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Development of QR Code Assisted Pop Up Book Based on Problem Based Learning (PBL) for Elementary School Mathematics

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ABSTRACT

Mathematics learning at the elementary level, particularly in spatial geometry, still faces challenges in improving students' conceptual understanding. These challenges are mainly related to students' difficulties in visualizing three-dimensional objects and the limited variety of learning media used in classrooms. Previous studies have examined Pop Up Book media and QR Code–based learning separately; however, few have explored their integration within a structured Problem Based Learning (PBL) framework to enhance conceptual understanding, especially in geometry. This study aims to develop a QR Code–assisted Pop Up Book learning media based on the Problem Based Learning model for elementary mathematics learning. It employs a Research and Development (R&D) approach using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The developed media was validated by three experts: a material expert, a media design expert, and a language expert. The implementation involved 55 fifth-grade elementary school students. Data were collected through observation, interviews, questionnaires, and learning outcome tests. The validation results showed Aiken's V values ranging from 0.67 to 1.00, indicating high content validity. Students' learning outcomes improved after using the media, as reflected in an N-Gain value of 0.79, categorized as high improvement. These findings demonstrate that integrating Pop Up Book visualization, QR Code–based digital resources, and the Problem Based Learning approach effectively enhances students' conceptual understanding of spatial geometry, offering a more comprehensive and integrated instructional approach.

1. Introduction

Mathematics, often regarded as the language of logic and structure, stands at the very core of human reasoning and decision-making. From everyday problem-solving to complex analytical thinking, its role is undeniably fundamental in shaping how individuals interpret the world. In educational contexts, mathematics is not merely a subject to be mastered, but a cognitive tool that cultivates reasoning, precision, and critical thinking. Developing mathematical competence from an early age is therefore essential, as it equips students with higher-order thinking skills that extend beyond academic achievement into real-life decision-making processes (Lesmana et al., 2022). At the elementary level, mathematics education becomes a foundational stage where students begin to construct systematic thinking patterns and problem-solving abilities that will influence their future learning trajectories (Tursynkulova et al., 2023).

Yet, the meaningfulness of mathematics learning depends greatly on how well concepts are connected to students' lived experiences. Learning becomes more effective when abstract ideas are contextualized within familiar situations, allowing students to internalize and apply knowledge in authentic ways (Patta, 2021). However, despite its importance, mathematics continues to be perceived as a difficult and intimidating subject by many learners. This perception is particularly evident in elementary classrooms, where students frequently struggle with abstract representations and experience anxiety during mathematical activities (Supriatna, 2023). Such conditions often lead to superficial understanding and low achievement, especially when instruction relies heavily on symbolic and procedural approaches without sufficient conceptual grounding.

One domain that exemplifies these challenges is geometry, particularly spatial geometry. Geometry

plays a crucial role in developing visualization skills, logical reasoning, and spatial awareness, all of which are essential for interpreting real-world structures. Concepts such as cubes and cuboids are not only foundational in mathematics but also relevant to everyday experiences. Understanding these concepts involves grasping relationships between dimensions and space, such as volume calculation (Zulyanti et al., 2024). However, students often encounter difficulties in accurately visualizing three-dimensional objects, which can lead to misconceptions and hinder conceptual understanding. These difficulties are frequently exacerbated by instructional practices that rely on two-dimensional representations, limiting students' ability to mentally construct spatial forms.

A growing body of research has highlighted that such difficulties are closely linked to instructional design and the limited use of effective learning media. In many classrooms, geometry instruction remains teacher-centered, with an emphasis on verbal explanations and textbook illustrations that fail to adequately represent spatial characteristics (Agusdianita & Kartjiyati, 2021). Studies have emphasized that insufficient visualization support contributes significantly to students' reliance on memorization rather than conceptual understanding (Farihah, 2021). Furthermore, research on learning media underscores their critical role in transforming abstract concepts into concrete representations that align with students' cognitive development (Aini et al., 2025; Aprilia et al., 2023). While various studies have explored visual media, digital tools, and interactive approaches independently, they often lack integration within a coherent instructional framework that systematically supports conceptual learning.

Learning media, therefore, are not merely supplementary tools but essential components that shape the quality of instructional experiences. Effective media can enhance clarity, engagement, and motivation, ultimately improving learning outcomes (Kintoko et al., 2020; Amalia et al., 2025). Among the promising visual media, Pop Up Books have gained attention for their ability to present three-dimensional representations that make abstract concepts more tangible and engaging (Pradiani et al., 2023; Jayanti & Wibawa, 2024). At the same time, advancements in educational technology have introduced QR Codes as a means of integrating printed materials with digital resources, enabling access to videos, animations, and interactive content (Fazira & Qohar, 2021; Trisna et al., 2025). Although prior studies have demonstrated the benefits of Pop Up Books and QR Code–based media separately (Rahmi et al., 2024; Merita et al., 2024), their integration within a structured pedagogical model remains underexplored.

Addressing this gap requires a pedagogically grounded approach that goes beyond combining media elements. From a theoretical standpoint, meaningful learning occurs when students actively construct knowledge through interaction and problem-solving. The integration of visual and digital media must therefore be aligned with instructional strategies that guide cognitive processes. Problem Based Learning (PBL) emerges as a suitable framework, as it emphasizes student-centered learning through contextual problem-solving activities (Subiyantoro, 2025). By engaging students in investigation, discussion, and solution development, PBL fosters critical thinking and conceptual understanding (Syamsidah & Suryani, 2018). However, existing studies rarely examine how visual media, digital tools, and PBL can be systematically integrated into a unified instructional design.

In response to this gap, the present study introduces a novel integration of Pop Up Book visualization, QR Code–based digital resources, and the Problem Based Learning model. This study contributes theoretically by synthesizing constructivist learning theory, multimedia learning theory, and cognitive load theory into a coherent framework for instructional design. Pedagogically, it offers an innovative model that aligns visual, digital, and problem-based elements to support meaningful learning in elementary mathematics. Empirically, it provides evidence on how such integration enhances students' conceptual understanding of spatial geometry, moving beyond fragmented approaches commonly found in previous research.

The significance of this study lies in its potential to transform mathematics learning into a more interactive, meaningful, and student-centered process. By developing and evaluating QR Code–assisted Pop Up Book media based on PBL, this research aims to improve students' learning outcomes while offering practical insights for educators. The findings are expected to contribute to the development of innovative instructional strategies that bridge the gap between abstract concepts and concrete understanding. Ultimately, this study highlights the importance of integrating media, pedagogy, and cognitive principles to create effective learning environments, with implications for enhancing mathematics education practices in elementary schools.

2. Method

This study employed a Research and Development (R&D) approach to design, validate, and evaluate a QR Code–assisted Pop-Up Book based on the Problem-Based Learning (PBL) model. The aim was not only to produce an instructional product but also to assess its feasibility and effectiveness in improving elementary students' conceptual understanding of spatial geometry.The development followed the ADDIE instructional design model, which includes five stages: analysis, design, development, implementation, and evaluation (Winarni, 2018). This model was chosen for its structured and iterative nature, enabling continuous refinement of the product through formative feedback at each stage.

2.1 Research Design and Development Procedure

The development procedure was carried out through five interconnected stages.

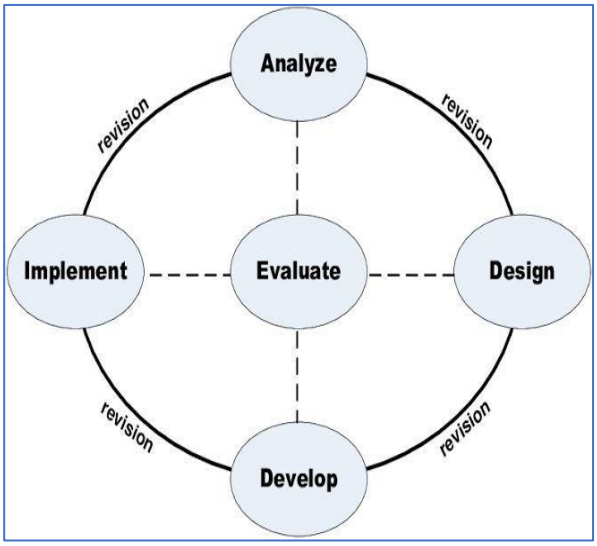

Figure 1. ADDIE Model

First, the *analysis stage* focused on identifying instructional needs and learning problems. This stage included curriculum analysis, teacher needs analysis, student needs analysis, and analysis of existing learning media (Winarni, 2018). The findings revealed that students experienced significant difficulties in visualizing three-dimensional objects, particularly cubes and cuboids, and that current instructional practices relied heavily on two-dimensional representations.

Second, the *design stage* involved developing a conceptual blueprint of the learning media. This included formulating learning objectives, mapping the stages of the Problem Based Learning model, designing the Pop Up Book structure, and integrating QR Codes linked to digital resources such as videos, animations, and interactive exercises. The design process also incorporated principles of multimedia learning and considered the cognitive characteristics of elementary school students.

Third, the *development stage* translated the design into a tangible product. A three-dimensional Pop Up Book was constructed using paper engineering techniques and integrated with QR Codes that connect to digital learning materials. The developed product was then subjected to expert validation to ensure its feasibility in terms of content, language, and media design.

Fourth, the *implementation stage* involved classroom trials in which students engaged with the developed media through Problem Based Learning activities. Students interacted with the Pop Up Book, scanned QR Codes to access digital resources, and participated in structured problem-solving tasks.

Finally, the *evaluation stage* assessed both the feasibility and effectiveness of the learning media. Evaluation was conducted formatively throughout the development process and summatively after implementation to determine its impact on students' learning outcomes.

2.2 Research Participants and Setting

The study was conducted at SD Negeri 76 Bengkulu City during the odd semester of the 2025 academic year. The participants consisted of **55 fifth-grade students**, divided into two classes: class V B (28 students) and class V C (27 students). A **purposive sampling technique** was used to select participants based on their relevance to the research objectives and accessibility for implementation.

In addition to student participants, the study involved **three expert validators**, comprising a material expert, a media design expert, and a language expert. Their role was to evaluate the quality and feasibility of the developed learning media prior to classroom implementation.

2.3 Data Collection

Data collection in this study was conducted using multiple instruments to ensure comprehensive and triangulated findings. The instruments included:

1) *Expert Validation Questionnaires.* These were administered to material, media, and language experts to assess the feasibility of the developed product. The evaluation covered aspects such as content accuracy, instructional alignment, clarity of language, visual design, and usability.
2) *Student Response Questionnaires* These questionnaires were used to measure students' perceptions of the learning media, including its attractiveness, practicality, ease of use, and effectiveness in supporting learning.
3) *Learning Outcome Tests* Pretest and posttest instruments were administered to measure students' conceptual understanding of spatial geometry. The test items evaluated students' ability to identify geometric shapes, understand their properties, and solve related problems.
4) *Observation and Informal Interviews* Observations were conducted during classroom implementation to capture students' engagement and interaction with the learning media. Informal interviews with teachers provided additional insights into instructional challenges and the practicality of the media.

2.4 Data Analysis

Data analysis was conducted using descriptive quantitative techniques to evaluate the feasibility, practicality, and effectiveness of the developed learning media.

- Validation Data Analysis
  Expert validation data were analyzed using Aiken's V coefficient to determine the degree of content validity. The coefficient was calculated using the formula:

$$V = \Sigma s / [n(c - 1)]$$

where *s* represents the adjusted score given by each expert, *n* represents the number of experts, and *c* represents the number of rating categories. The interpretation followed established criteria: values above 0.80 indicate high validity, 0.60–0.80 indicate moderate validity, and values below 0.60 indicate low validity. This analysis ensured that the developed media met acceptable standards before implementation.

- Student Response Analysis
  Data from student questionnaires were analyzed by calculating the average scores and percentage values. The results were categorized into levels of feasibility, ranging from very feasible to not feasible, to determine the practicality and attractiveness of the media.

- Learning Outcome Analysis
  Students' learning outcomes were analyzed by comparing pretest and posttest scores. The improvement in learning outcomes was measured using the normalized gain (N-Gain) formula:

$$g = (\text{posttest} - \text{pretest}) / (\text{maximum score} - \text{pretest})$$

The N-Gain values were interpreted based on standard criteria:

$g \geq 0.70$ (high improvement), $0.30 \leq g < 0.70$ (moderate improvement), and $g < 0.30$ (low improvement). This analysis provided a normalized measure of learning improvement that accounts for students' initial ability levels, ensuring a more accurate evaluation of instructional effectiveness.

3. Results

The results of this study are presented in the form of the development and testing of QR Code–assisted Pop Up Book learning media based on the Problem Based Learning (PBL) model designed to support Mathematics learning on spatial geometry topics for fifth-grade elementary school students. The results section describes the outcomes obtained at each stage of the ADDIE development process, including the analysis, design, development, implementation, and evaluation stages. The findings are presented descriptively based on the collected research data, including needs analysis results, media design outputs, expert validation results, student responses, and learning outcome improvements.

The development process produced a three-dimensional Pop Up Book learning media integrated with QR Code technology that connects printed materials with digital learning resources. The learning media was designed to support students' understanding of spatial geometry concepts such as cubes and cuboids while facilitating interactive learning activities aligned with the stages of the Problem Based Learning model.

3.1 Analysis of the need for QR Codes Assisted Pop Book

The analysis stage was conducted to identify the learning needs in Mathematics learning, particularly in the topic of spatial geometry for fifth-grade elementary school students. This stage involved classroom observations, informal discussions with teachers, and analysis of student learning outcomes in Mathematics. The analysis focused on identifying the challenges faced by students and teachers in learning spatial geometry concepts.

The results of the analysis showed that many students experienced difficulties in understanding the concept of three-dimensional geometric shapes, particularly in visualizing the edges, vertices, and faces of shapes such as cubes and cuboids. Students often relied on memorization rather than conceptual understanding when solving problems related to spatial geometry.

Learning activities in the classroom were generally conducted using textbooks and teacher explanations. The visual representations available in the textbooks were limited to two-dimensional images, which did not sufficiently represent the three-dimensional characteristics of spatial shapes. As a result, students found it difficult to imagine the structure of the geometric shapes being studied.

In addition to the limitations of visual representation, the learning media used in the classroom were mostly conventional and static, which reduced students' interest in learning. Teachers reported that students often appeared passive during learning activities and rarely participated actively in problem-solving discussions.

The results of the needs analysis also showed that teachers required learning media that were interactive, visually engaging, and capable of supporting student-centered learning activities. Teachers indicated that learning media integrating digital resources could support students in exploring learning materials more independently.

Another finding obtained during the analysis stage was related to students' Mathematics learning outcomes. Based on the Mid-Semester Assessment (PTS) results, the average Mathematics score of students was 67.68, which was below the Minimum Mastery Criterion (KKM) of 70 established by the school. This result indicated that students' understanding of the spatial geometry material was still relatively low.

Based on these findings, there was a need to develop innovative learning media that could support visualization of spatial shapes and increase student

engagement in Mathematics learning. Therefore, the development of QR Code–assisted Pop Up Book learning media based on the Problem Based Learning model was carried out as an alternative learning medium for spatial geometry material.

3.2 Design of QR Code Assisted Pop Up Book Based on Problem Based Learning

The design stage aimed to develop a structured plan for the learning media based on the results of the needs analysis. At this stage, the structure, content, visual design, and digital integration of the Pop Up Book learning media were systematically planned.

The learning media was designed by integrating three main components, namely the Pop Up Book as the main printed media, QR Code technology as the digital access tool, and the Problem Based Learning model as the instructional framework used in the learning activities.

The results of the media design stage are presented in Table 1.

Table 1. Media Design Components

Media Components	Description
Topic	Build a class V room
Main Media	Pop Up Book build space
Visual Elements	3D shapes (Pop Up) dan colored illustrations
Digital Elements	QR Code link to learning videos and Zep Quiz
Learning Mode	Problem Based Learning
Design Products	Storyboard

Based on Table 1, the media design included several main components consisting of topic selection, visual elements, digital integration, and learning model integration. The topic selected for the media development was the spatial geometry material for fifth-grade students.

The main learning media developed was a Pop Up Book representing spatial shapes using three-dimensional paper structures. The visual elements in the Pop Up Book consisted of three-dimensional representations of geometric shapes accompanied by colored illustrations designed to support students' visual understanding of spatial geometry.

The design also incorporated QR Codes embedded within the pages of the Pop Up Book. Each QR Code was connected to digital learning materials that could be accessed by students using mobile devices. The digital content included learning videos explaining spatial geometry concepts and interactive quizzes developed using the Zep Quiz platform.

In addition to visual and digital elements, the design stage also considered the learning model used in the instructional process. The Problem Based Learning model was integrated into the media design by embedding contextual problems within the Pop Up Book pages. These problems were structured to guide students through the stages of the PBL learning process during classroom activities.

The final output of the design stage was a storyboard that described the layout, sequence of learning content, placement of Pop Up structures, and location of QR Codes within the media pages**.** The storyboard served as a reference for the next stage of the development process.

3.3 Development of QR Code Assisted Pop Up Book Based on Problem Based Learning (PBL)

The development stage resulted in a physical Pop Up Book learning media integrated with QR Code technology. After the initial product was developed, expert validation was conducted to evaluate the feasibility of the learning media before classroom implementation.

The validation process involved experts who assessed the product based on several aspects, including content quality, language clarity, and media design. The validation results were analyzed using the Aiken's V coefficient to determine the validity level of each assessment indicator. The results of expert validation are presented in Table 2**.**

Table 2. Expert Validation Result Using Aiken's V

Validation Aspect	Indicator of Assesment	Aiken's V	Category
Content	Content completeness	1.00	Very Valid
	Content breadth	1.00	Very Valid
	Content depth	0.83	Very Valid
	Content presentation	1.00	Very Valid
Language	Clarity	1.00	Very Valid
	Communicativeness	1.00	Very Valid
	Suitability for students	1.00	Very Valid
	Language conventions	0.67	Valid
Design	Appropriateness of media ultilization	1.00	Very Valid
	Layout appearance	1.00	Very Valid
	Learning presentation	1.00	Very Valid
	Supporting elements for content presentation	0.83	Very Valid

Based on the results presented in Table 2, most of the validation indicators obtained Aiken's V values between 0.83 and 1.00, indicating a high level of validity. This suggests that the developed learning media is not only appropriate in terms of content accuracy but also consistently aligned with instructional objectives and student characteristics, The material aspect showed high validity across all indicators, including completeness, breadth, depth, and presentation of the content.

The language validation results showed that three indicators achieved a perfect score of 1.00, categorized as highly valid, reflecting a high level of clarity, communicativeness, and appropriateness for students. This indicates that the language used in the learning media effectively supports student understanding and facilitates the delivery of mathematical concepts. In contrast, the language convention indicator obtained a score of 0.67, categorized as valid, indicating that although the overall language quality is acceptable, minor improvements are still needed to improve consistency and adherence to formal language standards.

In terms of design, all indicators obtained scores ranging from 0.83 to 1.00, indicating a high level of feasibility. These results indicate that the visual appearance, organizational layout, and learning presentation are not only appropriate but also effectively support the presentation of learning content in a clear and structured manner. Furthermore, a well-organized design enhances usability and helps direct students' attention, which is crucial for facilitating understanding in visually oriented topics such as spatial geometry.

Based on these results, the developed learning media met the feasibility criteria for classroom implementation, with several minor revisions made based on validator suggestions before proceeding to the implementation stage.

3.4 Implementation of QR Code Assisted Pop Up Book Learning Media in Elementary School Mathematics Learning

The implementation stage was conducted through a limited classroom trial involving fifth-grade students at SD Negeri 76 Bengkulu City. The trial aimed to observe how the developed learning media was used during Mathematics learning activities and to collect students' responses toward the Pop Up Book learning media assisted by QR Codes.

The implementation was carried out during Mathematics lessons on spatial geometry material, particularly the topic of cubes and cuboids. The

learning process followed the stages of the Problem Based Learning model that had been integrated into the learning media during the design and development stages.

At the beginning of the learning activity, students were introduced to the Pop Up Book media and given instructions on how to use the media, including how to scan the QR Codes embedded in the pages of the Pop Up Book using mobile devices. Students were then guided through the learning process, which included observing the Pop Up Book structures, identifying geometric shapes, accessing supporting digital materials through QR Codes, and working collaboratively to solve contextual problems presented in the media.

To obtain data regarding students' responses to the developed learning media, a student response questionnaire was distributed after the learning activity was completed. The questionnaire measured several aspects related to the use of the learning media, including students' interest in the media, ease of media use, clarity of the learning material, and student engagement during the learning process. The results of the student response questionnaire are presented in Table 3.

Table 3. Students' Responses to the Pop Up Book Learning Media

Assessment Aspect	Obtained Score	Maximum Score	Percentage (%)	Category
Interest in the media	98	100	98%	Very good
Ease of media use	97	100	97%	Very good
Clarity of the material	99	100	99%	Very good
Student engagement in learning	98	100	98%	Very good
Average	**98**	**100**	**98%**	**Very good**

Based on the data presented in Table 3, all assessed aspects obtained percentage scores above 97%, indicating that the learning media received very positive responses from students. This consistently high response suggests that the integration of visual (Pop-Up Book), digital (QR-Code), and instructional (PBL) elements successfully created an engaging and accessible learning environment for elementary students.

The aspect of interest in the media obtained a percentage score of 98%, categorized as very good. This result shows that the visual appearance and characteristics of the Pop Up Book attracted students' attention during the learning process. Students showed enthusiasm when interacting with the Pop Up structures and observing the three-dimensional geometric shapes presented in the learning media.

The aspect of ease of media use obtained a score of 97%, which indicates that students were able to use the learning media without significant difficulty. Students were able to open the Pop Up Book pages, observe the three-dimensional structures, and scan the QR Codes to access the digital learning materials. These findings indicate that the media design was compatible with the abilities and developmental characteristics of elementary school students. The clarity of the material aspect obtained the highest percentage score of 99%, categorized as very good. This result shows that the spatial geometry material presented in the Pop Up Book was clearly understood by students. The visual representation of geometric shapes and the supporting digital explanations helped students recognize the structure of cubes and cuboids.

The aspect of student engagement in learning obtained a score of 98%, which indicates that the learning media encouraged students to participate actively during learning activities. During the learning process, students interacted with the media by observing the Pop Up structures, scanning QR Codes to access additional learning materials, and discussing problem-solving tasks with their peers.

Observations conducted during the classroom implementation also showed that students were actively involved in group discussions and were able to follow the learning activities systematically according to the stages of the Problem Based Learning model. Students showed curiosity when exploring the Pop Up Book pages and frequently interacted with the digital materials accessed through QR Codes.

Overall, the implementation results indicate that students were able to use the developed learning media effectively during the learning process. The average response percentage obtained from the questionnaire was 98%, categorized as very good, which indicates that the QR Code–assisted Pop Up Book learning media was well received by students.

Teachers who observed the learning activities also reported that the learning media was easy to use in classroom instruction and helped facilitate student participation during learning activities. Students demonstrated active involvement when observing the media, scanning QR Codes, and participating in discussions related to the contextual problems presented in the learning material.

3.5 Evaluation of Effectiveness of QR Code Assisted Pop Up Book Learning Media

The evaluation stage was conducted to measure the effectiveness of the QR Code–assisted Pop Up Book learning media in improving students' learning outcomes in spatial geometry material.

The evaluation was carried out by administering a pretest before the learning activity and a posttest after students completed the learning process using the developed learning media. The pretest was used to measure students' initial understanding of spatial geometry concepts, while the posttest measured students' understanding after participating in the learning activities.

The improvement in students' learning outcomes was calculated using the normalized gain (N-Gain) formula, which measures the increase in learning outcomes between pretest and posttest scores. The results of the evaluation are presented in Table 4.

Table 4. Evaluation Results of Effectiveness of QR Code Assisted Pop Up Book Learning Media

Component of Evaluation	Value
Average pretest score	40
Average posttest score	87
N-Gain value	0.79
Improvement category	High

Based on Table 4, the average pretest score before using the developed media was 40, indicating a relatively low initial understanding of spatial geometry. After learning with the QR Code–assisted Pop-Up Book, the average posttest score increased to 87, showing a substantial improvement. This suggests that the media effectively supports conceptual understanding through an integrated visual and interactive learning experience. The combination of three-dimensional visualization, digital resources, and structured problem-based activities appears to promote deeper understanding than conventional methods.

The improvement was further confirmed by an N-Gain score of 0.79, which falls into the high category. Students showed better performance in identifying geometric shapes, understanding the properties of cubes and cuboids, and solving spatial geometry problems more accurately. Overall, the evaluation indicates that the use of the QR Code–assisted Pop-Up Book significantly improved learning outcomes, as reflected in higher posttest scores and a high level of gain.

4. Discussion

Developing mathematics learning in elementary schools is an important effort to create a meaningful, engaging, and student-centered learning process. This effort can begin with selecting learning models, methods, and approaches that are relevant to the material and students' needs in the classroom. In mathematics learning, particularly in spatial geometry, teachers often face challenges due to the abstract nature of the material and the need for students to have high visualization skills. Therefore, the use of learning media is one strategic solution to help students understand concepts concretely. Through the use of media, students can more easily connect abstract concepts with real-life experiences. In addition, teachers, as learning facilitators, need to be creative in designing innovative, engaging, and student-centered media to make the learning process more interactive, meaningful, and able to improve student learning outcomes.

4.1 Analysis of the Need for QR Code Assisted Pop Book Learning Media

The analysis stage in this development research plays a crucial role in determining the direction and characteristics of the learning media being developed. Based on classroom observations, teacher discussions, and analysis of students' learning outcomes, fifth-grade elementary school students were found to experience persistent difficulties in understanding spatial geometry, particularly in visualizing three-dimensional objects such as cubes and cuboids. Students struggled to identify edges, vertices, and faces, indicating limited spatial visualization ability. While these findings are consistent with Fathonah and Purnomo (2025), this study further shows that such difficulties are influenced not only by cognitive factors but also by the nature of instructional support.

When geometry learning relies heavily on verbal explanations and two-dimensional textbook images, students must mentally construct three-dimensional representations, often leading to conceptual ambiguity (Ardini et al., 2025). Further, Nahdi (2024) also noted limitations in textbook-based visualization, but this study highlights that the issue lies not only in representation quality, but also in how learning experiences are structured. From a cognitive load perspective, this condition increases extraneous load, as students process abstract information without sufficient visual support, thereby hindering schema construction.

Unlike prior studies that mainly attribute learning difficulties to students' abilities, this study highlights the interaction between learner characteristics and instructional media. The continued use of conventional media fosters teacher-centered instruction and low student engagement, indicating that poor outcomes also stem from suboptimal instructional design. Research consistently shows that conventional approaches are monotonous, textbook-reliant, and teacher-centered, which undermine student engagement (Dewi et al., 2025). Such approaches lead students to become passive recipients rather than active participants in learning (Sheerah, 2020; Vaghela & Parsana, 2024). This pattern persists even when educators recognize the value of student-centered methods, as many continue traditional practices despite their limitations (Nadelson et al., 2018; Pimdee et al., 2024). Barriers such as the persistence of transmission-oriented teaching further entrench ineffective design (Greenhow & Chapman, 2020), reinforcing that poor learning outcomes arise not only from learner factors but also from inadequate instructional media and design choices (Dewi et al., 2025; Pimdee et al., 2024).

This need is reinforced by students' average PTS score of 67.68, which is below the Minimum Mastery Criterion. Ribaah et al. (2020) associated low achievement with inappropriate strategies, while this study adds that the absence of integrated visual, digital, and problem-based elements limits meaningful learning.

Therefore, integrating Pop Up Books, QR Codes, and Problem Based Learning is not merely a technological addition, but a pedagogical restructuring. This approach supports visualization, multiple representations, and guided problem-solving, aligning with constructivist principles and helping manage cognitive load through structured, multimodal learning experiences.

4.2 Design of QR Code Assisted Pop Up Book Based on Problem Based Learning (PBL)

The design stage in this development research was carried out as a direct response to the needs analysis, particularly students' difficulties in visualizing spatial geometry and the limited use of interactive media. The design aimed to develop learning media that not only supports spatial visualization but also creates more active and meaningful learning experiences. Difficulties in understanding three-dimensional objects are widely recognized as a challenge in elementary geometry due to the developmental nature of spatial reasoning (Putri & Fitriyani, 2024). However, this study emphasizes that these difficulties are also influenced by how learning representations are designed and sequenced.

The Pop-Up Book was designed to present geometric shapes through three-dimensional structures that students can directly observe and manipulate. This aligns with research emphasizing the role of visual and manipulative media in strengthening conceptual understanding (Yulia & Lova, 2025). As interactive three-dimensional tools, pop-up books can visualize content in more engaging and cognitively accessible ways than conventional two-dimensional materials (A et al., 2023). However, this study argues that physical visualization alone is insufficient for deeper conceptual processing. From a multimedia learning perspective, effective understanding requires integrating multiple representations so learners can process information through both visual and verbal channels (Shirazi & Behzadan, 2015). This principle is grounded in the Cognitive Theory of Multimedia Learning (CTML), which posits that individuals process verbal and visual information through separate channels, and meaningful learning occurs when both are engaged simultaneously (Shirazi & Behzadan, 2015; Utami et al., 2024). Accordingly, combining illustrated content with verbal information supports deeper understanding than relying on text alone (Utami et al., 2024; Wu & Shah, 2004). Multiple representations also help students visualize conceptual relationships and select appropriate forms of representation across different stages of understanding (Wu & Shah, 2004).

To address this, QR Code technology was integrated to connect the Pop Up Book with digital resources. These QR Codes provide access to videos, animations, and interactive tasks that enrich the static visual content. While Satriana and Ardianti (2025) emphasized the benefits of combining printed and digital media, this study extends the idea by focusing on instructional alignment. The integration is designed to be structured and complementary, where digital content reinforces and elaborates the visual representations in the Pop Up Book, supporting progressive and meaningful learning.

4.3 Development and Expert Validation of QR Code Assisted Pop Up Book Based on Problem Based Learning (PBL)

The development phase of this study focused on refining the learning media through a systematic expert validation process to ensure its feasibility before classroom implementation. Expert validation assessed content accuracy, language clarity, and media design,

reflecting a comprehensive evaluation of both pedagogical and technical aspects. While such validation procedures are commonly applied in development research, this study emphasizes not only the level of validity but also how each component contributes to supporting meaningful learning processes.

In the material aspect, the validation results indicated that the spatial geometry content met the criteria of completeness, depth, and curriculum relevance. This finding is consistent with Ali et al. (2024), who highlighted the importance of aligning learning materials with students' cognitive development. However, this study extends that perspective by demonstrating that content accuracy alone does not guarantee effective learning. The validators' feedback revealed that the integration of visual representations and contextual problem-solving elements played a crucial role in supporting conceptual understanding. This suggests that learning media should not be evaluated solely based on correctness of content but also on how effectively the content is transformed into learnable representations.

From a cognitive perspective, this finding reflects the need to balance intrinsic and germane cognitive load. Cognitive Load Theory (CLT) defines intrinsic load as the inherent complexity of content and germane load as the effort devoted to schema construction and automation (Haghani et al., 2020; Jong, 2009). Even accurate content can overwhelm learners if poorly represented, as high intrinsic and extraneous loads limit working memory for meaningful learning (Noushad & Khurshid, 2019; Sithole, 2018).

In contrast, well-structured representations support schema construction by optimizing germane load, allowing learners to organize and chunk information effectively (Blissett et al., 2015; Gould et al., 2022). Germane load enhances learning by directing cognitive resources toward processing and building schemas (Noushad & Khurshid, 2019; Sithole, 2018). Therefore, this study emphasizes both content structure and representational design, recognizing that instruction must manage intrinsic load while promoting germane load to support effective schema formation (Haghani et al., 2020; Jong, 2009; London & Royse, 2023).

In the language aspect, the validation results indicated that the language used was generally clear and appropriate for elementary students, although improvements were suggested in sentence structure and conventions. While Merita and Yudiana (2024) emphasized the role of language as a bridge between information and understanding, this study refines that view by showing that language clarity becomes increasingly critical when learning media combine visual and digital elements. In such contexts, ambiguous instructions may disrupt students' cognitive processing and reduce the effectiveness of multimedia integration.

Regarding media design, the Pop Up Book was considered highly feasible in representing spatial geometry through three-dimensional structures. Although this finding aligns with Ali et al. (2024), the present study challenges the assumption that visual attractiveness alone leads to effective learning. Instead, the design must support a structured learning sequence that guides students from observation to analysis and problem-solving.

The integration of QR Codes was also positively evaluated, not merely as an additional feature but as part of an instructional system. Unlike previous studies that treat QR Codes as supplementary tools, this study positions them as integral components that extend learning beyond printed media and support deeper conceptual exploration.

Overall, the validation results indicate that the effectiveness of the developed media lies in the alignment between content, representation, language, and instructional structure rather than in any single component.

4.4 Implementation of QR Code Assisted Pop Up Book Learning Media in Elementary School Mathematics Learning

The implementation phase aimed to examine how the QR Code–assisted Pop Up Book learning media based on the Problem Based Learning (PBL) model functioned in actual classroom settings. This stage focused not only on measuring user acceptance but also on understanding how the integration of visual, digital, and pedagogical elements influenced students' learning experiences. Observations of classroom activities and responses from both students and teachers provided insights into how the developed media operated within authentic instructional contexts.

The results showed that students responded positively, demonstrating high enthusiasm when interacting with the three-dimensional visual structures in the Pop Up Book. This finding is similar to Manik et al. (2024), who reported that visual media can increase students' attention. However, this study goes beyond that conclusion by showing that engagement was not solely driven by visual attractiveness. Instead, students' active involvement emerged from the integration of visual representation with problem-based learning tasks. Students were not only observing shapes but were also required to interpret and apply their observations in solving contextual problems. This indicates that engagement is more effectively sustained when visual media are embedded within structured cognitive activities.

From a constructivist perspective, learning occurs through active interaction between learners and instructional tools (Gerjets & Hesse, 2004; Sulindra et al., 2024). Unlike studies emphasizing the motivational effects of visual media, these findings show that meaningful engagement depends on how activities are

designed to support knowledge construction rather than passive observation (Gerjets & Hesse, 2004; Wulandari & Fitrianawati, 2023).

Constructivist technologies function as cognitive tools that scaffold engagement, knowledge construction, and reflection, rather than merely delivering instruction (Sulindra et al., 2024; Thota, 2015). However, providing a well-designed environment alone does not ensure productive learning; task design and sequencing are critical in fostering active knowledge construction (Gerjets & Hesse, 2004; Siregar et al., 2024). This supports the view that learning is a constructive process in which students build internal representations through experience and meaningful interaction with their environment (Chuang, 2021; Siregar et al., 2024), rather than passively receiving information from instructional media (Gerjets & Hesse, 2004; Wulandari & Fitrianawati, 2023). Students also reported that the learning media was practical and easy to use, particularly in scanning QR Codes to access digital resources. While Suseno et al. (2020) emphasized usability as a key factor in technology-based learning, this study refines that argument by demonstrating that usability alone is insufficient. The effectiveness of QR Code integration depends on how digital resources are aligned with learning objectives. In this case, QR Codes were intentionally embedded to support conceptual exploration, reducing unnecessary cognitive load by providing targeted explanations.

Furthermore, students indicated that the combination of three-dimensional visuals and digital explanations improved clarity of spatial geometry concepts. Although Sari and Qonita (2024) highlighted the benefits of QR Code–based media, this study extends those findings by showing that conceptual clarity is maximized when digital resources complement, rather than duplicate, visual representations.

From the teachers' perspective, the media facilitated the implementation of PBL by providing structured guidance for discussion and problem-solving activities. This suggests that learning media can function not only as instructional aids but also as pedagogical tools that help organize meaningful learning processes.

4.5 Evaluation of QR Code Assisted Pop Up Book Learning Media

The evaluation phase aimed to measure the effectiveness of the QR Code–assisted Pop Up Book learning media through the analysis of students' learning outcomes using pretest and posttest comparisons and the normalized gain (N-Gain) index. The average pretest score of 40 indicates that students initially had limited understanding of spatial geometry concepts, particularly in identifying elements of three-dimensional shapes and interpreting spatial relationships. While this finding is consistent with Sakti (2023), who linked low achievement to conventional learning media, the present study provides a deeper explanation by highlighting how insufficient visual and instructional support contributes to ineffective cognitive processing.

After the implementation, the average posttest score increased significantly to 87, indicating substantial improvement in students' conceptual understanding. Although Sembiring and Sujarwo (2024) reported that innovative media can enhance learning outcomes, this study refines that conclusion by demonstrating that improvement is not merely the result of novelty. Instead, the effectiveness lies in the integration of visual representation, digital resources, and structured problem-based activities. From a constructivist perspective, this combination enables students to actively construct knowledge through interaction, exploration, and reflection rather than passive reception.

The N-Gain value of 0.79, categorized as high improvement, further confirms the effectiveness of the learning design. However, unlike previous studies such as Pratama and Prayito (2024), which primarily attribute learning gains to media innovation, this study emphasizes the role of instructional coherence. The alignment between media design and learning activities helps manage cognitive load by reducing unnecessary processing and directing attention toward meaningful problem-solving tasks. In this sense, the integration of QR Codes and Pop Up Book elements supports multimedia learning by providing complementary rather than redundant information.

Moreover, this study challenges the assumption that technology alone guarantees improved learning outcomes. While digital tools are often associated with increased engagement, the findings suggest that their impact depends on how they are embedded within pedagogical structures. The use of QR Codes in this study was not incidental but intentionally designed to extend and reinforce conceptual understanding.

Therefore, the observed improvement reflects the cumulative effect of a systematic design process based on the ADDIE model. Evaluation results in development research represent the effectiveness of the entire instructional design rather than isolated components. This study thus highlights the importance of integrating media, pedagogy, and cognitive principles to achieve meaningful learning outcomes.

4.6 Study Limitations

Although this study demonstrates that the QR Code–assisted Pop-Up Book based on the Problem-Based Learning (PBL) approach improves students' understanding of spatial geometry, several limitations should be considered to avoid overgeneralization and clarify its scope. First, the study involved one elementary school with two fifth-grade classes totaling

fifty-five students, limiting external validity. The findings are therefore context-specific and may be influenced by classroom dynamics, teacher facilitation, and student characteristics, rather than being universally applicable. Second, the short implementation period, focused on cubes and cuboids, captures only immediate learning gains and does not address long-term conceptual retention. Third, the integration of QR code technology depends on access to mobile devices and stable internet, which may not be equally available across schools, raising concerns about equity and scalability.

Additionally, the scope of content was limited to spatial geometry, specifically cubes and cuboids, so its effectiveness for other mathematical topics remains uncertain, particularly those requiring different representations or levels of abstraction. These limitations suggest that future research should involve larger and more diverse samples, longer implementation periods, and comparative designs to enhance generalizability. For educational practice, teachers are encouraged to adapt the integration of visual, digital, and problem-based elements to their specific contexts rather than directly replicating the media design.

5. Conclusion

This study highlights the successful development and implementation of a QR Code–assisted Pop Up Book grounded in the Problem Based Learning framework to enhance elementary students' understanding of spatial geometry, demonstrating strong feasibility, practicality, and instructional effectiveness. The key findings show that the learning media achieved high validity across material, language, and design aspects, confirming its feasibility for classroom use, while student responses reached an average of 98%, indicating excellent engagement, usability, and clarity. Most importantly, the media significantly improved students' conceptual understanding of spatial geometry, as reflected in the increase from an average pretest score of 40 to a posttest score of 87 and a high N-Gain value of 0.79, demonstrating substantial learning gains. These results underscore that the effectiveness of the media is driven not merely by visual or technological enhancement, but by the coherent integration of three-dimensional visualization, QR Code–linked digital resources, and structured problem-solving activities that actively engage students in knowledge construction.

The study's novelty lies in this systematic instructional alignment, which bridges physical and digital learning environments within a unified pedagogical design. The findings imply that well-designed multimodal learning media can reduce abstraction, enhance cognitive processing, and foster deeper conceptual understanding in mathematics. Future research is recommended to test this integrated approach in wider contexts, investigate its long-term impact on retention, and explore its application to other mathematical topics and more adaptive digital learning environments.

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