

THE EFFECTIVENESS OF A QR CODE-ASSISTED POP-UP BOOK LEARNING MEDIA IN ENHANCING STUDENTS' MATHEMATICAL CONCEPTUAL UNDERSTANDING OF POLYHEDRA

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Abstract

This study was motivated by the low level of mathematical conceptual understanding among eighth-grade students at SMP Negeri 3 Brebes in learning polyhedra. The problem was primarily caused by students' difficulties in understanding abstract mathematical concepts and their passive participation during classroom learning. This study aimed to describe the differences in students' mathematical conceptual understanding before and after the implementation of a QR Code-assisted Pop-Up Book learning media and to determine its effectiveness in teaching polyhedra. This research employed a quantitative approach using a pre-experimental method with a one-group pretest-posttest design. The population consisted of 336 eighth-grade students from eleven classes at SMP Negeri 3 Brebes. The sample was selected through cluster random sampling, resulting in Class VIII E (30 students) as the experimental group. Data were collected using an essay-based mathematical conceptual understanding test and analyzed through the Shapiro-Wilk normality test, the Paired Sample t-Test, and the N-Gain Score. The findings revealed that the average pretest score increased from 47.13 to 72.53 on the posttest. The Paired Sample t-Test showed that the calculated t value (29.703) exceeded the critical t value (2.045), with a significance value of $0.000 < 0.05$, indicating a statistically significant difference in students' mathematical conceptual understanding before and after the treatment. Furthermore, the average N-Gain score was 0.775 (77.54%), which falls into the high category and indicates that the learning media was effective. It can therefore be concluded that the QR Code-assisted Pop-Up Book learning media is effective in improving the mathematical conceptual understanding of eighth-grade students in learning polyhedra during the second semester of the 2025/2026 academic year at SMP Negeri 3 Brebes.

Keywords: Effectiveness; Pop-Up Book; QR Code; Mathematical Conceptual Understanding; Polyhedra.

1 INTRODUCTION

Mathematics is one of the fundamental subjects that plays an essential role in broadening students' knowledge while fostering logical thinking, analytical reasoning, and problem-solving skills. The effectiveness of mathematics learning is closely associated with students' understanding of the subject matter, the development of their cognitive skills, and their ability to apply acquired knowledge to real-life situations [1]. Mathematical conceptual understanding refers to students' cognitive ability to comprehend mathematical ideas, which is reflected in their capacity to explain concepts, process information, and reconstruct mathematical ideas using their own words. This ability enables students to solve mathematical problems based on established principles and conceptual rules [2]. According to Bruner's learning theory, mathematics learning involves understanding mathematical concepts and structures as well as discovering relationships among them. Therefore, conceptual understanding serves as a fundamental component of effective mathematics learning [3].

Based on an interview conducted with an eighth-grade mathematics teacher at SMP Negeri 3 Brebes in January 2026, it was found that students' mastery of mathematical concepts remained relatively low. Consequently, students tended to participate passively during classroom activities, and most of them failed to achieve the Minimum Mastery Criterion (MMC). Furthermore, classroom observations conducted during the School Field Experience Program (PLP) revealed that students experienced considerable difficulties in understanding abstract geometry concepts, particularly in the topic of polyhedra. Their learning achievement in this topic reached only approximately 38.88% [4]. Moreover, representing three-dimensional objects merely through two-dimensional illustrations in textbooks or on whiteboards often makes it difficult for students to visualize the structures of geometric solids comprehensively [5].

One instructional medium that has the potential to address these problems is the Pop-Up Book, a three-dimensional learning medium that presents objects through folding, sliding, rotating, and movable paper

constructions. This interactive design provides an attractive visual representation capable of capturing students' attention and increasing their learning motivation [6]. Previous studies have also demonstrated that digital Pop-Up Books can significantly enhance students' interest and engagement because of their visually appealing and interactive characteristics [7].

To further improve learning effectiveness, the Pop-Up Book can be integrated with Quick Response (QR) Code technology. Through QR Codes, students are able to access additional multimedia resources—including instructional videos, interactive simulations, and practice exercises—simply by scanning the code using a smartphone. This integration creates a richer and more interactive learning experience [8]. QR Codes efficiently connect printed learning materials with digital content while providing students with flexible access to learning resources anytime and anywhere [9]. In addition, QR Codes have large data-storage capacity, are easy to scan, and can be recognized from various scanning angles [10]. Previous research has successfully implemented QR Code-assisted Pop-Up Books in elementary school cultural diversity learning, demonstrating positive educational outcomes [11].

Several previous studies support the educational benefits of Pop-Up Book learning media. Habibi and Setyaningtyas developed a Pop-Up Book to improve students' problem-solving skills in learning cubes and rectangular prisms, reporting that the media was valid, practical, and well received by both teachers and students [12]. Likewise, Hamidah, Fiantika, and Prayogo developed an ethnomathematics-based Pop-Up Book featuring the architecture of the Al-Akbar Mosque in Surabaya and found that integrating local cultural elements successfully increased students' learning interest [13]. Other studies have shown that Pop-Up Books designed for teaching geometry in elementary schools were rated as highly feasible by both media experts and subject-matter experts [14]. In addition, previous findings indicate that Pop-Up Book learning media positively affect students' learning achievement and motivation in geometry instruction [15]. However, most previous studies have primarily focused on media development or its influence on learning achievement and motivation. In contrast, the present study specifically investigates the effectiveness of a QR Code-assisted Pop-Up Book learning media in improving students' mathematical conceptual understanding in learning polyhedra.

Based on the background described above, this study addresses two research questions: **(1)** Is there a significant difference in the mathematical conceptual understanding of eighth-grade students before and after learning through a QR Code-assisted Pop-Up Book on the topic of polyhedra? **(2)** Is the QR Code-assisted Pop-Up Book effective in improving students' mathematical conceptual understanding? Accordingly, this study aims to examine the difference in students' mathematical conceptual understanding before and after the implementation of the QR Code-assisted Pop-Up Book learning media and to determine its effectiveness in enhancing students' mathematical conceptual understanding of polyhedra.

2 METHODOLOGY

2.1 Research Approach and Design

This study employed a quantitative approach using a pre-experimental method to investigate the effect of a treatment on a particular variable without involving a control group. The research adopted a one-group pretest–posttest design, in which participants completed a pretest before receiving the treatment and a posttest after the treatment had been implemented. The treatment consisted of learning activities using a QR Code-assisted Pop-Up Book learning media.

Tabel 1. Research Design

O₁	X	O₂
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Description:

- **O₁** = Pretest
- **X** = Learning using the QR Code-assisted Pop-Up Book
- **O₂** = Posttest

2.2 Population and Sample

The population of this study consisted of 336 eighth-grade students enrolled in the second semester of the 2025/2026 academic year at SMP Negeri 3 Brebes, distributed across 11 classes.

The sample was selected using the cluster random sampling technique. All eleven eighth-grade classes were randomly assigned through a lottery procedure. As a result, Class VIII E, consisting of 30 students, was selected as the experimental class, while Class VIII D, also consisting of 30 students, was used to pilot the research instrument.

2.3 Data Collection Techniques and Research Instrument

Data were collected using documentation and essay tests.

The research instrument consisted of eight essay questions designed to measure students' mathematical conceptual understanding. The test was administered twice:

- Pretest, before the implementation of the learning media.
- Posttest, after the implementation of the QR Code-assisted Pop-Up Book learning media.

Prior to the main study, the instrument was piloted in Class VIII D to evaluate its validity, reliability, item discrimination index, and difficulty level, ensuring that only appropriate test items were used in the actual research.

2.4 Data Analysis Techniques

Before hypothesis testing, prerequisite analysis was conducted using the Shapiro–Wilk normality test, as the sample size consisted of fewer than 50 participants.

Hypothesis testing was carried out in two stages.

The first hypothesis was tested using the Paired Sample *t*-Test to determine whether a significant difference existed between students' pretest and posttest scores [18]. The null hypothesis (H_0) was rejected if the calculated *t*-value exceeded the critical *t*-value at the 5% significance level.

The second hypothesis was analyzed using the Normalized Gain (N-Gain) Score to determine the magnitude of improvement in students' mathematical conceptual understanding and to evaluate the effectiveness of the learning media.

N-Gain Score	Category
$g > 0.70$	High
$0.30 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low

3 RESULTS AND DISCUSSION

3.1 Results

The study was conducted in Class VIII E of SMP Negeri 3 Brebes, involving 30 students over three instructional sessions. The research activities consisted of administering the pretest, implementing the QR Code-assisted Pop-Up Book learning media, and administering the posttest. A statistical description of the pretest and posttest results is presented in Table 2.

Table 2. Descriptive Statistics of the Pretest and Posttest Scores

Statistics	Pretest	Posttest
Number of Students	30	30
Maximum Score	60	80
Minimum Score	34	60
Mean	47.13	72.53
Median	46	74
Mode	46	76
Variance	54.26	41.64
Standard Deviation	7.24	6.34

As shown in Table 2, the mean score of students' mathematical conceptual understanding increased from 47.13 on the pretest to 72.53 on the posttest after the implementation of the QR Code-assisted Pop-Up Book learning media. Likewise, the median and mode values also increased, indicating an overall improvement in students' mathematical conceptual understanding following the treatment.

Before conducting hypothesis testing, the prerequisite assumption of normality was examined using the Shapiro–Wilk normality test. The results are presented in Table 3.

Table 3. Results of the Shapiro–Wilk Normality Test

Data	W Statistic	W Critical	Decision
Pretest	0.964	0.927	Normally Distributed
Posttest	0.949	0.927	Normally Distributed

The calculated W values for both the pretest and posttest were greater than the critical value (0.927). Therefore, the null hypothesis was accepted, indicating that both datasets were normally distributed. Consequently, the assumption required for conducting the Paired Sample t-Test was satisfied.

The first hypothesis was tested using the Paired Sample t-Test, and the results are presented in Table 4.

Table 4. Results of the Paired Sample t-Test

Calculated <i>t</i>	Critical <i>t</i>	Decision
29.703	2.045	Reject H_0

Based on Table 4, the calculated t-value (29.703) was substantially greater than the critical t-value (2.045) at the 5% significance level. Furthermore, the significance value was 0.000, which is lower than 0.05. Therefore, the null hypothesis (H_0) was rejected, indicating a statistically significant difference in students' mathematical conceptual understanding before and after learning through the QR Code-assisted Pop-Up Book.

To determine the effectiveness of the learning media, the second hypothesis was analyzed using the Normalized Gain (N-Gain) Score. The results are summarized in Table 5.

Table 5. *N-Gain Analysis*

Indicator	Result
Mean N-Gain	0.775
Mean N-Gain (%)	77.54%
Category	High
Interpretation	Effective

The average N-Gain score of 0.775 (77.54%) falls within the high category, indicating that the QR Code-assisted Pop-Up Book learning media was effective in improving students' mathematical conceptual understanding of polyhedra.

3.2 Discussion

The significant improvement in students' mathematical conceptual understanding after the implementation of the QR Code-assisted Pop-Up Book learning media can be explained not only through statistical evidence but also through relevant educational theories.

According to Jerome Bruner's theory of learning, effective mathematics instruction should guide learners through three stages of representation: enactive, iconic, and symbolic. The QR Code-assisted Pop-Up Book facilitates these three stages by allowing students to manipulate concrete three-dimensional objects before progressing to visual representations and abstract mathematical symbols. This gradual learning process enables students to construct conceptual understanding more effectively than receiving abstract explanations alone.

Similarly, Edgar Dale's Cone of Experience suggests that learning becomes more meaningful when students engage in direct and concrete experiences rather than relying solely on verbal explanations or two-dimensional illustrations. The three-dimensional characteristics of the Pop-Up Book provide students with tangible learning experiences that facilitate conceptual visualization and long-term retention.

Prior to the intervention, classroom instruction mainly relied on teacher explanations and two-dimensional images presented in textbooks or on the whiteboard. As a result, many students experienced difficulty visualizing three-dimensional geometric objects. After the implementation of the QR Code-assisted Pop-Up Book, students were able to observe and manipulate three-dimensional models directly while simultaneously accessing instructional videos through QR Codes. This integration of physical and digital learning resources provided richer learning experiences and made abstract mathematical concepts easier to understand. Consequently, students demonstrated significantly higher posttest scores than pretest scores.

The findings of this study are consistent with previous research. Habibi and Setyaningtyas reported that Pop-Up Book learning media were valid, practical, and effective for teaching cubes and rectangular prisms while receiving positive responses from both teachers and students. Likewise, Hamidah, Fiantika, and Prayogo found that ethnomathematics-based Pop-Up Books enhanced students' interest in learning and supported contextual understanding of geometry concepts. Other studies also concluded that Pop-Up Books are highly feasible instructional media and positively influence students' learning achievement and motivation in geometry learning.

Unlike previous studies, which primarily focused on media development or learning achievement, the present study specifically investigated the effectiveness of integrating QR Code technology into a Pop-Up Book learning media to improve students' mathematical conceptual understanding. The statistical analysis, supported by learning theories and previous empirical findings, demonstrates that the QR Code-assisted Pop-Up Book is an effective instructional medium for enhancing students' understanding of polyhedra.

4 CONCLUSION

Based on the results of the data analysis and discussion, two main conclusions can be drawn. First, there was a statistically significant difference in the mathematical conceptual understanding of eighth-grade students at SMP Negeri 3 Brebes before and after the implementation of the QR Code-assisted Pop-Up Book learning media on the topic of polyhedra. This finding is supported by the results of the Paired Sample *t*-Test, which showed that the calculated *t*-value (29.703) exceeded the critical *t*-value (2.045) at the 5% significance level, indicating that the learning media significantly improved students' mathematical conceptual understanding. Second, the QR Code-assisted Pop-Up Book learning media proved to be effective in improving students' mathematical conceptual understanding. This conclusion is supported by the average N-Gain score of 0.775 (77.54%), which falls into the high category and indicates a high level of instructional effectiveness. Based on these findings, mathematics teachers are encouraged to consider integrating QR Code-assisted Pop-Up Book learning media as an innovative instructional alternative for teaching geometry, particularly the topic of polyhedra. However, effective classroom management and appropriate time allocation remain essential to ensure that students' enthusiasm for the physical and digital features of the learning media contributes meaningfully to the achievement of the intended learning objectives.

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REFERENCE

- Alvira, E. M., Vaganza, A., Putri, A., & Setiawan, B. (2024). Analysis of Learning Problems: Factors Affecting the Effectiveness of the Learning Process Among Students. 2(1).
- Susmina, H., & Marlina, R. (2024). Mathematical Conceptual Understanding of Tenth-Grade Students on Sequences and Series. 10(2), 387–397.
- Tauhid, K., Safari, Y., & Rahmalia, S. M. (2024). The Importance of Fundamental Mathematical Concepts in Elementary Schools. 3, 9847–9855.
- Ashriyanto, A. M., & Tyaningsih, R. Y. (2025). The Effectiveness of Cabri 3D Learning Media on Students' Conceptual Understanding of Polyhedra. 7(1).
- Ayu, D., Ningsih, S., & Sari, N. T. (2025). Jurnal Perseda. 9(3), 93–100.
- Winarti, & Setiani. (2019). The Effectiveness of Pop-Up Book Media in Cooperative Learning Using the Make A Match Model. 02(2), 136–142.
- Magfiroh, A., Nindi, L., & Marfu, R. (2025). Literature Review: The Utilization of Pop-Up Book Media in Enhancing Students' Learning Interest. 4(April), 151–160.
- Satriana, D. R., Ismaya, E. A., Ardianti, S. D., & Kudus, U. M. (2025). The Implementation of the Think-Pair-Share Model Assisted by QR Code-Based Pop-Up Media to Improve Fifth-Grade Students' Conceptual Understanding. 6, 56–69.
- Radhita, R., & Eka, K. (2025). Integration of QR Codes into Smart Visual Learning Media for the Development of Modern Learning. 03(02), 524–532.

- Prathivi, R. (2018). QR Code System Analysis for Library Book Identification. 14(2), 37–40.
- Hafidah, Zainuddin, M., & Ahdhianto. (2024). Development of a QR Code-Assisted Pop-Up Book on Local Cultural Diversity Materials for Elementary Schools. 19(2), 127–138.
- Habibi, C. D., & Setyaningtyas, E. W. (2021). Development of Pop-Up Book Media to Improve Problem-Solving Skills in Learning Cubes and Rectangular Prisms for Fifth-Grade Elementary School Students. 05(02), 1341–1351.
- Hamidah, Fiantika, F. R., & Prayogo, A. (2025). Innovation in Geometry Learning through an Ethnomathematics-Based Pop-Up Book Featuring the Al-Akbar Mosque of Surabaya.
- Athala, Suratman, & Pasaribu. (2025). Development of Pop-Up Book Learning Media for Teaching Three-Dimensional Geometry at SD Negeri 1 Mempawah Hilir.
- Sari, & Disurya. (2025). The Effect of Pop-Up Book Media on Students' Learning Outcomes and Learning Motivation in Geometry.
- Subhaktiyasa, P. G. (2024). Determining Population and Sample: Approaches in Quantitative and Qualitative Research Methodology. 9, 2721–2731.
- Isnaini, M., Afgani, M. W., Haqqi, A., & Azhari, I. (2025). Data Analysis Techniques: Normality Testing. 4(2), 1377–1384.
- Risnawati, & Rahmani, H. (2025). Paired-Sample Student's t-Test for Dependent Samples. 4, 568–576.
- Kolopita, C. P., Katili, M. R., & Thohir, R. M. (2022). The Effect of Learning Media on Learning Outcomes and Basic Networking. 2(1), 1–12.
- Muhaimin, L. H., & Juandi, D. (2023). The Role of Learning Media in Learning Mathematics: A Systematic Literature Review. 13(01), 85–107. <https://doi.org/10.20961/jmme.v13i1.74425>