastery analysis based on the minimum mastery criterion (KKM = 75). The media were categorized as highly effective when at least 85% of students achieved the mastery criterion.

Results and Discussion

1. Analysis Phase

The analysis phase involved needs analysis, student characteristics, content analysis, and formulation of learning objectives. The needs analysis conducted at SDN Jatian 01 Jember revealed that mathematics learning was still dominated by textbooks and worksheets, with limited use of interactive learning media. In addition, no gamification-based media had previously been implemented in the classroom, and teachers expressed positive responses toward the development of innovative learning media. These findings indicate the need for learning resources that are more engaging and capable of facilitating meaningful learning experiences.

Student characteristic analysis showed that fifth-grade students are in Piaget's concrete operational stage, meaning they learn more effectively through visual, manipulative, and experiential activities. Therefore, the development of the Polymath Space board monopoly was designed to provide concrete experiences through project tasks, visual representations, and collaborative gameplay. This finding supports Piaget's cognitive development theory and is consistent with previous studies showing that game-based learning media can enhance students' engagement and conceptual construction through active participation.

Content analysis focused on solid geometry topics, including cubes, cuboids, prisms, and pyramids. The material covered identification of geometric elements, surface area, volume, and contextual applications encountered in daily life. Learning objectives were formulated based on the Phase C Curriculum (Grade V) and emphasized five indicators of mathematical conceptual understanding adapted from the National Council of Teachers of Mathematics (NCTM), namely: (1) restating concepts, (2) classifying objects according to their properties, (3) applying formulas, (4) analyzing relationships among concepts, and (5) solving contextual problems.

The results of this analysis stage became the foundation for integrating Project Based Learning (PjBL) with gamification elements in the Polymath Space media. The combination was intended not only to increase motivation but also to support conceptual understanding through project activities and collaborative problem solving. Previous studies on monopoly-based learning media mainly reported improvements in motivation and classroom participation. However, the present development specifically addressed conceptual understanding by embedding project cards and contextual tasks that required students to explore mathematical

concepts actively. Thus, the findings from the analysis phase confirmed the relevance of developing an instructional medium that aligns with students' characteristics and supports deeper conceptual understanding rather than procedural memorization alone.

2. Design Phase

Based on the results of the analysis phase, the learning media was developed under the name *Polymath Space* and designed using Canva. The media consists of several components, namely: (1) a 60 × 60 cm board monopoly containing mission card, travel card, and project card spaces; (2) travel cards (5 × 7 cm) containing concise explanations of solid geometry concepts, net diagrams, and contextual examples; (3) mission cards containing conceptual questions with three difficulty levels; (4) project cards containing exploratory mini-projects, such as drawing nets, calculating volumes of daily-life objects, and identifying geometric elements; (5) point cards replacing money with denominations of 5, 10, 20, 50, and 100 points; (6) five player pions and one die containing geometric representations; (7) a project card envelope containing numbered stickers; and (8) a packaging box for storing all components.

As shown in Figure 1, the main board design of *Polymath Space* consists of interconnected spaces that accommodate different learning activities. The arrangement of travel cards, mission cards, and project cards enables students to experience learning as a sequence of challenges rather than merely answering exercises. This design supports active participation and creates opportunities for students to construct mathematical concepts through gameplay in Figure 1.



Figure 1. Polymath Space Board Monopoly Main Design

As presented in Figure 2, the travel card, mission card, and project card were designed with different functions. The travel card provides concise conceptual information, the mission card assesses conceptual understanding, and the project card encourages students to conduct exploratory activities related to solid geometry. These complementary functions support meaningful learning by combining information, assessment, and project-based experiences.

The supporting cards were designed to provide information, assessment, and project-based learning activities. The designs of the travel card, mission card, and project card are presented in Figure 2.





Figure 2. Travel Card, Mission Card, and Project Card Design

Based on Figure 3, the pion and point card components were designed to strengthen the gamification elements. The use of character-based pions and point cards replaces conventional money systems and increases students' motivation through rewards and competition. Furthermore, the die requires students to identify the number of vertices before moving, thereby integrating mathematical concepts into the game mechanics.

To strengthen the gamification aspect of the learning media, several game components were developed, including pions, point cards, and dice. These components are presented in Figure 3.



Figure 3. Pion and Point Components of Polymath Space

As illustrated in Figure 4, all components are organized within a packaging box measuring $25 \times 17 \times 6$ cm. The packaging facilitates storage and portability, allowing the media to be reused in different learning contexts. This feature enhances the practicality and durability of the learning media.

All game components were packaged in a single storage box to improve practicality and ease of use. The packaging design is shown in Figure 4.



Figure 4. Packaging of Polymath Space

The gameplay was designed according to the syntax of Project Based Learning (PjBL), namely: (1) determining fundamental questions through challenges

provided by cards; (2) designing project plans based on the tasks obtained; (3) scheduling activities integrated into the game sequence; (4) monitoring students' activities through teacher facilitation; (5) testing project results through answer validation; and (6) evaluating learning experiences through reflection after gameplay. The game employs one die and five players per group, with students taking turns moving their pions and completing the corresponding activities.

The integration of gamification elements with PjBL syntax allows students to experience concept exploration in a concrete and collaborative manner. This design is consistent with constructivist learning theory and previous studies indicating that game-based learning combined with project activities can increase engagement and facilitate conceptual understanding rather than rote memorization.

a. Material Validation

Material validation involved two material experts and one practitioner using ten Learning Object Review Instrument (LORI) items covering content quality, learning goal alignment, feedback and adaptation, and motivation. The results are presented in Table 1.

Table 1. Material Validation Results

| Aspect | Expert 1 | Expert 2 | Practitioner |
|----------------------------------|------------------|----------|--------------|
| Content Quality | | | |
| Accuracy | 5 | 5 | 4 |
| Appropriateness | 5 | 5 | 5 |
| Systematic Presentation | 5 | 5 | 5 |
| Level Suitability | 4 | 4 | 5 |
| Learning Goal Alignment | | | |
| Aligned with Learning Objectives | 5 | 4 | 5 |
| Aligned with Learning Activities | 5 | 5 | 4 |
| Aligned with Assessment | 5 | 5 | 5 |
| Student Characteristics | 4 | 4 | 5 |
| Feedback & Adaptation | 5 | 4 | 5 |
| Motivation | 5 | 5 | 5 |
| Total Score | 48 | 46 | 48 |
| Mean Score | 4.7 (Very Valid) | | |
| Percentage | 96% | 92% | 96% |
| Mean Percentage | 95% (Very Valid) | | |

Based on Table 1, the material validation obtained a mean score of 4.7 with an average percentage of 95%, indicating a very valid category. High ratings across all aspects show that the content is accurate, systematically organized, aligned with learning objectives, and capable of motivating students. The highest score was obtained in the motivation aspect (100%), suggesting that the gamification elements effectively support students' engagement. These findings are in line with constructivist learning theory, which emphasizes meaningful learning through active interaction and experience.

The results are consistent with Apriyantini et al. (2024) and Rahayu et al. (2022), who reported that systematically designed Project-Based Learning media achieved high validity and supported students' conceptual understanding. However, unlike previous studies, Polymath Space integrates gamification elements through board monopoly activities, providing additional cognitive and motivational support. Practically, the high validity scores indicate that the material organization, assessment activities, and feedback mechanisms are suitable for classroom

implementation. Nevertheless, the limited number of validators may introduce evaluator bias; therefore, future studies are recommended to involve more experts.

Several revisions were made based on validators' suggestions, including numbering the project cards sequentially and correcting the grade label from "Class 6" to "Class 5." These revisions were implemented before field testing to improve the quality and usability of the media.

b. Media Validation

Media validation was conducted by two media experts and one practitioner using ten Learning Object Review Instrument (LORI) items covering presentation design, interaction usability, accessibility, and reusability. The results are presented in Table 2.

Table 2. Media Validation Results

| Aspect | Expert 1 | Expert 2 | Practitioner |
|--------------------------------------|------------------|----------|--------------|
| Presentation Design | | | |
| Board design supports learning | 5 | 4 | 5 |
| Clarity of narration, color, font | 5 | 4 | 5 |
| Interaction Usability | | | |
| Ease of use | 5 | 4 | 5 |
| Aligned with learning activities | 5 | 5 | 5 |
| Aligned with assessment | 4 | 4 | 5 |
| Student characteristics suitability | 5 | 5 | 5 |
| Accessibility | | | |
| Ease of access | 5 | 4 | 5 |
| Accommodates various learners | 4 | 4 | 5 |
| Reusability | | | |
| Usable for various learning contexts | 5 | 4 | 5 |
| Meets standards | 5 | 4 | 5 |
| Total Score | 48 | 42 | 50 |
| Mean Score | 4.8 | 4.2 | 5.0 |
| Overall Mean | 4.7 (Very Valid) | | |
| Percentage | 96% | 84% | 100% |
| Mean Percentage | 93% (Very Valid) | | |

Based on Table 2, the media obtained an overall mean score of 4.7 and an average percentage of 93% (rounded from 93.33%), indicating a very valid category. These results suggest that Polymath Space has an appropriate visual design, is easy to use, and can be applied in various learning contexts. According to multimedia learning theory and constructivist principles, the integration of visual elements and game activities facilitates meaningful learning and student engagement.

These findings are consistent with Apriyantini et al. (2024) and Rahayu et al. (2022), who reported that systematically designed learning media achieved high validity and supported learning effectiveness. However, unlike previous studies, Polymath Space incorporates gamification elements through board monopoly activities, providing both cognitive and motivational support. Practically, the media can be used as an alternative medium for learning solid geometry in elementary school. Nevertheless, the limited number of validators may have introduced evaluator bias, so future studies should involve more experts.

Several revisions were made based on validators' suggestions, including enlarging the board size to 60 × 60 cm, clarifying game instructions, standardizing terminology, simplifying card descriptions, and adding a glossary, quick guide, flowchart, and assessment rubrics. These improvements were implemented before field testing to enhance usability and instructional effectiveness.

c. One to One and Small Group Trials

One-to-one trials using cognitive walkthrough with 3 students (high, medium, low ability) yielded positive responses: students found the media enjoyable, understandable, and motivating. Small group trials with 9 students using heuristic evaluation showed a mean severity rating of 0.8 (Don't Agree), indicating no significant usability problems across all 10 Nielsen heuristic principles. Students reported the media made learning more interactive and collaborative.

4. Implementation Phase

a. Teacher UEQ Practicality Results

Practicality was assessed by 3 teachers using the UEQ instrument with 26 items across 6 scales. Results are presented in Table 3.

Table 3. Teacher UEQ Results (n=3)

| Scale | Mean | Benchmark |
|-----------------------------|------|-----------|
| Attractiveness (Daya Tarik) | 2.06 | Excellent |
| Perspicuity (Kejelasan) | 1.83 | Good |
| Efficiency (Efisiensi) | 1.92 | Excellent |
| Dependability (Ketepatan) | 1.67 | Good |
| Stimulation (Stimulasi) | 2.00 | Excellent |
| Novelty (Kebaruan) | 2.00 | Excellent |

Teacher evaluation showed all six UEQ scales received good to excellent ratings. Attractiveness (2.06), efficiency (1.92), stimulation (2.00), and novelty (2.00) reached the Excellent category, while perspicuity (1.83) and dependability (1.67) were categorized as Good. The excellent stimulation score reflects that the media creates a lively, interactive classroom atmosphere. The novelty score confirms the media is perceived as distinctly innovative compared to conventional learning.

b. Student UEQ Practicality Results

Practicality was also assessed by 25 students after using the media. Results are presented in Table 4.

Table 4. Student UEQ Results (n=25)

| Scale | Mean | Benchmark |
|-----------------------------|------|-----------|
| Attractiveness (Daya Tarik) | 1.71 | Good |
| Perspicuity (Kejelasan) | 2.07 | Excellent |
| Efficiency (Efisiensi) | 1.78 | Good |
| Dependability (Ketepatan) | 2.02 | Excellent |
| Stimulation (Stimulasi) | 1.86 | Excellent |
| Novelty (Kebaruan) | 2.04 | Excellent |

Student assessment showed perspicuity (2.07), dependability (2.02), stimulation (1.86), and novelty (2.04) in the Excellent category, while attractiveness

(1.71) and efficiency (1.78) reached Good. The high perspicuity score indicates clear game instructions aligned with fifth-grade cognitive development. The novelty score confirms students experienced a qualitatively different and innovative learning format. Overall, both teachers and students evaluated the media as practical and capable of providing a positive user experience, consistent with findings from Pretorius (2024) and Huang et al. (2023).

5. Effectiveness Testing

a. Descriptive Statistics

Effectiveness testing used a One Group Pretest Posttest design (O1-T-O2) with 25 fifth-grade students from April 1 to April 23, 2026. Descriptive statistical results are presented in Table 5.

Table 5. Descriptive Statistics of Pretest and Posttest

| | Mean | N | SD | Std. Error |
|----------|-------|----|--------|------------|
| Pretest | 62.30 | 25 | 13.918 | 2.784 |
| Posttest | 82.20 | 25 | 9.798 | 1.960 |

The mean pretest score was 62.30 (SD = 13.918), increasing to 82.20 (SD = 9.798) in the posttest an improvement of 19.90 points. The smaller standard deviation in the posttest indicates more homogeneous student scores, reflecting that media usage not only raised the mean but also equalized understanding among students.

b. Normality Test

Table 6. Normality Test (Shapiro-Wilk)

| Data | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|----------|--------------------|----|------|--------------|----|------|
| | Stat | df | Sig. | Stat | df | Sig. |
| Pretest | .097 | 25 | .200 | .969 | 25 | .620 |
| Posttest | .092 | 25 | .200 | .972 | 25 | .697 |

Based on Table 6, the Shapiro-Wilk test was used to assess normality because it is considered more appropriate for small sample sizes ($n < 50$). The pretest obtained a significance value of 0.620 and the posttest obtained 0.697, both exceeding 0.05. Therefore, both datasets are normally distributed, indicating that the assumption of normality was fulfilled and parametric analyses could be applied. The fulfillment of this assumption increases the reliability of subsequent analyses, particularly the paired sample t-test used to evaluate the effectiveness of the Polymath Space media.

c. Hypothesis Testing (Paired Sample t-Test)

Table 7. Paired Sample t-Test Results

| | Mean Diff. | SD | t | df | Sig. (2-tailed) |
|--------------------|------------|-------|---------|----|-----------------|
| Pretest - Posttest | -19.900 | 4.477 | -22.226 | 24 | .000 |

The paired sample t-test yielded sig. (2-tailed) = 0.000 < 0.05. Therefore H_0 is rejected and H_1 is accepted: there is a statistically significant improvement in students' mathematical concept understanding after using the Polymath Space board monopoly media. This finding is consistent with Rosyadi et al. (2025), Pratama (2020), and Huang et al. (2023), who demonstrated that gamification integrated with PjBL significantly improves mathematical competence.

d. Effect Size (Cohen's d)

The effect size was calculated to determine the practical significance of the intervention. Since the study employed a one-group pretest-posttest design, Cohen's *d* for paired samples was calculated using the mean difference divided by the standard deviation of the difference scores. This approach is considered more appropriate for repeated-measures designs because it accounts for the dependency between pretest and posttest scores.

$$d = \frac{\text{Mean difference}}{\text{SD difference}} = \frac{19,9}{4.447} = 4.45 \quad (1)$$

The obtained Cohen's *d* value of 4.45 indicates a very large effect size, suggesting that Polymath Space had a substantial practical impact on students' mathematical concept understanding. The large effect may be attributed to the integration of Project-Based Learning with gamification features, including mission cards, project cards, contextual tasks, reward mechanisms, and collaborative gameplay. These instructional features encouraged active participation and supported meaningful learning, which is consistent with constructivist learning theory.

The findings are in line with Richter & Kickmeier-Rust (2025), who reported positive effects of gamified learning on students' performance. However, the findings should be interpreted cautiously because the study involved a relatively small sample, was conducted in a single school, had a short implementation period, and did not include a control group. Future studies are recommended to employ larger samples and quasi-experimental designs to provide stronger evidence regarding the effectiveness of Polymath Space.

e. KKM-Based Learning Mastery

Learning mastery was evaluated based on the school's Minimum Mastery Criterion (KKM = 75). Results show that 23 out of 25 students (92%) achieved scores ≥ 75 , while 2 students (8%) did not reach mastery, with scores of 60 and 65. The mastery percentage formula:

$$\text{Mastery (\%)} = \frac{\text{Number of Students Achieving KKM}}{\text{Total Number of Students}} \times 100\% = 92\% \quad (2)$$

$$\text{Mastery (\%)} = \frac{23}{25} \times 100\% = 92\% \quad (3)$$

Table 9. KKM-Based Learning Mastery Categories

| Mastery (\geq KKM) | Category |
|-----------------------|------------------------|
| $\geq 85\%$ | Very Effective |
| 75% - 84% | Effective |
| 60% - 74% | Sufficiently Effective |
| < 60% | Not Effective |
| Result: 92% | Very Effective |

Based on Table 9, 23 out of 25 students (92%) achieved scores above the KKM, indicating a very effective category. Only two students (8%) did not achieve mastery. This high level of mastery suggests that Polymath Space successfully facilitated students' understanding of solid geometry concepts. The integration of mission cards, project cards, and collaborative gameplay enabled students to actively explore concepts and apply them to contextual problems, thereby supporting meaningful learning. In contrast, the two students who failed to achieve

mastery may have required additional scaffolding and more intensive guidance during group activities.

These findings support constructivist learning theory, which emphasizes that knowledge is developed through active interaction and concrete experiences. The combination of Project-Based Learning and gamification encouraged students to participate actively, receive immediate feedback, and learn collaboratively, contributing to the high mastery level achieved. One strength of the media is its ability to transform abstract concepts into contextual and enjoyable learning experiences. However, differences in students' prior knowledge and participation levels may have influenced the learning outcomes.

The findings are consistent with Apriyantini et al. (2024), who reported that game-based mathematics media produced posttest scores exceeding the minimum mastery criterion. Similarly, Pretorius (2024) and Latief & Novalia (2023) found that gamification creates engaging learning environments that enhance students' learning experiences. The present study extends these findings by demonstrating that integrating Project-Based Learning with board monopoly activities not only improves learning achievement but also enables most students to reach mastery standards.

Overall, the significant t-test results, very large effect size, and 92% mastery level indicate that Polymath Space has the potential to improve mathematical concept understanding among fifth-grade students. Nevertheless, these findings should be interpreted cautiously because the study involved a small sample, was conducted in a single school, had a relatively short implementation period, and did not include a control group. Future studies are recommended to involve larger samples and comparative designs to provide stronger evidence regarding the effectiveness of the media.

Conclusion and Suggestion

This study successfully developed the Polymath Space gamification board monopoly media based on Project-Based Learning using the ADDIE model for fifth-grade solid geometry learning. The results showed that the developed media met the very valid criteria, with material and media validation scores of 4.7 (95%) and 4.7 (93%), respectively. Teacher and student evaluations also indicated good to excellent practicality across most UEQ dimensions, suggesting that the media is attractive, easy to use, and capable of creating engaging learning experiences. Furthermore, the effectiveness analysis revealed a statistically significant improvement in students' mathematical concept understanding (sig. = 0.000), a very large effect size (Cohen's $d = 4.45$), and a learning mastery level of 92%, indicating that integrating Project-Based Learning with gamification features, such as mission cards, project cards, rewards, and collaborative activities, effectively supports meaningful learning and improves students' understanding of solid geometry concepts.

Nevertheless, the findings should be interpreted cautiously because this study involved a relatively small sample of 25 students from a single elementary school, was conducted over a short period, and did not include a control group. Therefore, future studies are recommended to develop a digital version of Polymath Space, such as an Android-based or web-based application equipped with adaptive

difficulty levels, automated scoring, and interactive feedback features. In addition, future research should involve larger samples, multiple schools, and experimental or quasi-experimental designs with control groups to provide stronger evidence regarding the effectiveness of the media in diverse educational settings.

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