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# Design and Development of a Project-Based Learning Mathematics Teaching Module for Geometry in Second Grade of Elementary School Based on Expert Consensus

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**Abstract**
Project-based learning in mathematics education has demonstrated potential for enhancing student engagement and conceptual understanding. However, systematic validation of project-based learning instructional modules for elementary geometry remains limited, particularly within contemporary curriculum frameworks. This study addresses this gap by designing, developing, and validating a comprehensive project-based learning mathematics teaching module for elementary geometry instruction aligned with Indonesia's Merdeka Curriculum. Using design and development research methodology, the study integrates the Fuzzy Delphi method and Content Validity Index analysis for module validation. Fifteen subject matter experts participated in Fuzzy Delphi rounds to establish consensus on module components, while three mathematics education experts conducted content validation analysis. Results demonstrate robust expert consensus on problem-oriented learning scenarios, collaborative activities, and project-based assessment mechanisms. Content validation yielded high validity indices for most module components, with minor refinements recommended for specific elements. The study contributes methodologically by combining expert consensus with quantitative validation techniques, theoretically by providing an evidence-based framework for mathematics module development, and practically by delivering a validated geometry module for classroom implementation. Future research should evaluate the module's effectiveness through classroom implementation studies and explore adaptation for other mathematical domains.
**Keywords:** Project-Based Learning, Elementary Geometry, Fuzzy Delphi, Module Design, Mathematics

## Introduction
Mathematics education at the primary school level plays a crucial role in building the foundational cognitive and problem-solving skills that students will use throughout their lives. However, traditional approaches to teaching mathematics often emphasize rote learning and

procedural fluency, which can limit students' engagement and hinder their understanding of abstract concepts. Many students struggle to relate mathematical material to their everyday experiences, which can impede their grasp of basic mathematical principles (Tobias, 2018; Rahardjo, 2020).

To address these challenges, there is a growing need for more innovative and contextual learning approaches. One such approach gaining traction is Project-Based Learning (PjBL). PjBL emphasizes active student involvement in real-world projects, enabling students to apply their mathematical knowledge and skills in meaningful contexts. Through PjBL, students not only deepen their understanding of mathematical concepts but also develop essential skills in problem-solving, collaboration, and critical thinking (Bell, 2010; Thomas, 2000).

Research demonstrates that PjBL significantly enhances students' conceptual understanding and sustained engagement with mathematical content, particularly by contextualizing abstract concepts within real-world applications (Zhao, 2024). This pedagogical shift aligns with broader educational transformations toward student-centered, competency-based learning frameworks that prioritize deep understanding over procedural memorization.

The implementation of project-based learning in mathematics education has gained considerable momentum, with systematic evaluations revealing positive impacts across diverse educational contexts and student populations (Nguyen et al., 2024). However, this growing body of research has identified persistent challenges in developing validated instructional materials that effectively operationalize project-based learning principles while maintaining curricular alignment and pedagogical rigor.

Geometry presents unique pedagogical challenges that make it particularly suitable for project-based learning interventions. Elementary students often struggle with spatial visualization, abstract geometric relationships, and the transition from concrete manipulative experiences to formal mathematical reasoning. Traditional instructional approaches frequently fail to address these cognitive challenges, resulting in limited conceptual understanding and decreased mathematical confidence (Saragih & Napitupulu, 2015). Recent research has demonstrated project-based learning's effectiveness in addressing these specific geometric learning challenges. Katuuk & Tarusu, (2024) found that project-based learning models significantly enhanced technology-integrated geometry learning among elementary students, effectively bridging the gap between concrete experiences and abstract geometric concepts. Similarly, Tilari et al., (2024) documented significant achievement gains when students engaged with geometry through technology-enhanced project-based learning compared to conventional instructional methods. Furthermore, Wulandari et al., (2023) demonstrated that project-based learning enables students to articulate complex geometric relationships through multimodal presentations, suggesting enhanced conceptual understanding and communication skills.

Despite these promising findings, a critical examination of existing literature reveals significant methodological and practical limitations. Current research predominantly focuses on classroom implementation outcomes rather than the systematic development and validation of instructional modules. While studies confirm project-based learning's effectiveness across various mathematical domains (Asmi et al., 2022; Trio Putra Siregar, 2024; Uyangör, 2012), few provide rigorously validated instructional resources that practitioners can implement with confidence. The few existing module development studies typically employ limited validation procedures, often relying on informal expert reviews or basic feasibility assessments rather than systematic validation methodologies. This limitation is particularly problematic given the complexity of designing effective project-based learning experiences that balance authentic problem contexts, appropriate mathematical content, collaborative learning structures, and valid assessment mechanisms.

Moreover, the rapid implementation of competency-based curricula, such as Indonesia's Merdeka Curriculum, has created urgent demand for validated instructional materials that align with contemporary educational standards while maintaining pedagogical effectiveness. The absence of systematically validated project-based learning modules creates significant barriers for educators seeking to implement evidence-based practices within these evolving curricular frameworks.

This study addresses these critical gaps by developing a comprehensive project-based learning geometry module grounded in established learning theories and validated through rigorous expert consensus procedures. The theoretical framework integrates cognitive constructivism (Piaget, 1970), social constructivism (Vygotsky, 1978), spiral curriculum principles (Bruner, 1960), and geometric thinking development stages (Van Hiele, 1986) to create coherent learning progressions that support conceptual understanding and skill development. In addition, the ADDIE instructional design approach (Branch, 2010) and (Dick W., Carey L., 2015) (learning system design model) were used to ensure a systematic development process. The objectives of this study were (i) to determine the components of the Maths-PjBL module based on expert consensus and (ii) to build a content-validated module prototype.

The novelty of this research lies in the integration of the Fuzzy Delphi method with the Content Validity Index (CVI) to design a Project-Based Learning (PjBL)-based geometry module that combines both qualitative expert consensus and quantitative content validation. This dual-validation approach ensures that the module is not only pedagogically sound but also meets measurable validity standards, making it adaptable for replication across diverse educational contexts.

This study offers three key contributions to mathematics education research and practice. Methodologically, it introduces a novel approach to educational module development by integrating expert consensus and statistical validation, providing a replicable framework for future projects. Theoretically, it enhances our understanding of how expert consensus can inform evidence-based instructional design in project-based learning contexts. Practically, the study delivers a validated geometry module that is immediately applicable within the Independent Curriculum, offering a practical solution to the resource limitations in schools while supporting ongoing professional development for educators.

The research pursues two primary objectives: (1) to identify the essential components of a project-based learning mathematics module through systematic expert consensus procedures, and (2) to develop a content-validated prototype of the module ready for classroom implementation. These objectives not only address immediate practical needs but also contribute to the broader methodological knowledge on educational resource development and validation.

## Research Method

*Research Design*

This study employed a Design and Development research approach (Richey, R., Klein, 2007) structured in two sequential phases to systematically develop and validate a Mathematics Project-Based Learning (PjBL) Teaching Module. The research design was specifically chosen to address the dual objectives of creating an evidence-based educational resource and ensuring its content validity through rigorous expert evaluation. This methodological framework ensures rigorous development and validation of the Mathematics-PjBL Teaching Module through systematic expert consensus achievement and empirical content validity assessment.

*Phase I: Design and Development Stage*

The initial phase focused on module design based on comprehensive needs analysis data collected in Stage I of the broader research framework. This phase aimed to synthesize theoretical foundations with practical requirements identified through needs assessment, resulting in a preliminary module framework that addresses specific gaps in mathematics PjBL instruction.

*Phase II: Expert Validation Stage*

The validation phase employed two complementary methodologies: Fuzzy Delphi technique for achieving expert consensus on module components, and Content Validity Index (CVI) for systematic content validation.

The selection of Fuzzy Delphi technique was based on three compelling methodological advantages. First, this approach provides systematic integration of expert opinions while producing reliable decisions through the identification of key factors based on robust expert consensus (≥75%) (Alqahtani & Noman, 2024). Second, Fuzzy Delphi demonstrates superior capability in obtaining high-validity feedback on complex educational problems and associated instruments (Montes et al., 2023). Third, the technique possesses three distinctive properties essential for educational research: transparency in decision-making processes, controlled feedback mechanisms, and sophisticated group statistical analysis capabilities (Armstrong, 1999). The Fuzzy Delphi analytical process follows a systematic six-step procedure outlined in Table 1, each step designed to progressively refine expert input toward consensus achievement.

Table 1
*Analytical Steps in Fuzzy Delphi Technique*

| Steps | Objective | Methodological Rationale |
|---|---|---|
| **1. Expert Selection** | Appointment of 15 domain experts based on specialized expertise | Ensures data validity and reliability through expert qualification |
| **2. Linguistic Scale Selection** | Implementation of seven-point linguistic scale | Provides sufficient granularity for nuanced expert judgment |
| **3. Mean Value Calculation ($a_1$, $a_m$, $a_3$)** | Computation of triangular fuzzy numbers for each expert response | Captures uncertainty and variability in expert opinions |
| **4. Threshold Value Determination (d)** | Assessment of expert agreement degree through $d \leq 0.2$ criterion | Establishes consensus threshold exceeding 75% for item acceptance |
| **5. Fuzzy Evaluation Process** | Generation of triangular fuzzy numbers for defuzzification | Prepares quantified expert judgments for final analysis |
| **6. Defuzzification Process** | Ranking determination based on highest defuzzification values | Produces objective hierarchy of module components |

Note: adapted from Ridhuan (2021)

**Participant**

*Fuzzy Delphi Expert Panel*

The expert panel comprised 15 carefully selected participants representing diverse but complementary expertise in mathematics education: three university mathematics lecturers, one educational supervisor, one curriculum developer, and ten primary school teachers with minimum ten years of teaching experience. This composition was strategically designed to balance theoretical knowledge with practical classroom experience. The panel size aligns with established methodological guidelines recommending 10-20 experts when expertise homogeneity and competency levels are high (Yusoff et al., 2021). Research demonstrates that minimum 10 experts are required to achieve high opinion consistency, while the upper limit of 20 prevents unwieldy group dynamics that may compromise consensus quality.

*Content Validity Index (CVI) Expert Panel*

The content validation phase engaged three mathematics education experts, each possessing minimum ten years of combined academic and practical experience (Montes et al., 2023). While relatively small, this panel size meets methodological requirements established by Lynn (1986) for I-CVI calculations and reflects the specialized nature of geometry education expertise required for this study.

**Instruments and Data Analysis**

*Fuzzy Delphi Instrumentation*

The Fuzzy Delphi instrument consisted of a structured questionnaire employing a seven-point linguistic scale (1 = strongly disagree to 7 = strongly agree) to assess module components systematically. Questionnaire items were developed through rigorous synthesis of existing literature and identified needs in elementary geometry education.

Representative instrument items include:
- "The problem orientation component effectively facilitates student understanding of geometric concepts through authentic real-world experiences"
- "Collaborative learning activities within the module successfully develop students' mathematical communication competencies"

Data Analysis Protocol:
Data analysis followed established Fuzzy Delphi procedures to determine: (1) threshold values (d ≤ 0.2), (2) minimum consensus levels (≥75%), (3) fuzzy evaluation outcomes, and (4) defuzzification rankings for component prioritization (Alqahtani & Noman, 2024).

*Content Validity Index (CVI) Methodology*
Content validity assessment employed both Item-Content Validity Index (I-CVI) and Scale-Content Validity Index (S-CVI) calculations with minimum acceptance criteria of 0.8, consistent with established standards in educational and health research (Polit & Beck, 2006; Lynn, 1986; Almanasreh et al., 2019).

CVI Calculation Components:
1. I-CVI (Item-level Content Validity Index): Proportion of experts assigning scores of 3 or 4 (relevant/highly relevant) to individual items
2. S-CVI/Ave (Average Content Validity Index): Mean of all I-CVI values across instrument items
3. S-CVI/UA (Universal Agreement): Proportion of items achieving complete expert consensus

Table 2
*Example CVI Results*

| Item | Description | I-CVI | Status |
|---|---|---|---|
| **1** | Module enhances student learning motivation | 1.00 | Valid |
| **2** | Module promotes independent learning capabilities | 1.00 | Valid |
| **3** | Module supports metacognitive development strategies | 0.67 | Requires revision |

**Overall CVI Performance:**
- S-CVI/Ave = 0.92 (exceeds 0.8 threshold)
- S-CVI/UA = 0.75 (acceptable for preliminary validation)

Interpretation: Results indicate strong overall content validity with majority of items meeting acceptance criteria, while specific items requiring minor revisions were systematically identified for improvement.

**Research Results**
The integration of Project-Based Learning (PjBL) with expert validation through Fuzzy Delphi methodology for educational module development represents an emerging yet underexplored research domain. Current literature demonstrates convergent evidence supporting this methodological approach across diverse educational contexts. Shahira Amiruddin et al., (2025) successfully applied analogous methodology in developing children's

science modules for home-based learning, establishing the efficacy of Fuzzy Delphi technique in achieving robust consensus on module components. This foundational work validates the methodological framework employed in the current study.

Complementary research by Putra et al. (2025) demonstrates the pedagogical innovation potential of combining PjBL with ethnomathematics approaches in teacher education, revealing significant enhancement in pedagogical competence development. Furthermore, Fitrah et al. (2025) provide empirical evidence for the effectiveness of PjBL integration with flipped classroom methodologies in strengthening 21st-century computational thinking skills among students. The application of Fuzzy Delphi methodology in digital module development within higher education contexts, as demonstrated by Syahfutraa et al. (2024), further substantiates the methodological relevance and transferability of this approach to elementary education module development. These convergent findings establish a compelling theoretical and empirical foundation for the current study's methodological approach, positioning it within a growing body of evidence supporting innovative educational module development strategies.

**Fuzzy Delphi Analysis Results**

*Expert Consensus Achievement*

The Fuzzy Delphi analysis successfully achieved robust expert consensus across all seven module components without requiring additional validation rounds. All components satisfied both critical consensus criteria: (1) threshold values $d \leq 0.2$ for individual items, and (2) consensus percentages exceeding 75% across all evaluated items. This achievement indicates exceptional expert agreement quality and eliminates the need for iterative consensus-building rounds typically required in Fuzzy Delphi applications. Notably, all validated items demonstrated defuzzification values exceeding 0.8, indicating strong expert confidence in component relevance and appropriateness for the target educational context. This high-threshold achievement suggests both methodological rigor and substantial expert agreement on module design elements.

*Component-wise Analysis and Ranking*

The systematic ranking of module components based on defuzzification values reveals expert prioritization patterns that inform evidence-based module design decisions. Table 3 presents the comprehensive ranking analysis across seven critical module dimensions.

Table 3
*Expert Consensus Rankings by Module Component*

| Component | Priority Item | Threshold (d) | Consensus | Defuzzification | Rank |
|---|---|---|---|---|---|
| **Module Objectives** | Enhance students' 4K skills development | 0.163 | 93.33% | 0.849 | 1 |
| | Strengthen teachers' PjBL implementation capacity | 0.172 | 93.33% | 0.831 | 2 |
| | Deepen teachers' PjBL conceptual understanding | 0.145 | 93.33% | 0.829 | 3 |
| **Module Structure** | Assessment of students' initial competencies | 0.125 | 100% | 0.880 | 1 |
| | Integration of learning tools, materials, and media | 0.118 | 100% | 0.873 | 2 |
| | Clear module identity and framework | 0.143 | 100% | 0.869 | 3 |
| **Geometry Content** | Spatial relationships and object positioning | 0.102 | 100% | 0.884 | 1 |
| | Construction and decomposition of plane figures | 0.125 | 100% | 0.880 | 2 |
| | Recognition of diverse geometric shapes | 0.118 | 100% | 0.873 | 3 |
| **PjBL Strategies** | Student interest exploration and engagement | 0.118 | 100% | 0.873 | 1 |
| | Comprehensive project assessment rubrics | 0.111 | 100% | 0.867 | 2 |
| | Effective questioning techniques | 0.111 | 100% | 0.867 | 3 |
| **Learning Resources** | Accessible tools and materials | 0.136 | 100% | 0.862 | 1 |
| | Visual learning supports (images) | 0.160 | 100% | 0.858 | 2 |
| | Interactive gaming elements | 0.175 | 100% | 0.847 | 3 |
| **21st Century Skills** | Listening and reading comprehension | 0.084 | 100% | 0.871 | 1 |
| | Collaborative planning and decision-making | 0.147 | 100% | 0.844 | 2 |
| | Active group contribution | 0.147 | 100% | 0.844 | 3 |
| **Assessment Methods** | Oral presentation capabilities | 0.094 | 93.33% | 0.909 | 1 |
| | Systematic observation techniques | 0.112 | 86.67% | 0.904 | 2 |
| | Prototype and product evaluation | 0.136 | 100% | 0.862 | 3 |

The analysis reveals several significant patterns in expert prioritization:

1. Assessment-Focused Approach: Oral presentation assessment achieved the highest overall defuzzification value (0.909), indicating expert recognition of communication skills as paramount in PjBL contexts.

2. Spatial Reasoning Emphasis: Within geometry content, spatial relationships and object positioning received highest priority (0.884), aligning with developmental mathematics learning progressions.
3. Student-Centered Orientation: Consistent prioritization of student engagement elements (interest exploration, initial competency assessment) demonstrates expert alignment with learner-centered pedagogical principles.
4. Comprehensive Skill Development: The balanced representation across 4K skills (Critical thinking, Communication, Collaboration, Creativity) reflects contemporary educational priorities.

*Module Development Process*

Following expert consensus achievement, module development proceeded through systematic application of the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional design model. Figure 1 illustrates the adapted ADDIE framework specifically tailored for Mathematics-PjBL module development. The adaptation incorporates iterative feedback loops between development phases and integrates expert validation outcomes directly into design decisions, ensuring evidence-based development throughout the process.

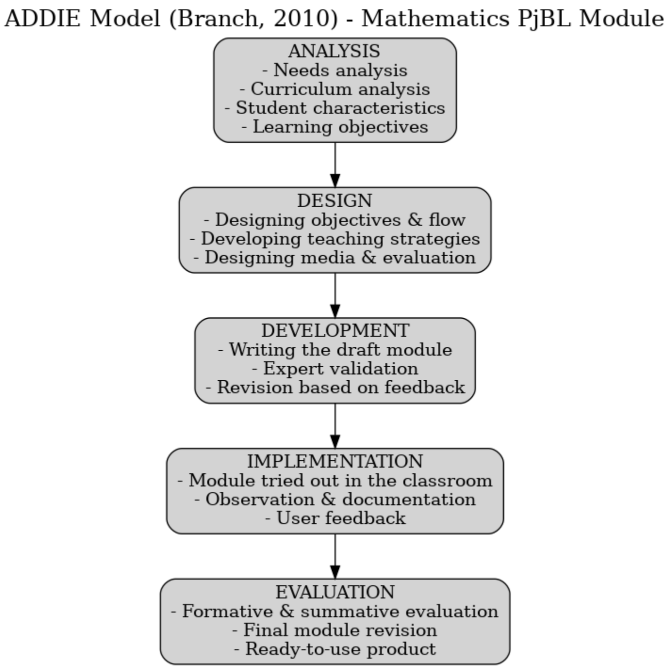


Figure 1: Adapted ADDIE Model for Mathematics-PjBL Module Development

*Content Validity Index (CVI) Assessment Results*

Content validation by three qualified experts (university lecturers and Ministry of Education officials) demonstrated exceptional module validity across all assessed dimensions. The comprehensive evaluation yielded overall content validity percentages exceeding 70% and CVI values surpassing 0.83, substantially exceeding established validity thresholds for educational materials. Table 4 presents detailed CVI assessment results across eleven critical module dimensions, revealing consistently high validity ratings.

Table 4
*Comprehensive CVI Assessment Results*

| Assessment Dimension | Validity Percentage | Validity Category | Critical Analysis |
|---|---|---|---|
| **Module Display** | 97.22% | Excellent | Superior visual presentation and user interface design |
| **Learning Objectives** | 100% | Excellent | Complete alignment with educational standards and PjBL principles |
| **Learning Outcomes Alignment** | 90.63% | High | Strong coherence between objectives and anticipated outcomes |
| **Content Accuracy** | 89.58% | High | Robust mathematical content with age-appropriate complexity |
| **Information Presentation** | 88.89% | High | Clear, systematic information delivery structure |
| **Instructional Design** | 93.75% | High | Effective pedagogical framework implementation |
| **Attractiveness and Aesthetics** | 100% | Excellent | Optimal visual appeal for target demographic |
| **Equality of Access** | 87.50% | High | Inclusive design accommodating diverse learning needs |
| **Affective & Metacognitive Elements** | 80.56% | High | Adequate emotional engagement and self-reflection components |
| **PjBL Methodology Relevance** | 95.24% | High | Strong alignment with project-based learning principles |
| **Learning Assessment** | 93.75% | High | Comprehensive evaluation strategy integration |

The CVI assessment reveals several noteworthy quality indicators:
1. Exceptional Design Standards: Perfect validity scores (100%) in learning objectives and aesthetic attractiveness demonstrate superior educational design quality.
2. Strong Pedagogical Alignment: The high PjBL methodology relevance score (95.24%) confirms successful integration of project-based learning principles throughout the module.
3. Comprehensive Assessment Strategy: The robust learning assessment validity (93.75%) indicates effective evaluation framework implementation.
4. Areas for Enhancement: While all dimensions achieved acceptable validity levels, affective and metacognitive elements (80.56%) represent the primary area for continued development focus.

The convergent evidence from both Fuzzy Delphi consensus achievement and CVI validation establishes strong empirical support for the developed Mathematics-PjBL Teaching Module. The systematic expert agreement across all module components, combined with exceptional content validity performance, demonstrates successful methodological integration and validates the module's readiness for implementation in late Phase A (Grade 2) geometry instruction. These results collectively indicate that the developed module successfully addresses identified educational needs while maintaining high standards of academic rigor and pedagogical effectiveness, positioning it as a valuable contribution to elementary mathematics education resources.

**Discussion**

The results showed that all components of the Mathematics-PjBL module for the topic of geometry Phase A elementary school have met the criteria of expert consensus with a percentage above 75%, threshold value (d) ≤ 0.2, and defuzzification score > 0.8. This finding confirms that the module development process through the Fuzzy Delphi method resulted in high agreement among experts, in line with the findings of Montes et al., (2023) who emphasised the effectiveness of this method in collaboratively screening and validating instructional components. From an HRM perspective, this consensus-building approach demonstrates the importance of leveraging collective expertise in educational resource development, reflecting best practices in knowledge management and collaborative decision-making within educational institutions.

In the module objectives component, the item 'improving students' 4K skills' (critical thinking, creativity, collaboration, communication) obtained the highest score. This indicates that learning geometry through PjBL is considered capable of integrating 21st century skills, as evidenced by Rehman et al., (2024) who found that the application of mathematics PjBL to primary school students significantly promoted the development of 21st century skills in primary school students in the context of mathematics learning more effectively than traditional methods. This emphasis on 21st century skills has significant implications for teacher competency frameworks and professional development programs. Educational HRM systems must align teacher training initiatives with these competency requirements to ensure effective module implementation and sustainable pedagogical transformation.

The module structure component showed full agreement (100%) on the indicators of 'students' initial competence' and 'learning tools, materials, media'. This agreement shows that the designed module should consider prerequisite knowledge and availability of resources to ensure effective implementation of PjBL. The emphasis on students' initial readiness is in line with the research results of Ndiung & Menggo (2024) which confirmed that the success of PjBL in improving mathematical problem solving ability is strongly influenced by learners' prior knowledge. This finding underscores the need for systematic teacher training on diagnostic assessment and differentiated instruction, representing critical areas for human resource development in educational settings.

The results of the study show that the oral presentation aspect received the highest score in the module validation. This finding indicates that experts consider mathematical communication skills through oral presentations to be an important component in PjBL-based geometry learning. A critical analysis of these findings shows that presentation skills are in line with 21st century skills that emphasize communication, collaboration, creativity, and critical thinking. In the context of the Merdeka Curriculum, oral presentations are also considered relevant because they provide space for students to communicate ideas, explain solutions, and build academic confidence (Kemendikbudristek, 2022). The prioritization of oral presentation skills necessitates targeted professional development programs to enhance teachers' facilitation capabilities and assessment competencies in this domain, representing a strategic HRM investment in pedagogical capacity building.

Conversely, metacognitive and affective elements received lower scores. This can be explained because, compared to cognitive and performative skills, the assessment of these elements tends to be more subjective and difficult to measure consistently. Experts say that teachers need more detailed guidelines on how to incorporate affective and metacognitive indicators into modules so that student learning outcomes can be assessed more comprehensively. This identified gap highlights the critical role of continuous professional development and mentoring programs in building teacher expertise in complex assessment domains. Educational HRM frameworks must prioritize the development of advanced assessment literacy as a core competency for effective PjBL implementation. Therefore, more relevant affective and metacognitive assessment rubrics will improve these modules.

The content validation process (CVI) by three mathematics education experts resulted in scores of 80-100% on all aspects, indicating a high level of content suitability. I-CVI and S-CVI values ≥ 0.8 on all indicators indicate that the module has strong content validity, in line with Almanasreh et al. (2019) recommendation that a threshold of ≥ 0.8 is important to ensure the quality of educational instruments. The strength of this approach also lies in the integration of constructivist learning theory (Piaget, 1970; Vygotsky, 1978; Bruner, 1960) with the ADDIE and Dick & Carey instructional design frameworks. Such integration ensures that the module is not only content valid, but also pedagogically and systematically relevant. This is supported by Himmi et al.(2025) which found that PjBL in mathematics education becomes more effective when supported by a structured instructional design. The successful integration of multiple theoretical frameworks demonstrates the importance of evidence-based curriculum development, requiring teachers with strong theoretical grounding and practical implementation skills, competencies that must be systematically developed through comprehensive HRM strategies.

From an implementation perspective, the main challenges in applying this module in Indonesia lie in teacher readiness, limited resources, and administrative workload. Many teachers are still adapting to the Merdeka Curriculum paradigm, which demands a high degree of flexibility, while professional training on the design and application of PjBL-based modules has not been evenly distributed. These challenges represent critical HRM priorities: developing adaptive teaching competencies, establishing equitable professional development access, and creating supportive organizational cultures that facilitate pedagogical innovation. In addition, limited learning media and high teacher-student ratios have the potential to hamper the effectiveness of implementation. From an HRM standpoint, addressing these constraints requires strategic workforce planning, resource allocation optimization, and the development of collaborative teaching models that maximize human capital utilization.

The successful implementation of this module necessitates a comprehensive teacher development framework encompassing: (1) initial competency assessment and gap analysis, (2) structured professional learning communities for peer support and knowledge sharing, (3) ongoing mentoring and coaching programs, and (4) performance evaluation systems aligned with PjBL pedagogical approaches. These elements represent fundamental HRM functions that must be strategically coordinated to ensure sustainable educational transformation. Therefore, institutional support in the form of training, provision of resources, and policies that support the reduction of teachers' administrative burdens are crucial to ensure the success of this module.

Furthermore, this module has the potential to be adapted to an international context, particularly in countries that implement competency-based curricula and emphasize 21st-century skills. For example, ASEAN countries with relatively similar socio-cultural backgrounds could be relevant testing grounds. However, such adaptation requires content adjustments in line with cultural contexts, levels of mathematical literacy, and local education policies. From an HRM perspective, successful international adaptation would require cross-cultural competency development, collaborative professional networks, and adaptive change management strategies that respect local contexts while maintaining pedagogical effectiveness.

Overall, the results of this study reinforce recent literature that the development of scientifically validated PjBL-based modules is able to address 21st century learning needs, particularly in improving students' cognitive and collaborative skills. This finding is in line with the meta-analysis by Kwon et al., (2025) who reported that PjBL in STEM education has a great effect on students' creativity. The integration of HRM principles throughout this study demonstrates that successful educational innovation requires not only sound pedagogical design but also strategic human resource development that aligns teacher competencies with curricular demands.

Thus, this study not only confirms the relevance of PjBL in geometry learning, but also provides critical insights into the challenges of implementation and opportunities for global adaptation. These findings emphasize the importance of synergy between module development, teacher capacity building, and policy support in establishing sustainable learning practices. The HRM implications extend beyond individual teacher development to encompass organizational learning, knowledge management, and strategic workforce planning elements essential for creating educational environments that support continuous pedagogical innovation and student success.

**Conclusions**

This study successfully designed and validated a Mathematics-PjBL Module for Phase A geometry topics, meeting expert consensus and content validity standards. The use of Fuzzy Delphi and Content Validity Index (CVI) confirmed the module’s pedagogical relevance and accuracy in aligning with learning outcomes. All key indicators achieved consensus scores ≥ 75%, with threshold (d) ≤ 0.2, defuzzification > 0.8, and I-CVI and S-CVI ≥ 0.8, indicating the module’s feasibility for implementation.

The module integrates 21st-century skills, including critical thinking, creativity, collaboration, and communication, within contextualized geometry learning. It combines constructivist frameworks (Piaget, Vygotsky, Bruner, Van Hiele) with ADDIE and Dick & Carey models, ensuring both theoretical and practical integration in the classroom. As a result, the Mathematics-PjBL module is recommended for widespread use in primary schools and can serve as a model for other subjects seeking to integrate PjBL.

However, the study has limitations, including the small number of experts (three) in content validation, potential expert bias, and the lack of real classroom testing. Future research should involve classroom trials to assess effectiveness, expand the module to other subjects, and explore its international applicability in competency-based curricula. These steps will contribute to improving mathematics education in Indonesia and enrich global literature on PjBL-based instructional design.

**Research Implications**

The findings of this study carry significant implications for human resource development in education, particularly in the enhancement of teacher professionalism. From the perspective of teacher professional development, the validated Project-Based Learning (PjBL)-based geometry module serves as an effective tool for improving teachers' pedagogical skills while simultaneously fostering key 21st-century competencies, such as communication, collaboration, creativity, and problem-solving. By integrating these competencies into the teaching process, the module contributes to the continuous capacity building of educators, ensuring their preparedness to meet evolving educational demands.

From an educational human resource management standpoint, this study underscores the critical role of institutional support in the implementation of PjBL-based modules and associated training programs. Such support is essential for the long-term development of teacher competencies, facilitating improved teacher retention and job satisfaction. By incorporating these modules into teacher education programs (PPG), professional development courses, and continuous professional development (CPD) initiatives, educational institutions can not only enhance teaching quality but also create a supportive environment for teachers' professional growth.

Furthermore, from a policy perspective, this study aligns with the goals of Indonesia's Merdeka Curriculum, which emphasizes flexibility, differentiation, and project-based learning approaches. The validated PjBL-based module can be used as an official reference in the development of teaching materials that comply with national educational policies. Its successful implementation within the current curriculum can also serve as a model for broader educational reforms, providing a scalable framework that can be adapted across various subjects and educational contexts, fostering a more adaptive and context-sensitive learning ecosystem.

In conclusion, this research not only contributes to advancing academic methodologies in the design of educational modules but also provides actionable insights that support the strengthening of human resource management in education. By focusing on teacher development, capacity building, and policy alignment, the findings offer a pathway for sustainable improvements in educational quality and the professionalization of teaching.

**References**

Almanasreh, E., Moles, R., & Chen, T. F. (2019). Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy*, *15*(2), 214–221. https://doi.org/10.1016/j.sapharm.2018.03.066

Alqahtani, F. M., & Noman, M. A. (2024). An Integrated Fuzzy Delphi and Fuzzy AHP Model for Evaluating Factors Affecting Human Errors in Manual Assembly Processes. *Systems*, *12*(11). https://doi.org/10.3390/systems12110479

Asmi, A. W., Rahmat, F., & Adnan, M. (2022). *The Effect of Project-Based Learning on Students' Mathematics Learning in Indonesia: A Systematic Literature Review*. *5*(4), 311–333. https://doi.org/10.5281/zenodo.7106324

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39-43. https://doi.org/10.1080/00098650903505415

Branch, R. M. (2010). Instructional design: The ADDIE approach. In *Instructional Design: The ADDIE Approach*. Springer US. https://doi.org/10.1007/978-0-387-09506-6

Dick, W., Carey L., J. O. C. (2015). *The systematic design of instruction* (eighth). Pearson.

Fitrah, M., Sofroniou, A., Setiawan, C., Widihastuti, W., Yarmanetti, N., Jaya, M. P. S., Panuntun, J. G., Arfaton, A., Beteno, S., & Susianti, I. (2025). The Impact of Integrated Project-Based Learning and Flipped Classroom on Students' Computational Thinking Skills: Embedded Mixed Methods. *Education Sciences*, *15*(4). https://doi.org/10.3390/educsci15040448

Himmi, N., Armanto, D., & Amry, Z. (2025). A Implementation of Project Based Learning (PjBL) in Mathematics Education: A Systematic Analysis of International Practices and Theoretical Foundations. *Science Insights Education Frontiers*, *26*(2), 4305–4321. https://doi.org/10.15354/SIEF.25.OR699

Katuuk, D. A., & Tarusu, D. T. (2024). Effectiveness of Geometry Learning Based on PPG Daljab Student Technology through the Project-Based Learning Model in Elementary School Students. *International Journal of Information Technology and Education*, *3*(2), 122–130. https://doi.org/10.62711/ijite.v3i2.182

Kemendikbudristek. (2022). *Panduan Pembelajaran dan Asesmen*.

Kwon, H., Lee, Y., Kwon, H., & Lee, Y. (2025). A meta-analysis of STEM project-based learning on creativity. *STEM Education 2025 2:275*, *5*(2), 275–290. https://doi.org/10.3934/STEME.2025014

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research*, *35*(6), 382–385. https://doi.org/10.1097/00006199-198611000-00017

Montes, R., Zuheros, C., Morales, J., Zermeño, N., Duran, J., & Herrera, F. (2023). Design and consensus content validity of the questionnaire for b-learning education: A 2-Tuple Fuzzy Linguistic Delphi based Decision Support Tool. *Applied Soft Computing*, *147*, 110755. https://doi.org/10.1016/j.asoc.2023.110755

Ndiung, S., & Menggo, S. (2024). Project-Based Learning in Fostering Creative Thinking and Mathematical Problem-Solving Skills: Evidence from Primary Education in Indonesia. *International Journal of Learning, Teaching and Educational Research*, *23*(8), 289–308. https://doi.org/10.26803/IJLTER.23.8.15

Nguyen, H. T. M., Nguyen, G. T. C., Thai, L. T. H., Truong, D. T., & Nguyen, B. N. (2024). Teaching Mathematics Through Project-Based Learning in K-12 Schools: A Systematic Review of Current Practices, Barriers, and Future Developments. *TEM Journal*, *13*(3), 2054–2064. https://doi.org/10.18421/TEM133-33

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? critique and recommendations. *Research in Nursing & Health*, *29*(5), 489–497. https://doi.org/10.1002/nur.20147

Putra, Z. H., Hermita, N., Alim, J. A., Dahnilsyah, D., & Gunawan, Y. (2025). The role of project-based ethno-didactics of mathematics learning toward pre-service elementary teachers' perspectives, mathematical, and didactic knowledge. *Frontiers in Education*, *10*, 1568366. https://doi.org/10.3389/FEDUC.2025.1568366/BIBTEX

Rahardjo, B. S. (2020). *Pendekatan konstruktivisme dalam pendidikan matematika*. Jakarta: Penerbit Grafindo.

Rehman, N., Huang, X., Batool, S., Andleeb, I., & Mahmood, A. (2024). Assessing the Effectiveness of Project-Based Learning: A Comprehensive Meta-Analysis of Student Achievement between 2010 and 2023. *ASR: Chiang Mai University Journal of Social Sciences and Humanities*, *11*(2). https://doi.org/10.12982/CMUJASR.2024.015

Richey, R., Klein, J. (2007). *Design and Development Research*. Routledge.

Ridhuan, M. N. R. (2021). *Kepelbagaian Metodologi dalam Penyelidikan Reka Bentuk dan Pembangunan* (ketiga). Qaisar Prestige Resources: Selangor D E.

Saragih, S., & Napitupulu, E. (2015). Developing Student-Centered Learning Model to Improve High Order Mathematical Thinking Ability. *International Education Studies*, *8*(6), p104. https://doi.org/10.5539/IES.V8N6P104

Shahira Amiruddin, N., Omar, R., Nabila, U., Tazli, A., & Abdullah, N. (2025). Fuzzy Delphi method for project approach module in early science for children. *Journal of Education and Learning (EduLearn)*, *19*(4), 2166–2174. https://doi.org/10.11591/EDULEARN.V19I4.22652

Syahfutraa, W., Ab Aziz Wan Daud, W., & Hafezah, N. (2024). Application of Fuzzy Delphi Method in the Design of Reading Digital Modul for University Students in Riau. *Arab World English Journal*, *15*(3), 67–88. https://doi.org/10.24093/AWEJ/VOL15NO3.5

Thomas, J. W. (2000). A review of research on project-based learning. *Autodesk Foundation*

Tilari, A. G., Firmansyah, F. A., & Cipta, E. S. (2024). Pengaruh model project-based learning berbantuan geogebra terhadap hasil belajar matematika materi bangun ruang sisi datar di madrasah ibtidaiyah. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *7*(2), 385–396. https://doi.org/10.22460/jpmi.v7i2.18105

Trio Putra Siregar. (2024). The Effect of Project-Based Learning Method on Understanding Geometry Concepts in Secondary School Students. *Attractive : Innovative Education Journal*, *6*(3), 302–310. https://doi.org/10.51278/AJ.V6I3.1545

Uyangör, S. M. (2012). The Effect of Project-Based Learning on Teaching of Polygon and Plane Geometry Unit. *The New Educational Review*, *29*(3), 212–223. https://doi.org/10.15804/TNER.12.29.3.18

Wulandari, Y. O., Yuniarto, E., & Octavianti, C. T. (2023). Project-Based Learning in Analytic Geometry Courses to Support Student's Mathematic Communication Skill. *Tarbiyah : Jurnal Ilmiah Kependidikan*, *12*(2), 89–97. https://doi.org/10.18592/tarbiyah.v12i2.9784

Yusoff, A. F. M., Hashim, A., Muhamad, N., & Hamat, W. N. W. (2021). Application of Fuzzy Delphi Technique to Identify the Elements for Designing and Developing the e-PBM PI-Poli Module. *Asian Journal of University Education*, *17*(1), 292–304. https://doi.org/10.24191/ajue.v17i1.12625

Zhao, Z. (2024). *Research on Teaching Strategies for Project-Based Learning in Upper Elementary School Mathematics Culture*. *1*(4), 1–7.