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# **GeoPUB: A 3D Interactive Visualization Tool for Solid Geometry Learning and Volume Calculations**

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# ABSTRACT

This study investigated the validity of GeoPUB, short for Geometry Pop-Up Book, a 3D interactive visualization tool for enhancing solid geometry learning and volume calculations among Grade 7 students at Linga National High School. The primary objective is to assess whether GeoPUB improves spatial reasoning and comprehension of solid shapes compared to traditional teaching materials. A quasi-experimental quantitative research design was employed to facilitate a structured comparison between the effectiveness of GeoPUB and conventional methods. This design was chosen because it allows for the identification of causal relationships by measuring changes in student performance before and after the intervention, thereby providing robust statistical insights. Using simple random sampling, the researchers selected 25 students from a total population of 247. Data were collected through pre-tests and post-tests, as well as custom-designed questionnaires to identify students' learning styles and evaluate their performance on volume calculations of various solid shapes. The study involved multiple-choice tests and interviews to gather comprehensive data on students' experiences. The findings reveal that GeoPUB, with its tactile and dynamic elements, significantly enhanced students' understanding of three-dimensional shapes and volume calculations, showing improved comprehension compared to traditional materials. These results support the potential of interactive, multisensory tools in promoting deeper mathematical understanding, aligning with the educational goals outlined in Sustainable Development Goal 4. The study contributes to the development of instructional materials and suggests innovative strategies to accommodate diverse learning styles, advocating for the integration of interactive resources in geometry education.

Keywords: 3D Interactive Visualization Tool, GeoPUB, Solid Geometry, Validity

# 1. Introduction

The mastery of solid geometry, particularly in understanding the volume of three-dimensional shapes, is a fundamental aspect of Mathematics education. Developing students' spatial reasoning and problem-solving skills in this area is crucial, as it not only builds mathematical proficiency but also supports learning in various scientific and technical disciplines. However, conventional teaching methods often rely on static diagrams and abstract representations, making it challenging for students to grasp the spatial relationships and visualize three-dimensional objects effectively.

The purpose of this study is to develop and validate GeoPUB, short for Geometric Pop-Up Book, a 3D interactive pop-up book aimed at improving students' understanding of solid shapes and volume calculations in geometry. This research is significant because traditional teaching methods often fail to adequately convey the complexities of three-dimensional geometry, leading to difficulties in student comprehension, Lowrie et al. (2019). GeoPUB offers an innovative solution to these challenges by providing an interactive and engaging learning tool that enhances spatial reasoning and problem-solving skills.

The study aims to bridge the gap in traditional geometry education, which relies heavily on static diagrams and abstract concepts. By integrating 3D visualization, GeoPUB facilitates better comprehension of spatial relationships and geometric structures, making learning more intuitive and engaging. This research is crucial as it contributes to improving educational practices in teaching geometry, offering an alternative to conventional methods that struggle to meet students' learning needs.

# 2. Literature Review

# 2.1 Review of Related Literature and Studies

POP-UP BOOK

Rusanti et al. (2023) emphasized the distinctiveness of pop-up books compared to conventional storybooks. They highlighted that when opened, pop-up books transform into three-dimensional structures, contrasting with their two-dimensional form when closed. This unique characteristic tends to captivate student's interest and engagement, particularly in educational activities, thus fostering the development of linguistic intelligence in students.

According to Nisa (2020), character-based pop-up storybooks demonstrate effectiveness in enhancing children's compassionate traits. These books contribute to fostering socially caring characteristics, encompassing traits like understanding kindness, desiring kindness, and actively engaging in kind behavior. These aspects, described as habits of mind, habits of heart, and habits of action, can all be stimulated through the use of character-based pop-up storybooks.

Haryanto and Karyono (2021) describe pop-up book illustration as the evolution of two-dimensional fine arts applied to create three-dimensional forms. This art form involves various techniques closely tied to paper and handcrafting. The uniqueness of pop-up book illustration lies in its precision of paper mechanics, resulting in expressive and artistic illustrations that educate readers through visual communication meticulously designed by the illustrator.

Based on the results of the post-test analysis conducted of Patri and Heswari (2019), the results of the analysis of the student perception questionnaire showed the category of "very positive" besides based on observations of students' attitudes during the learning process positive and high enthusiasm in participating in learning activities. Patri and Heswari (2019) conclude that, multimedia teaching materials based on PBL using 3D Professional Pageflip on geometry material are effective as it is used for the learning process.

Noto et al. (2020) conducted a study where they created digital 3D books grounded in the mathematical principles of a linear system with two variables. Their findings reveal a 92% validity and 91.67% practicality for the use of these digital 3D books. In summary, these results suggest that 3D books are effective for learning linear systems with two variables, providing a user-friendly resource for both teachers and students, enabling independent learning.

#### POP-UP BOOK AS SUPPLEMENTAL LEARNING MATERIAL

As for Yanto et al. (2023), Pop-Up Book Media can improve learning outcomes and can train high-level thinking skills in learners. It was also found that Pop-Up Book media can provide cognitive reinforcement and increase learner motivation. Also, based upon the study of Yanto et al. (2023), they conclude that the use of Creative Learning media such as Pop-up Book media has a positive impact on the learning process.

According to Wahjuningsih, E. (2019), the use of pop-up books had a significant impact on students' reading comprehension achievement. This finding was accepted. Wahjuningsih, E. (2019) come to the conclusion that pop-up books are a useful instructional tool for reading comprehension.

Umar (2020) reported that the comprehensive evaluation by experts indicated an 89.42% eligibility rate, categorizing the approach as "highly feasible" and endorsing its progression to the subsequent phase. The utilization of a Pop-Up Book learning medium in social studies, specifically focusing on Indonesian businesses and economic activities, was found to significantly enhance student learning outcomes. This was evident through the average pretest score of 65.85, which markedly increased to 80.4 in the posttest. Beyond average scores, the improvement in learning outcomes was also reflected in the mastery of the subject matter, rising from 35% in the pretest to a substantial 80% in the posttest results.

Based on the findings of Akina et al. (2023) incorporating Pop-up Book learning media into mathematics instruction enhances students' academic achievements in the context of flat shape materials. These outcomes are transferable to natural science education, underscoring the importance of educators taking a more dynamic and efficient role in guiding students through experiments and demonstrations, ensuring active student engagement in the learning process.

Rusanti et al. (2023) outlined three learning techniques utilizing pop-up book media to enhance children's linguistic intelligence: a preliminary learning stage, a primary learning stage, and a post-learning assessment. Their research claimed that the learning process follows a logical sequence through these stages, meeting the expectations of both instructors and students.

Colidiyah (2018) presented research data indicating that the integration of pop-up books in English teaching effectively addressed issues at SDN 2 Gadingkulon. This approach fostered increased student engagement and cooperation within the classroom. Moreover, the utilization of pop-up books notably aided students in comprehending lessons. The incorporation of suitable teaching media in English instruction notably heightened students' interest in studying the language.

# POP-UP BOOK VALIDATION

Yuningsih et al. (2022) conducted research and development on Pop-Up book learning media for descriptive text material targeted at first-grade junior high school students. Employing the ADDIE model, the media development involved stages such as cover design, background design, material typing, Pop-Up image design, and component assembly. The experts' evaluations indicated high feasibility, with media experts giving an average score of 4.50, material experts 4.83, and educators 4.65. Students at MTs Al-KhairiyahPontang, Serang Regency, Banten responded positively, with an average percentage score of 90.8%, categorizing the media as very interesting. The comprehensive validation and testing stages affirmed the Pop-Up book's suitability for use, demonstrating consistently favorable assessments across various criteria. The observed impact during the research suggested that the Pop-Up book media effectively heightened students' interest in learning English.

Rahayu et al. (2021) found that the outcomes of their research regarding the creation of Pop-Up Book media fall within the highly feasible range. Additionally, according to assessments from teachers actively engaged in teaching, the Pop-Up Book media falls within the highly practical category for integration into thematic learning for younger elementary school students. Moreover, students' evaluations indicate that the Pop-Up Book media is not only highly appealing but also easily accessible for lower-grade students. Mohamed and Ismail (2021) verified that incorporating color, motion, and anthropomorphic features into educational content for students enhances its appeal and significantly contributes to its value, a principle that extends to pop-up books.

Rosyida et al. (2021) confirmed the viability of the developed Pop-Up Book for instructing written English descriptive text. Validation by both media and subject matter experts yielded scores of 4.4 and 4.2 respectively, affirming its suitability. Small-scale product trials further substantiated its effectiveness, receiving a commendable score of 4.24 and falling within the 'very good' category. Moreover, during large-scale trials, the media garnered a highly positive response from students, achieving a score of 4.5 and also falling within the 'very good' criteria.

Lestariningsih et al. (2021) conducted research and development on a Pop-Up Book educational tool focusing on natural resource material for 4th-grade students at Sidoarjo Indonesia Primary School. The assessment of the Pop-Up Book's teaching efficacy deemed it highly feasible for use, substantiated by the outcomes of product trials. The researchers conducted expert testing to determine the product's viability, yielding the following validation results: a) Content experts validated the material within the Pop-Up Book teaching media with a 100% validity rate, signifying its suitability for educational purposes. b) Design experts found the design of the Pop-Up Book teaching media to be valid, achieving a 90% validity rate. c) Linguists attested to the language's suitability within the Pop-Up Book learning media, achieving a 100% validity rate for its appropriateness.

# 3. Theoretical Framework

# Figure 1



#### Research Paradigm

The research is guided by Dr. Sivasailam Thiagarajan's 4D model (Define, Design, Develop, Disseminate), which ensures a structured approach to the development of GeoPUB. The framework begins by identifying students' learning needs, followed by the design and development of the tool, incorporating feedback from experts, and finally disseminating it to students for practical use.

Cognitive Load Theory, developed by John Sweller, recognizes that working memory has limited capacity, and assisting learners in managing essential versus non-essential information is crucial for effective learning and transferring knowledge to long-term memory. Working memory refers to the information we actively process while learning, and its capacity is about four items, give or take one. This capacity is even smaller for children, making it essential to carefully structure learning materials to avoid overwhelming their working memory.

CLT emphasizes the importance of designing instructional materials that account for the limited capacity of working memory. In teaching threedimensional geometry, traditional two-dimensional methods often overwhelm students, leading to high cognitive load. When applied to geometry learning, pop-up books alleviate this cognitive strain by breaking down complex 3D concepts into simpler, visual forms. This reduces the mental load on students and enhances their ability to grasp geometric ideas, making pop-up books a powerful tool for improving learning outcomes (Deans 2023).

# 4. Methodology

#### 4.1 Research Design

Creswell (2018) explains that a quantitative approach to data analysis involves making specific assumptions and using data collection methods to confirm or challenge those assumptions. In this study, a quasi-experimental quantitative research method will be employed to evaluate the effectiveness of GeoPUB as a supplementary learning material for Grade 7 students' understanding of solid geometry and volume calculations. According to Bhandari (2020), quantitative research involves gathering and interpreting numerical data. It allows for the identification of trends and averages, formulation of hypotheses, examination of causality, and extrapolation of findings to larger populations.

Given that this study will compare pre-test and post-test results to identify differences in students' performance following the intervention with GeoPUB, the quasi-experimental design is deemed most appropriate. This method enables the researchers to conduct proper statistical analysis, interpretation, and

comparisons to reveal the relationships between the variables under study, specifically evaluating the impact of GeoPUB on students' understanding of solid geometry and volume calculations.

# 4.2 Research Locale

This study was conducted at Linga National High School, which is located in Barangay Linga, Pila, Laguna. The researchers selected Linga National High School as the research site because it offers the necessary information and data regarding the students that are required for the study.

#### 4.3 Population and Sampling Design

In this study, the population consists of Grade 7 students at Linga National High School. The total population of Grade 7 students is 247. The sample includes 25 Grade 7 students selected through simple random sampling. This method was chosen to ensure that every student had an equal chance of being selected, making the sample representative of the larger population. The selection aligns with the Most Essential Learning Competencies (MELCs) for Grade 7 Mathematics, focusing on their understanding of solid geometry concepts.

#### 4.4 Research Instrument

In this study, the researchers developed and used their own validated questionnaire to identify first the learning style of the students. It was composed of 17 questions. This was to gather data and information from specific group of individuals. The survey questionnaire was used by the researchers to collect data, which was then assessed.

The tests that were used in pre- test and post- test with the topic of "Solid Geometry; Volume calculations." It was composed of 5 questions for each solid shape in the form of multiple choice. The GEOPUB, a book developed by the researchers about solid geometry; a 3D visualization of solid shapes. Lastly, the validation tool used was to validate the GEOPUB in terms of objectives, presentation, and design.

### 4.5 Data Gathering Procedure

The data collection process for this study involved several key steps to ensure a comprehensive evaluation of the effectiveness of the GeoPUB material in enhancing Grade 7 students' understanding of solid geometry. First, the researchers obtained permission from Linga National High School to conduct the study and gather data from the students, providing a formal letter to facilitate this process and inform potential participants about the study's objectives. Next, the researchers reviewed a list of potential participants to determine the total population, ultimately selecting 25 Grade 7 students for participation. A pre-test and questionnaire were then administered to these students to gather baseline data on their learning styles and understanding of geometric concepts, which aimed to identify areas of difficulty and learning needs. After introducing the GeoPUB material as a supplementary learning tool, a posttest was administered to evaluate any changes in the students' understanding of volume calculations in solid geometry. The developed GeoPUB was reviewed and validated by five Master Teachers/Experts using a dedicated evaluation tool, which assessed the material's objectives, presentation, and design to ensure its educational effectiveness. Finally, the collected data were analyzed using quantitative methods, with statistical analysis applied to the pre-test and post-test assessments to determine any significant differences in student performance.

# Table A

Scoring Range of the category of product quality

Range	Value	Interpretation	Category
1.00 - 1.79	1	Very Low	Poor Material
1.80 - 2.59	2	Low	Below Average Material
2.60 - 3.39	3	Moderate high	Average Material
3.40 - 4.19	4	High	Good Material
4.20 - 5.00	5	Very high	Excellent Material

#### Management and Treatment of Data

The following statistical procedures were used to interpret the data gathered from the respondents of the study. The selection of these specific statistical procedures is essential to ensure the accurate interpretation of the data collected from the selected respondents. These procedures have been chosen based on their appropriateness for the research objectives and the type of data gathered. By applying these statistical methods, the researcher aims to analyze, synthesize, and draw meaningful conclusion from the collected data, thus enhancing the validity and reliability of the research findings.

#### Table B

Sta	tisti	cal	tools

STATEMENT OF THE PROBLEM	STATISTICAL TREATMENT	FORMULA
1. What is the most prevalent learning style among Grade 7 students using Dunn and Dunn's Leaning Style test?	Frequency and Percentage Distribution	$=\frac{1}{N} \times 100$
2. What is the mean pre-test score of Grade 7 students in their understanding of volume calculations in solid geometry?	Mean	$\overline{\mathbf{x}} = \frac{\sum \mathbf{x}}{n}$
3. What is the mean post-test score of Grade 7 students in their understanding of volume calculations in solid geometry?	Mean	$\overline{\mathbf{x}} = \frac{\sum \mathbf{x}}{n}$
4. What is the mean level of validity of GeoPUB: A 3D Interactive Visualization for Solid Geometry Learning and Volume Calculations among the five (5) selected Master Teachers/Experts, as assessed according to the following criteria?	Mean	$\bar{\mathbf{x}} = \frac{\sum \mathbf{x}}{n}$
4.1. Book Objectives;		
4.2. Book Presentation;		
4.3. Book Design?		
5. Is there a significant difference between the pre- test and post-test scores of Grade-7 students in their understanding of volume calculations in solid geometry after using GeoPUB as a supplementary learning material?	Paired t-test	$t = \frac{\Sigma D}{\sqrt{\frac{n(\Sigma D^2) - (\Sigma D)^2}{n-1}}}$

**Findings and Discussion** 

The aim of this study was to determine the validity of GeoPUB in Solid Geometry Learning and Volume Calculations as supplemental learning material. The data collected from the Experts were analyzed and interpreted to gain insights and determine whether GeoPUB is a poor, below average, average, above average, or excellent material before the dissemination. The GeoPUB evaluation was conducted by providing the experts with a judgment questionnaire in the form of a checklist to validate the product.

The experts evaluated three criteria: Book Objectives, Book Presentation, and Book Design. The results of the checklist questionnaire are explained below. The judges evaluated the instructional material using an evaluation rubric provided by the researchers.

# Table 1

Frequency and Percentage Distribution of the Most Prevalent Learning Style among Grade 7 Students Using Dunn and Dunn's Learning Style Test

Learning Style	Frequency	Percentage (%)
Visual	12	48%
Bodily-Kinesthetic	7	28%
Auditory	6	24%
Total	25	100%

The results indicate that visual learning is the dominant learning style among the students, with the highest number of students (48%) preferring this approach. This suggests that these students respond more effectively to visual aids such as diagrams, charts, and written materials. Bodily-Kinesthetic learning ranked second, with 28% of the students favoring hands-on activities and physical engagement, highlighting that interactive and movementbased tasks also play an important role in their learning process.

Auditory learning, preferred by 24% of the students, ranked lowest. This suggests that fewer students benefit from listening-based activities such as discussions, lectures, or verbal instructions. While auditory methods are still useful, the data indicates that students generally favor visual and kinesthetic approaches more.

The findings suggest that these students prefer learning through visual materials and physical engagement, with auditory strategies being the least favored among the group. Educators may consider incorporating more visual and kinesthetic activities into their lessons to maximize student engagement and comprehension.

#### Table 2

The mean pre-test score of Grade 7 students

TEST	MEAN
PRE-TEST	10.24

The mean pre-test score of Grade 7 students was 10.24 out of 25 items. This score suggests that, prior to any instructional intervention or learning activities, the students had a foundational understanding of the material being assessed. However, this mean score indicates that there is significant room for improvement in their knowledge and skills related to the subject matter.

# Table 3

The mean post test score of Grade 7 students

TEST	MEAN
POST TEST	15.64

The mean post-test score of Grade 7 students was 15.64 out of 25 items. This increase from the pre-test score indicates that students showed significant improvement in their understanding and retention of the material after the instructional intervention. The post-test mean score reflects a positive learning outcome, demonstrating that the teaching methods employed were effective in enhancing student learning. The results suggest that the instructional strategies used contributed to a deeper comprehension of the subject, as evidenced by the substantial increase in mean scores from pre-test to post-test.

#### Table 4

Legend:

Ran

The mean level of validity of GeoPUB

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-		Validators	
	Criteria	Mean Score	Interpretation
-	Book Objectives	4.30	VH
	Book Presentation	4.47	VH
	Book Design	4.54	VH
-	Total	4.44	VH
-			
	Ir	terpretation	Category
1.79		Very low (VL)	Poor Material
2.59		Low (L)	Below Average Material

2.60 - 3.39	Moderately High (MH)	Average Material
3.40 - 4.19	High (H)	Above Average Material
4.20 - 5.00	Very High (VH)	Excellent Material

The presented table above was obtained from the Experts regarding the overall quality of GeoPUB. Based on the results presented above, the overall mean level of validity for GeoPUB is 4.44. This was interpreted as very high level and categorized as excellent material. The maximum score for each item was five (5), and one (1) was the minimum. The 3D book GeoPUB was assessed and evaluated by four (4) Experts using three (3) criteria: Book Objectives, Book Presentation, and Book Design.

#### Table 5

The pre-test and post-test scores of Grade-7 students

Mean					
Pretest	Post test			P-value	Remarks
		t-stats	t-value		
10.25	15.64	-9.353074	2.064	0.0001	There is a significant difference.

A paired t-test was conducted to compare the pre-test and post-test scores of Grade-7 students in their understanding of volume calculations in solid geometry after using GeoPUB as a supplementary learning material. The results showed that the mean post-test score (15.64) was higher than the mean pre-test score (10.24), indicating an improvement in scores. With a t-statistic of -9.353 and a p-value (0.0001) significantly below the 0.05 significance level, there is strong evidence to reject the null hypothesis.

The results of the paired t-test indicate a significant difference between the pre-test and post-test scores of Grade-7 students after the use of GeoPUB as a supplementary learning tool. This suggests that GeoPUB had a positive impact on the students' understanding of volume calculations in solid geometry. Therefore, the null hypothesis is rejected. There is a significant difference between the pre-test and post-test scores of Grade-7 students in their understanding of volume calculations in solid geometry after using GeoPUB as a supplementary learning material. It is concluded that GeoPUB significantly improved the students' performance.

# Conclusion

Summary of Findings

The following were the findings of the study:

1. The most prevalent learning style among Grade 7 students is visual learning (48%), followed by bodily-kinesthetic (28%) and auditory learning (24%). This indicates that visual and hands-on approaches effectively engage students.

2. The pre-test mean score was 10.24 out of 25, showing a basic understanding of the material but significant room for improvement.

3. Following the instructional activities, the mean post-test score increased to 15.64 out of 25 items. This increase shows significant improvement in the students' understanding, demonstrating that the teaching methods were effective in enhancing their learning.

4. The overall mean level of validity for GeoPUB, as assessed by five selected Master Teachers/Experts, was 4.44, categorized as excellent.

5. Significance of Pre-Test and Post-Test Scores: There was a significant difference between the pre-test and post-test scores of Grade 7 students in their understanding of volume calculations in solid geometry after using GeoPUB. The mean post-test score was 15.64, compared to a mean pre-test score of 10.25. The t-statistic was -9.353 with a p-value of 0.0001, indicating strong evidence to reject the null hypothesis.

The study has concluded the following based on the aforementioned findings:

The findings of this research demonstrate that GeoPUB effectively enhances Grade 7 students' learning experiences. Visual learning is the most prevalent style, preferred by 48% of students, followed by bodily-kinesthetic learning at 28%. In contrast, auditory learning is the least favored at 24%. This indicates that visual aids and hands-on experiences are the most effective methods for engaging these learners.

The evaluation of GeoPUB by five Master Teachers showed it to be an excellent supplementary learning tool. The significant improvement in students' understanding of volume calculations after using GeoPUB emphasizes its positive impact on learning. Overall, the evidence supports the conclusion that GeoPUB significantly enhances educational outcomes for Grade 7 students in solid geometry, demonstrating the importance of using effective materials aligned with students' learning preferences.

The following recommendations are made in regards to the study's findings and conclusion:

1. Incorporate the GeoPUB 3D interactive workbook as a regular part of the mathematics curriculum, particularly in lessons focusing on solid geometry and volume calculations.

2. Encourage students to interact physically with the pop-up elements of GeoPUB during lessons to reinforce their understanding of three-dimensional shapes and their properties.

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