

Development of GeoGebra-Based PjBL Activities Containing Ethnomathematics in Spatial Geometry to Improve Mathematical Communication

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Abstract. The low mathematical communication skills of junior high school students, particularly in presenting mathematical ideas and arguments in writing, form the background of this study. As a solution, a Project-Based Learning (PjBL) activity that integrates ethnomathematics content and is assisted by GeoGebra software was developed. This research is a development study (R&D) that adopted the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The aim of this research is to develop ethnomathematics-based Project-Based Learning activities and teaching tools assisted by GeoGebra on the topic of three-dimensional flat-sided shapes (cubes, cuboids, prisms, and pyramids), as well as to test their validity. The ethnomathematics context used is the architecture of the Dieng Temple to study the concept of surface area. The resulting product was assessed by subject matter and media experts. The validation results show an average score of 0.8542, which falls into the highly valid category. Therefore, the developed learning product is declared valid and feasible for use to support mathematical communication.

Keywords: Project-Based Learning, *Ethnomathematics*, *Mathematical Communication*, *Spatial Geometry*

INTRODUCTION

In the context of 21st-century education, mathematical communication skills occupy an essential position that must be prioritized within the mathematics learning process. As emphasized by the National Council of Teachers of Mathematics (NCTM, 2000), mathematical communication is a dynamic process that is not limited to the ability to present ideas, but also involves the capacity to read, listen, write, explain, and interpret mathematical concepts. Mathematical communication ability serves as a crucial prerequisite for facilitating junior high school students' understanding of abstract spatial reasoning concepts, as they often struggle to translate three-dimensional objects into visual or symbolic forms (Hadi et al., 2024). Thus, it is imperative to develop an innovative learning strategy that integrates technology utilization, implements a project-based approach, and incorporates cultural contexts relevant to students' daily lives.

One relevant approach is Project-Based Learning (PjBL). Through the implementation of tangible projects, this model encourages students to engage directly in contextual problem-solving while simultaneously developing critical thinking, collaborative, and communicative skills (Khafah et al., 2023). Findings from numerous studies indicate that the implementation of Project-Based Learning in mathematics education promotes student engagement and enhances

mathematical communication abilities. Among these findings 1) Research demonstrated that interactive project-based learning contributed to a 77% improvement in students' mathematical communication abilities (Susanti et al., 2019), 2) The successful implementation of Project-Based Learning in enhancing mathematics education is contingent upon thorough preparation, adequate support, and its alignment with the local context (Himmi et al., 2025), and 3) The design of interactive learning media is deemed pertinent as it aligns with student characteristics, curriculum requirements, and the principles of Project-Based Learning (Harun et al., 2021). Thus, the effectiveness of Project-Based Learning can be enhanced through interactive media support capable of visualizing abstract mathematical objects.

Furthermore, the integration of ethnomathematics serves as a crucial aspect in contextualizing learning. Ethnomathematics posits that local wisdom, artifacts, and cultural activities of a community inherently embody mathematical elements. These elements can be leveraged as an effective bridge or scaffolding tool to foster students' mathematical comprehension (D'Ambrosio, 2016). Research indicates that ethnomathematics-based instruction demonstrates efficacy in enhancing students' creative thinking abilities (Richardo et al., 2023), fostering metacognitive skills (Sutarto et al., 2022), and cultivating students' mathematical communication (Sudirman et al., 2020). This is attributed to the presentation of content anchored in cultural contexts familiar to students. However, research that integrates PjBL, GeoGebra, and ethnomathematics remains severely underexplored, particularly in the context of spatial geometry instruction at the junior high school level.

Significance of study

The imperative to enhance students' mathematical communication skills is underscored by consistent empirical evidence revealing significant deficiencies in this core competency. Previous studies (Elfareta & Murtiyasa, 2022) indicate that a substantial proportion of students struggle to express mathematical ideas coherently, with one finding that 21% of students were unable to communicate their mathematical reasoning effectively. A more critical finding (Lubis et al., 2023) indicated that as many as 37.04% of the student population, forming the largest cohort, possessed only low-level skills. These findings posit weak mathematical communication as a critical barrier to overall achievement, transforming it from a peripheral goal into a fundamental component of conceptual understanding. This study, therefore, advances an innovative instructional design that orchestrates a synergistic integration of Project-based Learning (PjBL), the dynamic mathematics software GeoGebra, and an ethnomathematics framework.

A number of studies have implemented the Project-Based Learning approach to cultivate students' ability to express mathematical ideas both in written and oral forms. However, these studies were predominantly conducted within conventional instructional settings and have not yet fully leveraged digital technology to its optimal potential. On the other hand, the use of GeoGebra as a visualization tool has demonstrated efficacy in enhancing students' conceptual understanding of spatial geometry. However, its implementation is predominantly confined to teacher-led demonstrations and has not yet been comprehensively integrated into collaborative, ethnomathematics-based projects. Furthermore, although ethnomathematics has been extensively studied as a scaffold to connect cultural contexts with mathematical concepts, its application to spatial geometry content remains underexplored as a framework for cultivating communication skills. This research is designed to address a specific gap in the literature by moving beyond conventional approaches, offering a structured, context-rich learning activity. The anticipated outcome is a significant contribution to mathematics pedagogy, providing a practical and meaningful framework to simultaneously foster advanced mathematical communication and cultivate appreciation for local cultural heritage.

METHODS

This study employs a development research design, also known as Research and Development (R&D). The Research and Development methodology is employed to create an innovative product, whose effectiveness is subsequently evaluated through a series of iterative assessments (Sugiyono, 2016). This study aims to develop educational products in the form of an ethnomathematics-based learning module and student worksheet (LKPD), integrating cultural elements of the Dieng Temple into the spatial geometry topic of polyhedron surface area. The

development process is grounded in the ADDIE instructional design model as its methodological framework. The researchers selected the ADDIE development model to design ethnomathematics-based student worksheets due to its systematic framework comprising five distinct phases analysis, design, development, implementation, and evaluation (Ubaidillah & Khotimah, 2023)

Analysis

This phase focuses on the execution of two core activities. Firstly, conducting a comprehensive analysis of the need for developing innovative learning strategies. Secondly, assessing the feasibility and identifying the necessary prerequisites for implementing the developed strategy. More specifically, the analysis is divided into two primary aspects: a needs assessment to identify existing gaps, and a content analysis to systematically evaluate the scope and alignment of instructional materials. This construct is operationalized and benchmarked against three key indicators: (1) the ability to explain mathematical ideas in writing using diverse representations (concrete, visual, and symbolic); (2) the competency to translate concrete representations (e.g., objects, diagrams) into abstract mathematical ideas; and (3) the capacity to express real-world situations in the language or symbols of mathematics (Lubis et al., 2023).

Design

Based on the findings from the analysis phase, the instructional module was designed. This design phase involves a series of systematic and structured activities, including identifying the essential components to be incorporated into the module development. These activities encompass formulating the instructional module, compiling student worksheets (LKPD), preparing assessment rubrics, developing teaching materials, designing learning media, and meticulously mapping out detailed requirements. Furthermore, during this phase, the researchers also prepare the necessary evaluation instruments, encompassing draft instructional modules, draft student worksheets, expert validation questionnaires, as well as pre-test and post-test instruments designed to gauge the effectiveness of the developed product.

Development

This phase involves the execution of the pre-designed development plan for the Student Worksheets. In the development phase, the pre-designed conceptual framework is implemented into a tangible, functional prototype ready for initial implementation. Concurrently, a product validity assessment is conducted through expert evaluations using pre-designed validation instruments, ensuring academic robustness and feasibility prior to the implementation phase.

Implementation

The implementation phase is initiated only after the product has been rigorously vetted and deemed to meet all feasibility standards through a comprehensive expert validation process. Implementation should only commence once all prerequisite foundational stages encompassing analysis, planning, and development have been meticulously completed. (Widyastuti & Susiana, 2019), in this phase, the developed instructional module and Student Worksheets are subsequently trialed on a small scale with students in an authentic classroom environment. The field trial was conducted at SMP Negeri 1 Kertek as the research site to empirically evaluate the product's quality.

Evaluation

The evaluation phase of this study was conducted using data collected through previously administered questionnaires. Data collection employed validation instruments specifically developed for this research, comprising feasibility validation tools and practicality assessment measures. Data analysis was performed using quantitative-descriptive techniques applied to expert validation results and student feedback, which yielded composite mean scores. These scores were subsequently converted into qualitative descriptors to facilitate a nuanced interpretation of each performance level. All data collection procedures utilized structured, closed-ended questionnaires. In analyzing mathematical communication skills, evaluation was based on student achievement across three indicators: (1) accuracy

in formulating mathematical statements, (2) ability to connect real-world objects to mathematical concepts, and (3) proficiency in utilizing diverse forms of mathematical representation.

FINDINGS

The development process for ethnomathematics-based activities commenced with the compilation of diverse relevant sources, including the Grade VIII Mathematics textbook of the Merdeka Curriculum and online literature, which served as the referential foundation for designing the learning activities. Following the completion of the design phase, the process subsequently transitioned to the development of instructional tools, encompassing the creation of a PjBL-based teaching module, Student Worksheets, learning media, and an assessment rubric. All products developed during this phase subsequently underwent rigorous validation by experts to ensure their feasibility and alignment with learning objectives. Consistent with the study by (Ubaidillah & Khotimah, 2023) which posits that the development phase comprises two key sub-stages: initial product creation followed by rigorous testing with experts to evaluate feasibility.

Analysis

The analysis phase of this study was initiated through systematic observation of mathematics instructional practices across multiple junior high schools, serving as a foundational basis for developing a GeoGebra-integrated Project-Based Learning framework that incorporates ethnomathematical elements within the spatial geometry domain. Based on observations and interviews with mathematics teachers, it was found that the learning process remains predominantly dominated by conventional, teacher-centered approaches. Consequently, students tend to remain passive, and their mathematical communication skills both oral and written remain underdeveloped in expressing ideas, explaining problem-solving processes, and using mathematical language and symbols accurately. Based on this needs analysis, the researchers developed an instructional design integrating Project-Based Learning, the GeoGebra platform, and ethnomathematical elements. The selection of PjBL was grounded in its demonstrated capacity to create meaningful learning experiences through authentic projects, thereby fostering collaboration, discussion, and the expression of mathematical ideas ultimately scaffolding students' communication skills.

To provide cultural context and bridge mathematics with local wisdom, the learning design also integrates elements of ethnomathematics. Ethnomathematics, which serves as a pedagogical bridge between mathematics and culture, is implemented by exploring spatial geometry forms present in traditional architecture, cultural artifacts, or local crafts (Iffah et al., 2025). For instance, students can explore concepts of cubes, rectangular prisms, and pyramids through the forms of traditional houses, temples, or woven crafts. This approach not only enhances the appeal and relevance of learning but also provides opportunities for students to appreciate their cultural heritage while deepening their understanding of mathematical concepts (Turmuzi et al., 2023).

Design

Based on the previously conducted needs analysis, the design phase commenced with the comprehensive structuring of learning activities. The core component involved developing Student Worksheets that integrate ethnomathematical content through the context of Dieng Temple as a representation of geometric spatial structures within local culture. Subsequently, a Project-Based Learning instructional syntax was designed, comprising five core phases: formulating fundamental questions, planning the project, scheduling activities, monitoring progress, and testing and evaluating outcomes. The use of GeoGebra as an interactive visualization medium was integrated to scaffold students' conceptual understanding, particularly in visualizing spatial nets to explore geometric properties more deeply through dynamic manipulation. Additionally, supportive instructional materials were designed to enrich the local wisdom context derived from Dieng Temple.

Development

During the development phase, a comprehensive instructional module was structured, integrating three core components: Project-Based Learning, GeoGebra, and the ethnomathematical context of Dieng Temple. The Student Worksheet shown in Figure 1 was designed utilizing Google Maps (Figure 2) to guide students in identifying the forms and quantities of spatial structures within the Dieng Temple complex. The instructional activities were structured across two sessions: the first session focused on content introduction and spatial figure identification through digital exploration, while the second session tasked each group with constructing a temple miniature based on the data they had collected. As an implementation of collaborative learning, students were divided into five groups, each assigned to analyze one of the five main temples in the Dieng Temple Complex. This approach ensured that all groups collectively examined the diversity of spatial forms within the cultural site.



FIGURE 1. Lembar Kerja Peserta Didik



FIGURE 2. Tampilan Candi Dieng pada Google Maps

Implementation

During the implementation phase, a limited trial of the developed product was conducted with 32 eighth-grade students at SMP Negeri 1 Kertek. The trial was carried out in a natural classroom setting using the

ethnomathematics-based Student Worksheets that had been developed. Based on the analysis of validation questionnaire data, the learning materials achieved a validation score of 0.8542, which falls within the high validity category, as show in table 1 and the validation sheet was assessed by two teachers. This aligns with Aiken's assertion in (Nabil et al., 2022) which states that a validity index value exceeding 0.80 indicates a high level of validity. Thus, it can be concluded that the developed learning materials meet the feasibility criteria for implementation in instructional activities. The entire learning process implemented the GeoGebra-assisted Project-Based Learning syntax in accordance with the pre-designed framework. Through this trial, the researchers were able to directly observe the implementation of learning activities in practice and collect data on instructional fidelity and student engagement with the developed materials.

TABLE 1. Validation Score

No	Aspect	Amount	Average	Category
1	Content Feasibility	4	0.8333	High level of validity
2	Presentation Feasibility	8	0.8541	High level of validity
3	Language and Readability	3	0.7778	High level of validity
4	Learning Feasibility	9	0.8889	High level of validity
	Total	24	0.8542	High level of validity

The learning activity commenced with a student-led identification process of the temple's structural features using Google Maps as a visual exploration tool, as illustrated in Figure 3. Based on these identification results, students proceeded to the second session by constructing physical miniatures of the temple, representing the 3D geometric structures they had analyzed. This activity tangibly integrated mathematical concepts with cultural context, as documented in Figure 4.



FIGURE 3. Aktivitas Pembelajaran Pertemuan Pertama



FIGURE 4. Aktivitas Pembelajaran Pertemuan Kedua

Evaluation

Based on observations conducted during the two-session implementation, it can be concluded that the learning activities within this ethnomathematics-infused, GeoGebra-assisted PjBL module were executed seamlessly and aligned rigorously with the predefined instructional syntax. The adopted Project-Based Learning syntax consists of the following six phases: 1) formulating a fundamental question, 2) developing project plans, 3) creating a timeline, 4) monitoring student and project progress, 5) assessing outcomes, and 6) evaluating the learning experience (Fuadin & San Fauziya, 2022) was fully and sequentially implemented throughout the activity flow. Students exhibited marked enthusiasm from the initial session, particularly during the project planning phase when engaging in the identification of spatial structures within Dieng Temple's architecture. The utilization of GeoGebra facilitates the visualization of spatial nets, thereby enhancing students' comprehension of abstract geometric concepts. During group work, students actively discussed to analyze and identify the spatial structures composing the cultural object, while collaboratively developing solution plans.

Based on observational data from the implementation phase, it can be concluded that the learning activities within this ethnomathematics-infused, GeoGebra-assisted PjBL module were executed with high fidelity to the designed instructional syntax. This was particularly evident in the second session, which focused on the construction of Dieng Temple miniatures as a tangible application of geometric concepts. All groups demonstrated high levels of enthusiasm when constructing spatial structures based on their prior identifications, utilizing readily available tools and materials. Although the working time was limited, this constraint actively stimulated collaborative engagement and intensive mathematical communication to address authentic problems. Thus, it can be demonstrated that this activity design is not only feasible for implementation but also effectively fosters a dynamic learning environment and stimulates active student involvement.

DISCUSSION

An analysis of student work samples, as demonstrated in Figures 5 and 6, indicates that mathematical communication competency can be categorized into three primary indicators, which are consistent with the framework of the questions. In responding to question (a) on identifying three-dimensional figures, students successfully formulated mathematical statements by identifying specific geometric entities: a rectangular prism and a cuboid in Semar Temple, and a square pyramid, a cuboid, and a cube in Puntadewa Temple. Despite a redundancy in the use of the terms 'rectangular prism' and 'cuboid,' which are conceptually identical, the analysis revealed the students' capacity to observe and identify a range of geometric forms within an authentic visual context. The analysis of responses to question (b) concerning shape properties reveals that students engaged in connecting concrete objects to abstract mathematical concepts. They delineated characteristics using geometric attributes specifically, the count of faces, edges, and vertices and correlated these with the specific physical structures of the temple: its roof, main body, and base. In response to question (c) concerning visual representation, students demonstrated an attempt to produce mathematical representations through diagrams of the spatial figures, complete with component labeling. Nevertheless, the execution was suboptimal, primarily attributable to limitations in the allotted time.

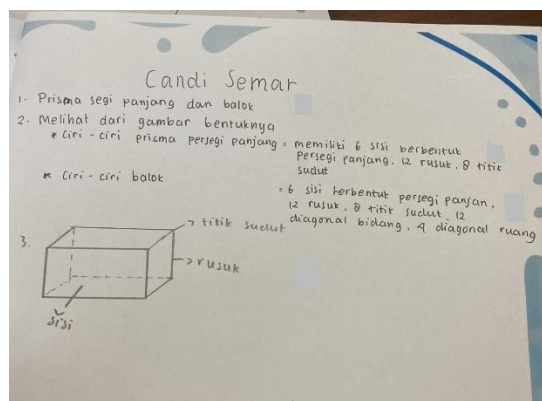


FIGURE 5. Student Work Sample 1

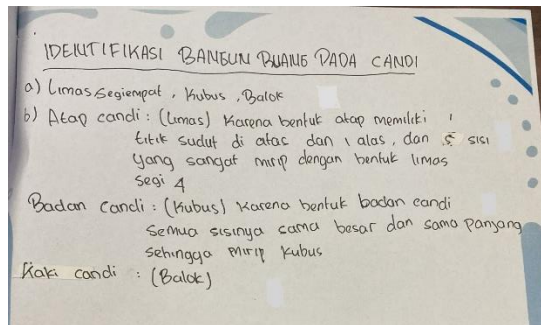


FIGURE 6. Student Work Sample 2

In this study, the developed ethnomathematics-based PjBL learning activity demonstrates significant potential for introducing students to the richness of local culture, while simultaneously serving as an engaging mechanism that renders abstract mathematical material more concrete and contextual. This finding aligns with the study by (Khasanah et al., 2025) which revealed that the arithmetic patterns of Batik Lampung hold potential as an effective learning resource in mathematics education, further underscoring the instructional relevance of cultural artifacts. This is exemplified in one of the project activities where students analyzed the structure of Dieng Temple through the integration of Google Maps platform. This activity not only cultivated their mathematical communication skills in explaining properties of spatial structures, but simultaneously introduced the historical and cultural values embodied in the temple.

CONCLUSIONS

Based on the entire research process, it is concluded that the development of Ethnomathematics-based, GeoGebra-assisted Project-based Learning (PjBL) activities for spatial geometry topics was successfully conducted. The development, which adhered to the Research and Development (R&D) method using the ADDIE model, was executed in alignment with PjBL syntax and indicators of mathematical communication skills, resulting in a product with a high level of validity (validation score: 0.8542). The limited implementation phase empirically assessed these learning activities, confirming their validity and feasibility. However, constraints in time and funding confined the application to a small scale. Consequently, for further research, it is recommended to develop similar activities utilizing other dynamic applications, implement them with larger sample sizes, and incorporate a wider variety of tasks to rigorously test their effectiveness.

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Authors' contributions

FF: main idea, conceptualization, collected data, dataanalysis, and wrote the manuscript, MW: main ide, conceptualization, supervision and review.

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Availability of data and materials

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Competing interests

The authors declare that the publishing of this paper does not involve any conflicts of interest. This work has never been published or offered for publication elsewhere, and it is completely original.

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