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Discovery-Project-Evaluation-STEM model: A promising learning model for Bima local cultural character

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Abstract

An effective learning model that actively involves students in the learning process is essential. This development research aims to identify the factors responsible for the observed low problem-solving ability in geometry and to develop a model that effectively enhances these skills. The research process begins with the creation of flow diagrams using the ADDIE model, encompassing the analysis, design, development, implementation, and evaluation phases. The study focuses on junior high school students. The research findings, which consider the unique cultural characteristics of the Bima people, suggest that the Discovery-Project-Evaluation (DPjE) learning model, incorporating STEM elements, can be an effective alternative or complement to traditional teaching methods. Six experts confirmed that the geometric problem-solving skills test instrument outperformed other learning tools. Data from limited trials indicate that using lesson plans and worksheets, along with positive feedback from educators and students, supports the effectiveness of the developed learning materials. This demonstrates the practical application of the DPjE model, with STEM elements based on Bima Local Cultural Character (BLCC), in teaching mathematics. The BLCC-based DPjE-STEM model assesses the learning process's efficiency using data from initial and final tests.

Keywords: geometry, local culture, problem solving, STEM

Introduction

The necessity for research on mathematical problem-solving abilities is critical (Björn et al., 2016; Maf'ulah & Juniati, 2020). A primary aim of mathematics education, particularly in geometry, is to develop students' proficiency in problem-solving techniques, approaches, and strategies. Therefore, cultivating problem-solving skills is essential in mathematics learning. Ke & Clark (2020) and Yu et al. (2015) suggest that enhancing students' problem-solving abilities, especially in geometry, can improve the quality of education in Indonesia. Given that students gather and process information in diverse ways, their problem-solving skills will inevitably vary (Susanti, 2020). These variations in problem-solving approaches are attributable to the different cognitive levels among students (Khoiriyah, 2013). It means that this research highlights the urgent need to develop students' problem-solving skills in geometry, emphasizing that individual differences in cognitive processing influence problem-solving abilities and thereby affect the overall quality of mathematics education in Indonesia.

Problem-solving is a crucial skill for students learning mathematics (Amalia et al., 2017). It involves identifying a solution to achieve a goal that is not immediately attainable. Engaging in problem-solving allows students to actively participate in addressing issues by independently researching, acquiring, and processing information into concepts, principles, or conclusions. This process highlights the essential role of problem-solving in mathematics education.

Astari et al. (2018) define the discovery learning model as an innovative environment that encourages students to actively seek knowledge independently to enhance learning outcomes. This concept emphasizes experimentation and observation, where students manipulate variables and parameters to observe their effects within the domain (Saab et al., 2005). Teachers support students in responding to various questions and solving problems to uncover concepts, with students acquiring part or all the knowledge independently (Nahdi, 2018). Additionally, students actively contribute to developing their foundational knowledge by independently testing hypotheses (Bailin et al., 2018).

Through this learning paradigm, students gain firsthand experience, making the learning process more relevant (Gunawan et al., 2021). In discovery learning, both students and teachers act as guides (Simamora & Saragih, 2019). This approach fosters a dynamic learning environment where students' active participation and independence are integral to their educational experience, promoting deeper engagement and understanding.

Amini et al. (2019) describe the Project-Based Learning (PjBL) model as a learning paradigm focused on long-term projects aimed at producing tangible products. In the PjBL approach, students design, build, and showcase products developed to address real-life issues. Implementing this paradigm begins with defining significant questions that lead to students' project work (Ismuwardani et al., 2019). Project-Based Learning is learner-centered, emphasizing the fundamental ideas and concepts of a field while promoting inquiry, problem-solving, and the creation of tangible products (Santyasa, 2006).

The PjBL model encourages students to collaborate, apply prior knowledge, and understand new concepts (Ummah et al., 2019). By presenting reports or projects they have created, students are motivated to solve real-life problems, develop scientific skills, and improve academic performance (Smale-Jacobse et al., 2019). Project-Based Learning allows students to explore science topics in depth and develop life skills simultaneously (Sucilestari & Arizona, 2018). This approach fosters a comprehensive educational experience that integrates practical application with theoretical understanding.

Evaluation is a critical component of the learning system, enabling teachers to assess students' learning progress (Arifin, 2009). The data gathered from these evaluations serve as feedback for teachers, helping them refine and enhance their lesson plans and instructional strategies. By systematically evaluating students, teachers can ensure that their teaching methods are effective and address the needs of all learners.

Furthermore, the evaluation process measures and assesses various learning abilities, such as knowledge, attitudes, and skills, providing a comprehensive understanding of students' capabilities (Wulan & Rusdiana, 2015). This thorough assessment allows teachers to identify areas where students excel and where they may need additional support, facilitating targeted interventions to improve overall learning outcomes.

STEM learning, integrating principles from science, mathematics, engineering, and technology, represents an interdisciplinary approach that connects academic concepts with real-world applications. This approach bridges educational institutions, communities, workplaces, and the global community, fostering an environment that promotes STEM literacy and prepares individuals to compete in the evolving economic landscape (Harper et al., 2019; Maass et al., 2019; Seage & Türegün, 2020).

Local cultural character, acquired or inherited, significantly influences the educational process, introducing new dimensions. Education, as a cultural mission, encompasses several critical processes: cultural inheritance, guiding individuals in making choices, teaching them to fulfill social roles, integrating diverse individual identities into broader cultural contexts, and fostering social innovation (Kesiman & Agustini, 2013; Kustyarini & Puspitasari, 2020; Pham & Renshaw, 2015). Indonesia's rich cultural diversity enhances educational endeavors, particularly in understanding the unique Bima cultural identity of specific regions. This diversity enriches educational practices by fostering a deeper appreciation of local cultural nuances and traditions.

The DPjE-STEM learning model, known as Discovery-Project-Evaluation in STEM education, was specifically developed to harness the unique cultural characteristics of the Bima Local Cultural Character (BLCC), aiming for distinctiveness (Changtong et al., 2020; Li et al., 2019). Within this model, BLCC functions to integrate mathematical concepts within the cultural context of Bima. This local cultural framework seeks to maintain communal identity through entrenched attitudes and daily practices. Concerning the acquisition of mathematical knowledge, a student's mathematical identity denotes what they retain or endeavor to attain.

Interest, recognition, competence, and performance constitute the foundational components of a mathematical identity (Dou & Cian, 2022; Verdín et al., 2018). Interest encompasses students' feelings of enjoyment, fascination, and practical relevance in engaging with geometric concepts. Both educators and students recognize themselves as learners capable of grasping geometric content. Competence reflects students' confidence in their ability to understand and consistently engage with geometric materials. Performance denotes the measurable outcomes of students' abilities in assessments or problem-solving tasks related to geometric reasoning.

Methods

Research and development (R&D) utilizing the ADDIE model, pioneered at Flora State University, served as the research methodology employed in crafting the BLCC-based DPjE-STEM learning model (Branch & Kopcha, 2014). Systematic and structured research procedures are essential for ensuring the orderly progression of the study. Designing a learning system through the ADDIE model involves several sequential processes and developmental stages. First is the analysis phase, where the focus is on assessing the necessity, feasibility, and requirements for model development, as well as conceptualizing teaching and learning activities. This stage also encompasses the comprehensive design of the BLCC-based DPjE-STEM learning model, including defining learning objectives, scenarios, educational tools, evaluation materials, and developmental strategies.

Following the design phase is the development stage, during which the model conceived in the previous phase is transformed into a tangible product ready for implementation. Product validation involves seeking expert evaluations on the developed model, while product revision aims to refine and enhance it based on feedback gathered during validation. The implementation phase then translates the developed learning model into real-world settings, specifically within classroom environments. Lastly, the evaluation phase measures the attainment of project objectives among target students, evaluates the model's effectiveness, and assesses stakeholders' interest in the product. This stage involves gathering feedback from potential users of the learning model, such as mathematics educators.

Several instruments were employed to gather data in this research. Validation sheets were utilized to assess the validity of the developed learning models and tools through expert evaluations. Questionnaire sheets were administered to gather feedback from both teachers and students regarding their experiences with the learning models and tools throughout the learning process. An observation sheet was used to collect data on the practical application of the BLCC-based DPjE-STEM learning model that was developed. Additionally, a test sheet comprising problem-solving questions was used in both initial and final assessments to measure students' problem-solving abilities.

Results and Discussion

The geometry problem-solving ability test administered is a written assessment comprising eight descriptive questions. It aims to evaluate students' proficiency in solving geometry problems, assessing five key indicators. Initial assessments of students' geometry problem-solving abilities were conducted prior to any interventions, using scores from the initial test. Following the implementation of the treatment, students' geometry problem-solving abilities were reassessed using scores from the final test to measure the effectiveness of the intervention.

The assessment instrument used in this study focuses on gauging students' capacity to apply geometric principles to solve practical problems. It includes questions designed to elicit responses that demonstrate a deep understanding of geometric concepts and their real-world applications. The assessment's structure ensures that it accurately measures not only students' theoretical knowledge of geometry but also their ability to apply this knowledge in problem-solving contexts.

Data collected from the initial and final geometry problem-solving tests provide insights into the effectiveness of the intervention employed in enhancing students' geometric problem-solving skills. By comparing scores before and after the treatment, researchers can assess the impact of the intervention on students' abilities to analyze geometric situations, devise solutions, and communicate their reasoning effectively. This structured approach to assessment ensures that findings are robust and applicable to improving teaching methods in geometry education.

The initial ability data utilized in this research comprises students' scores from the initial test administered before any treatment was provided. Conversely, the final ability data represents the outcomes from the students' final test following the completion of the treatment. Both sets of data from the initial and final tests are detailed in Table 1.

Table 1. Data on students' geometry problem-solving abilities

	Group A		Group B	
	Initial Test	**Final Test**	**Initial Test**	**Final Test**
The highest score	22.50	94.38	31.25	83.75
Lowest Value	11.25	51.88	7.50	68.75
Number of Students	25		27	

Table 1 presents the results of students' geometry problem-solving abilities, indicating that the highest score achieved on the initial test was 31.25, while on the final test it reached 94.38. Conversely, the lowest score recorded on the initial test was 7.50, whereas on the final test it improved to 51.88. For a detailed analysis of these results and students' overall performance in geometry problem-solving, please refer to the attached document.

The data in Table 1 provides a clear comparison of students' performance before and after the intervention, highlighting significant improvements in their ability to solve geometric problems. This analysis underscores the effectiveness of the educational approach employed, demonstrating measurable advancements in students' proficiency and understanding within the context of geometry education. For a comprehensive examination of the findings and their implications, the attached document offers a detailed exploration of the results and their significance in enhancing teaching strategies and educational outcomes in geometry.

The data from the initial and final tests assessing geometry problem-solving abilities were also utilized to compute the average scores for each test and to analyze improvements. Figure 1 illustrates the average scores of the initial and final tests.

Figure 1 displays the average geometry problem-solving ability of students before treatment, which was 17.13 initially and 17.43 subsequently, while after treatment, these averages increased to 77.73 and 76.41 respectively. This upward trend is also evident in the average N-gain scores.

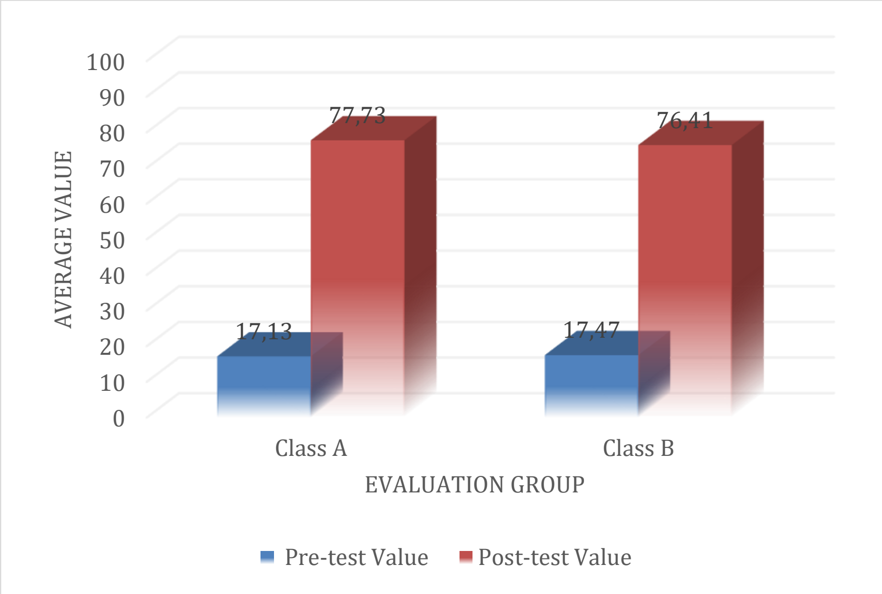

Figure 1. Average of the Preliminary Test and Final Test of Students' Geometry Problem Solving Ability

The average N-gain percentages are depicted in Figure 2, showcasing the improvement in students' geometry problem-solving abilities following the intervention. These figures provide a quantitative representation of the effectiveness of the treatment in enhancing students' skills and understanding in geometry.

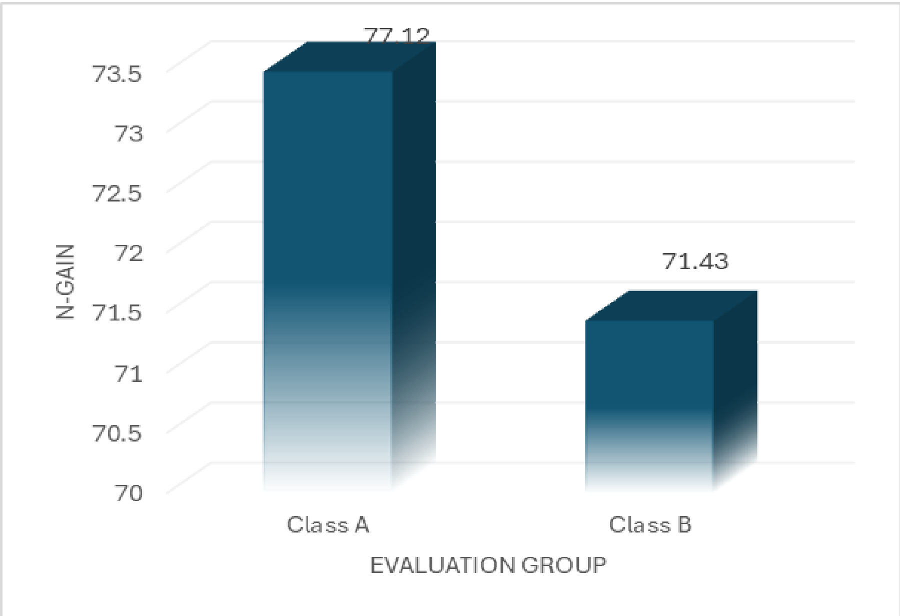

Figure 2. Average Percentage N-Gain of Students' Geometry Problem Solving Ability

Figure 2 illustrates that the average percentage improvement for class B-SMPN 14 Kota Bima is 73.123%, while for class A-SMPN it is 71.43%. The average increase in students' geometry problem-solving abilities across these two classes falls within the high category at 72.28%.

The data on geometry problem-solving abilities were further analyzed to ascertain the percentage contribution of each indicator. Through tabulation and calculation of test scores, the percentages for IPM-1 to IPM-5 indicators were determined for both classes, as presented in Table 2. This analysis provides a detailed breakdown of how students in classes B-SMPN 14 Kota Bima and A-SMPN have improved their geometry problem-solving abilities. By examining the distribution of scores across different indicators, this study identifies specific areas of strength and areas that may require further attention in future educational interventions.

Table 2. Average Preliminary Test Ability to Solve Geometry Problems for Each Indicator

	Average Value IPM (%)				
Class	**IPM-1**	**IPM-2**	**IPM-3**	**IPM-4**	**IPM-5**
Class A	23%	17%	17%	16%	13%
Class B	23%	15%	18%	18%	14%

Table 2 presents the average percentage of geometry problem-solving ability for each indicator. In the initial test, IPM-1 achieved an average percentage score of 23% for both classes A and B. IPM-2 obtained an average percentage score of 17% for class A and 15% for class B. For IPM-3, IPM-4, and IPM-5, the average percentage scores were 17% and 18%, 16% and 18%, 13%, and 14%, respectively, for the two classes. It also provides a detailed breakdown of students' performance across various aspects of geometry problem-solving. The percentages reflect the initial assessments of each indicator's contribution to overall problem-solving abilities in classes A and B. These findings highlight specific areas where students demonstrated strengths and areas that may require additional focus in future instructional strategies.

Analyzing the distribution of scores across IPM-1 to IPM-5 allows for a nuanced understanding of students' competency levels in different facets of geometry problem-solving. This data aids educators and researchers in identifying effective approaches to enhance specific skills necessary for proficient problem-solving in geometry.

Table 3. Final Test Average Geometry Problem Solving Ability for Each Indicator

	Average Value IPM (%)				
Class	**IPM-1**	**IPM-2**	**IPM-3**	**IPM-4**	**IPM-5**
Class A	93%	76%	88%	71%	65%
Class B	63%	57%	61%	58%	56%

Table 3 further illustrates that in the final test, IPM-1 obtained the highest percentage increase for both classes, while IPM-5 recorded the lowest improvement across both classes. The data from both tables indicate significant advancements in each indicator.

These findings underscore the effectiveness of the interventions implemented to enhance students' geometry problem-solving skills. By comparing initial and final test results across IPM-1 to IPM-5, educators can discern notable improvements in specific problem-solving abilities. Such detailed analysis provides valuable insights into the effectiveness of instructional strategies tailored to bolster students' proficiency in geometry.

The systematic examination of each indicator's progression offers educators and researchers a comprehensive view of how targeted interventions impact students' skill development in geometry. This data-driven approach not only validates the efficacy of educational methods but also informs future instructional practices aimed at fostering robust problem-solving capabilities among students.

In addition to analyzing the N-Gain test to quantify the improvement in students' problem-solving abilities, statistical tests were conducted. The chosen statistical method was a parametric paired sample t-test, employed to evaluate the efficacy of the treatment by examining differences in averages before and after its implementation. The outcomes of this paired sample t-test analysis, facilitated using SPSS, are detailed in Table 4.

The paired sample t-test serves as a robust tool in educational research, particularly in assessing the impact of interventions on student learning outcomes. It compares the mean scores of the same group of students before and after a treatment or educational intervention, providing statistical evidence of effectiveness. This methodological approach ensures rigor in evaluating the effectiveness of strategies aimed at enhancing students' problem-solving skills in geometry.

Table 4 presents the results derived from the application of the paired sample t-test, illustrating statistically significant changes in students' problem-solving abilities following the intervention. These findings not only validate the efficacy of the implemented educational interventions but also offer insights into the specific areas where students demonstrated measurable improvements. Such statistical analyses are essential for informing evidence-based decisions in educational practices and for further refining instructional strategies to optimize student learning outcomes.

Table 4. Paired Sample T-test Results

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pretest - Postest	-59.76	9.27	1.29	-62.34	-57.18	-46.51	51	.000

According to the "Paired Samples Test" output in Table 4, the significance value (2-tailed) is 0.000, which is less than 0.05. This indicates a statistically significant average difference in students' problem-solving abilities before and after receiving the BLCC-based DPjE-STEM model treatment. The BLCC-based DPjE-STEM learning model underwent validation and subsequent revision based on feedback from validators (draft 2), followed by limited trials to assess the practicality of the BLCC-based DPjE-STEM learning model (Susanto & Retnawati, 2016). A learning model is deemed practical when experts and practitioners affirm its potential for implementation in real-world settings, achieving a favorable level of execution (Dewi & Harahap, 2016; Rahawarin et al., 2020). Practical data in this study included observations of learning implementations, assessments of students' mathematical geometry problem-solving abilities, teacher questionnaires, and student surveys.

Validation and revision of the BLCC-based DPjE-STEM model involved iterative processes to refine its design and functionality, ensuring alignment with educational objectives and practical implementation criteria. This phase included feedback incorporation from validators to enhance the model's effectiveness and applicability in educational settings. The subsequent limited trials aimed to evaluate the model's feasibility and effectiveness in real-world classroom environments, focusing on practical aspects such as implementation logistics and educational outcomes.

Data collected during product testing encompassed diverse perspectives, including observations of instructional practices, evaluations of students' problem-solving capabilities in mathematical geometry, and feedback from educators and learners through structured questionnaires. These insights provided comprehensive feedback on the model's practicality and its potential impact on enhancing teaching and learning experiences in geometry education.

The BLCC-based DPjE-STEM model, revised based on implementation outcomes, underwent re-evaluation across different classes during the evaluation stage. The primary objective was to assess the effectiveness of the developed BLCC-based DPjE-STEM model. This evaluation involved 25 students from class VIII-B at SMPN 14 Bima City and 27 students from class VIII-A at SMPN, conducted over five sessions.

Product trials were conducted to gather data on the efficacy of the learning process using the BLCC-based DPjE-STEM model. Implementation of the BLCC-based DPjE-STEM model occurred in two classes, where the researchers conducted learning sessions using the model over three meetings per class.

The effectiveness data in this research pertains to students' geometry problem-solving abilities, derived from results of initial and final tests, and analyzed for improvements using N-Gain. The N-Gain test for students' geometry problem-solving abilities is categorized into three parts: overall N-Gain, N-Gain for each indicator, and N-Gain for each sub-material.

According to the N-Gain analysis, the average geometry problem-solving abilities of students before treatment were 17.13 and 17.43, while after treatment, they increased to 77.73 and 76.41, respectively. This improvement is also reflected in the average N-Gain scores, with class A showing an average percentage increase of 73.12% and class B showing 71.43%. Overall, the average increase in geometry problem-solving abilities across these classes falls within the high category at 72.28%.

The outcomes of the learning process revealed significant improvements in students' geometry problem-solving abilities, categorized as high due to the implementation of student-centered learning approaches and the integration of Bima's unique cultural aspects into group activities. Initially, students' performance on the geometry tests was low, reflecting their limited exposure to geometry concepts beyond basic spatial structures like squares and triangles, typically covered in elementary school (Sholihah & Afriansyah, 2017). Students' difficulties stem from several factors, including insufficient understanding of the concepts and properties of quadrilaterals, weak foundational knowledge of plane geometry, inadequate problem-solving skills for geometrical applications, and less-than-optimal classroom learning environments.

The findings underscore the impact of student-centered learning methodologies and culturally relevant pedagogical approaches in enhancing students' grasp of geometry. By integrating Bima's cultural elements into group activities, students were encouraged to actively engage in problem-solving tasks, fostering a deeper understanding of geometric concepts and their practical applications. Despite initial challenges linked to foundational knowledge gaps and conceptual misunderstandings, the structured application of culturally contextualized learning strategies proved instrumental in overcoming these barriers.

The study's results highlight the importance of tailored educational strategies that address both conceptual gaps and environmental factors affecting learning outcomes in geometry. By leveraging culturally embedded teaching practices and student-centered methodologies, educators can effectively enhance students' mathematical competencies while fostering a conducive learning environment conducive to their academic growth.

The significant increase in average final test scores among students is noteworthy, particularly in the context of two classes utilizing the BLCC-based DPjE-STEM model. This educational approach integrates STEM principles with local Bima cultural characteristics, encouraging students to construct their own knowledge, develop high-level inquiry skills, foster independence, and enhance self-confidence (Pramesti et al., 2022; Rofieq et al., 2019). Discovery-based learning combined with STEM not only facilitates problem-solving abilities but also promotes lifelong skills such as teamwork and effective communication.

Moreover, the improvement in students' ability to solve geometry problems can be attributed to the incorporation of concept visualization through local Bima region imagery. These visuals are integrated into each instructional material, facilitating a deeper understanding among students. Research indicates that visual memory tends to be more effective than verbal memory, underscoring the significance of imagery in educational contexts (Nolan et al., 2018). Visualization plays a crucial role in learning by providing concrete references, enhancing attention and emotional engagement, simplifying complex information, illustrating relationships through diagrams, and offering multimodal information channels to aid comprehension (Smaldino et al., 2008).

In summary, the implementation of the BLCC-based DPjE-STEM model, enriched with local cultural imagery, has significantly enhanced student learning outcomes. By fostering a conducive environment for inquiry and leveraging visualization techniques, this approach not only improves academic performance but also cultivates essential skills crucial for future success.

The analysis of geometry problem-solving abilities also includes specific indicators. Initial test results indicate that IPM-1 scored an average of 23% for both classes A and B. For IPM-2, the scores were 17% for class A and 15% for class B. In the second round of assessments (IPM-3, IPM-4, and IPM-5), the scores were 17%, 18%, 16% for class A and 18%, 13%, 14% for class B, respectively. In the final test, IPM-1 achieved the highest percentage score among all classes, while IPM-5 recorded the lowest score for both classes.

The analysis of geometry problem-solving abilities also examined data by sub-material to assess improvements. In Class A, the average initial test score ranged from 19.40 in the cube and beam sub-material to 12.20 in the pyramid sub-material. For the final test, scores ranged from 79.90 in the prism sub-material to 75.80 in the pyramid sub-material. The average N-gain score for each sub-material indicated improvements, with the prism sub-material showing the highest increase at 75.64% and the cube and beam sub-material showing the lowest increase at 72.21%.

In Class B, the average initial test score varied from 22.22 in the pyramid sub-material to 14.54 in the cube and beam sub-material. The final test scores ranged from 83.80 in the pyramid sub-material to 73.75 in the cube and beam sub-material. Similarly, the average N-gain scores demonstrated improvement across sub-materials, with the pyramid sub-material recording the highest increase at 79.17% and the prism sub-material showing the lowest increase at 68.56%.

Conclusion

The BLCC-based DPjE-STEM learning model demonstrates validity, practicality, and effectiveness in enhancing students' geometry problem-solving skills. This model integrates STEM principles with local cultural contexts, fostering a holistic understanding of mathematics that extends beyond theoretical knowledge to practical applications in everyday life. By promoting active engagement and inquiry-based learning, the BLCC-based DPjE-STEM model offers a promising approach to mathematics education, encouraging students to perceive mathematics as a dynamic and beneficial discipline.

Despite its strengths, the BLCC-based DPjE-STEM learning model may face several limitations. Implementing this model effectively requires substantial resources and specialized training for educators to integrate STEM and cultural elements seamlessly. Additionally, the applicability of this model across diverse educational settings and cultural contexts may vary, influencing its scalability and generalizability.

Further research is needed to assess long-term outcomes and sustainability, as well as to identify potential challenges in implementation, particularly in resource-constrained environments or where cultural adaptation is complex. It should explore several avenues to enhance the efficacy and applicability of the BLCC-based DPjE-STEM learning model. Investigating the impact of varying instructional strategies within this model could provide insights into optimizing student engagement and learning outcomes. Longitudinal studies are essential to assess the persistence of improved geometry problem-solving abilities over time and to uncover any differential effects among student subgroups. Moreover, comparative studies across different cultural and educational contexts can deepen our understanding of how cultural integration influences learning outcomes and teacher practices. Addressing these research gaps will contribute to refining the BLCC-based DPjE-STEM model's implementation and advancing mathematics education methodologies globally.

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Conflicts of Interest

No conflict of interest regarding the publication of this manuscript.

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