

The Effect of Project-Based Learning Method on Understanding Geometry Concepts in Secondary School Students

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ABSTRACT

This study aims to analyse the effect of project-based learning (PBL) method on the understanding of geometry concepts in secondary school students. The main focus of the research is to understand how the application of PBL can help students overcome difficulties in understanding abstract geometry concepts, while improving critical thinking and collaboration skills. This research uses the literature study method by reviewing various scientific journals, books, and relevant articles that discuss the effectiveness of PBL in teaching geometry. This research method involves collecting, analysing, and synthesising previous research results to identify trends, successes, and challenges in the implementation of PBL. The results show that PBL is able to create a more interactive and contextualised learning environment, which allows students to connect geometry theory with practical applications through projects such as geometric model making, building design, or analysis of geometric shapes in everyday life. PBL is an effective method to improve the understanding of geometry concepts in secondary school students. This approach not only enriches students' learning experience but also helps them develop 21st century skills, such as problem solving and teamwork. The implications of this study underline the importance of training for educators as well as the provision of supporting facilities to maximise the potential of PBL in teaching geometry.

Keywords: *Project Based Learning, Geometry, Concept Understanding, Secondary School, Literature Study*

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INTRODUCTION

The study of geometry is frequently perceived as a challenging pursuit among those engaged in mathematics at the secondary school level. The abstract nature of geometry, coupled with the necessity for higher-order cognitive skills such as spatial visualization, an understanding of the relationships between shapes, and the application of various theorems and concepts, contribute to this perception. The secondary school curriculum encompasses a range of topics, including angles, lines, triangles, circles, and three-dimensional space, necessitating an integration of conceptual and procedural understanding.

The deductive reasoning required to comprehend concepts such as postulates and theorems represents a significant challenge for students who are not accustomed to abstract, logical thinking. For instance, the relationship between two parallel lines

necessitates both imaginative insight and an understanding of how the concept applies in the real world (Khatri & Khanal, 2024).

The prevailing pedagogical approach, which frequently relies on didactic lectures and problem-based exercises, tends to segregate the conceptualisation of geometry from its practical applications in everyday life. This impedes students' capacity to perceive the intrinsic relevance of the subject matter they are learning. To illustrate, students may be instructed in the methodology of calculating the area of a building, yet remain unaware of the manner in which this concept is operationalised in architectural design and construction (Paudel & Ghimire, 2024). Traditional instructional methods are frequently teacher-centred, offering students minimal opportunity to engage actively with the learning material. This lack of engagement can diminish student interest and motivation, particularly in subjects such as geometry that necessitate visual comprehension and problem-solving abilities. In response to these challenges, project-based learning (PBL) has emerged as an innovative approach that can bridge the gap between theory and practice in geometry learning. PBL engages students in practical projects focused on solving real-world problems, designed to connect geometry concepts with concrete applications.

Project-based learning (PBL) enables students to apply geometric concepts in the context of tangible projects, such as garden design, architectural modelling and geometric artwork. This approach facilitates students' comprehension that geometry is not merely an abstract theory but also a practical instrument for resolving real-world issues (Ibrahim & Yew, 2023). The undertaking of projects affords students the opportunity to assume responsibility for the planning, organisation and completion of tasks. This process encourages active engagement, fosters a sense of ownership over their learning, and facilitates the development of cooperation and communication skills. Furthermore, PBL places equal emphasis on fostering critical thinking, creativity, and problem-solving abilities, in addition to a solid grasp of fundamental geometry concepts. By situating learning within the context of real-world scenarios, students are presented with opportunities to develop the skills that will prove invaluable in both their professional and personal lives (Youayia & Wijaya, 2022).

This research project aims to investigate the extent to which PBL can influence the understanding of geometry concepts in secondary school students. The efficacy of PBL in enhancing conceptual understanding of geometry is a study that students who engaged in projects exhibited superior conceptual understanding compared to those who received instruction through lectures alone. One of the key advantages of PBL is its ability to overcome the limitations of traditional methods. For instance, this approach facilitates collaborative learning, which is a rarity in traditional instructional methods. The implementation of PBL presents certain challenges, including the necessity to provide training for teachers and ensure the availability of sufficient resources to facilitate effective project implementation. The objective of this research is to provide a comprehensive insight into how PBL can be applied in geometry learning, with the aim of creating a more meaningful and relevant learning experience for secondary school students. This will be achieved through a literature study (Professor Steve Dele Oluwaniyi et al., 2024).

METHOD

This research employs the literature study method, which is a systematic approach to the review, analysis, and synthesis of various relevant literature sources. This approach is designed to facilitate a comprehensive understanding of the impact of

project-based learning (PBL) on the comprehension of geometry concepts among secondary school students. This stage is concerned with the identification and collection of a range of relevant literature sources. The steps involved are as follows:

The determination of search criteria was conducted in order to identify relevant literature sources. These included academic journals, reference books, scientific articles, research reports, and conference publications that addressed the topics of project-based learning (PBL), geometry, and secondary education. Keywords such as 'project-based learning', 'geometry learning', 'conceptual understanding', and 'secondary education' were used to search for relevant sources. Reliable Database Sources: The literature was collected from academic databases, including Scopus, Google Scholar, ProQuest, and SpringerLink, as well as from university libraries. This ensures that the sources used are valid and reliable. Literature Selection and Screening: Once the initial literature list was compiled, it was subjected to screening in order to ensure its suitability to the research topic. The screening criteria included the relevance of the content, the year of publication (with recent literature, that is to say, literature published within the last ten years, being preferred), and the level of credibility of the journal or publisher in question.

The outcome of this phase is a bibliography comprising a range of theoretical perspectives and empirical research findings pertaining to PBL and geometry. At this juncture, the collected literature was subjected to a comprehensive analysis in order to gain insight into the substance of each source. The analysis process entailed the following steps: Critical Reading and Data Extraction: Each piece of literature was subjected to a rigorous examination to identify pertinent information, including the research objectives, methodology employed, findings, and conclusions. The extracted data was then organised in a tabular format for convenient comparison.

Information synthesis: The data collected from the various literatures were synthesised in order to identify patterns, similarities and differences among previous studies. The main focus was to ascertain the relationship between PBL and geometry comprehension, including the supporting factors and constraints that influence the effectiveness of this method. The results of the analyses were also linked to relevant educational theories, such as Piaget's theory of constructivism and active learning approaches. This allowed for an explanation of the reasons and mechanisms through which PBL affects the understanding of geometry concepts.

The outcome of this stage is a mapping of the key findings from the literature, which includes an evaluation of the effectiveness of the method, an analysis of the implementation challenges, and an investigation of the factors that contribute to the success of project-based learning. The final stage of this literature study is the organisation of the findings according to the themes identified during the analysis. Clustering was employed to facilitate the presentation of the results in a systematic manner, thereby enhancing the reader's comprehension of the relationships between findings. The primary themes utilised were as follows: Method Effectiveness: The findings related to the extent to which PBL succeeded in improving students' understanding of geometry concepts, including quantitative data such as improved test scores and qualitative data such as student and teacher perceptions.

Implementation challenges comprise obstacles encountered during the implementation of project-based learning (PBL). These include, for instance, the necessity for teacher training, the availability of suitable facilities, and the time required to complete the project.

Learning outcomes: an in-depth understanding of the impact of project-based learning (PBL) on other aspects of learning, including learning motivation, collaboration skills and students' critical thinking abilities.

The results are presented in a logical and comprehensive narrative, offering a detailed insight into the implications of PBL in the context of teaching geometry..

RESULT AND DISCUSSION

Improving Concept Understanding through Project Based Learning Method

The Project-Based Learning (PBL) method has been identified as an effective pedagogical approach for enhancing students' comprehension of geometry concepts. The primary advantage of PBL is its capacity to integrate theoretical and practical elements, facilitating relevant and meaningful learning experiences for students. PBL is designed to provide students with more active and interactive learning opportunities than traditional learning methods. In the context of geometry learning, it allows students to not only learn theories such as angle definitions, triangle properties, or perimeter formulas, but also to apply them in relevant projects (Warni & Afria, 2023). To illustrate, a project that requires students to design a miniature building using geometric concepts enables them to engage in a practical exploration of the various elements of geometry, including:

- Symmetry is a fundamental concept in geometry, ensuring visual balance in a design.
- Angles: The calculation of specific angles for the purpose of ensuring structural stability.
- The measurement and calculation of perimeter and area are essential skills in the field of architecture.

The integration of these elements in real projects facilitates a more robust conceptual understanding. Students come to recognize that geometry concepts are not merely mathematical abstractions; rather, they are valuable tools utilized in a multitude of fields, including architecture, civil engineering, and design.

The experiential learning approach inherent to Project-Based Learning (PBL) has been demonstrated to enhance knowledge retention. Constructivist educational theory posits that students are more likely to remember and comprehend concepts if they actively construct that knowledge through real-life experiences. In PBL, students are confronted with situations that necessitate the application of concepts, thereby rendering learning more meaningful (Yensy et al., 2022).

To illustrate, in a project to construct a miniature bridge, students must comprehend and apply the principles of symmetry and stability to develop a secure structure. Upon successful completion of this challenge, their comprehension is not only theoretical but also closely linked to practical experience. This reinforces their memory of geometry concepts and their practical applications.

Furthermore, PBL fosters the development of critical thinking and problem-solving abilities, which are crucial for comprehending geometry. In projects, students are frequently confronted with intricate challenges, such as:

- The selection of the most appropriate material for the construction of a geometric model.
- The calculation of proportions or dimensions with a high degree of precision.
- The integration of disparate mathematical concepts that were previously studied in isolation (Hamdani et al., 2024).

To illustrate, when students are tasked with designing a garden incorporating specific geometric shapes, they must consider perimeter and area in order to determine the optimal layout for plants, paths and other elements. This challenge necessitates a holistic approach, the integration of diverse aspects of geometry and the formulation of innovative solutions.

In addition to the cognitive benefits, PBL also facilitates the development of social skills, such as collaboration and communication. Projects are typically conducted in groups, necessitating students to work collectively to accomplish the task. In the context of geometry learning, this collaboration entails discussions on design ideas, task sharing for measurements or calculations, and joint evaluation of the final project results (Utami & Irawati, 2024).

Such abilities are not only pertinent to the field of geometry but also offer supplementary benefits for students in their preparation for the complexities of the professional world.

While PBL offers numerous benefits, its implementation does present certain challenges, including:

- **Teacher Readiness:** It is essential that teachers possess a comprehensive understanding of this pedagogical approach and demonstrate the capacity to design projects that are aligned with students' abilities and competencies.
- **Availability of Resources:** The lack of access to the necessary tools and materials represents a significant challenge, particularly in educational settings with limited resources.

Time management is a significant challenge in the implementation of PBL, as it requires more time than traditional methods. Therefore, it is essential for teachers to possess effective scheduling and organisation skills to ensure the fulfilment of the curriculum within the allocated time frame (Fitriany, 2024).

Students' Active Engagement in Project Based Learning

One of the principal advantages of the project-based learning (PBL) method is its capacity to enhance students' active involvement in the learning process. This active engagement represents a crucial element in the learning process, as it facilitates the creation of a meaningful and sustainable learning experience. The following section provides a comprehensive account of the manner in which this method affects students' active engagement.

In project-based learning (PBL), students are assigned specific responsibilities related to the completion of a given project. These projects are often complex and require collaboration, which fosters a sense of individual and collective responsibility among students. To illustrate, in a project to design a geometric model of a building, students may be responsible for certain aspects, such as dimensional calculations, visual design, or presentation (Jafaruddin & Chen, 2023).

This sense of responsibility provides students with intrinsic motivation to actively participate, as the success of the project depends on the contribution of each team member. When students feel their work is valued and has a real impact, their engagement is likely to increase.

The PBL method affords students the latitude to pursue their ideas in the completion of the project. This latitude encompasses the selection of methods, tools, or approaches deemed most suitable. This autonomy serves as a substantial motivational factor, as students perceive control over their learning process. When students are

afforded the opportunity to make decisions, they demonstrate heightened emotional and cognitive engagement in the project at hand (Tyata et al., 2021).

Projects in PBL are frequently conducted in a group setting, necessitating students to collaborate in order to attain a shared objective. This collaborative approach not only enhances students' social competencies but also cultivates a sense of collective responsibility. Students learn to actively listen to others' ideas, provide constructive feedback, and resolve conflicts, all of which require active engagement.

In the context of geometry, for instance, students may collaborate to construct a three-dimensional model, necessitating discussion and collective problem-solving. This process fosters effective communication and critical thinking, thereby enhancing engagement during the learning process (Asfihana et al., 2024).

Project-based learning (PBL) is typically designed to align with real-world scenarios, enabling students to perceive the practical applicability of the knowledge they are acquiring. This relevance serves to further motivate students to engage with the material, as they recognize the potential for applying the concepts they are learning beyond the confines of the classroom.

To illustrate, a project to design an urban park using the principles of geometry will engage students because they can perceive the concrete outcomes of their efforts. This relevance fosters in students the perception that learning is not merely theoretical, but has tangible consequences, which engenders enthusiasm.

Problem-based learning (PBL) frequently incorporates challenges that prompt students to engage in critical and creative thinking. These challenges, such as solving a design problem or optimising a geometric structure, necessitate active student participation as they require the formulation of innovative solutions (Chang et al., 2024).

When students are presented with a challenge, they are more likely to engage with the material, as the problem-solving process often elicits curiosity and a competitive spirit. Additionally, these challenges facilitate the development of skills such as decision-making and time management.

In PBL, students receive regular feedback throughout the project process, from both the teacher and their peers. This feedback helps students to maintain focus on the project objectives and provides motivation to continuously improve their work. This process also ensures sustained engagement, as students continue to feel encouraged to do their best.

Upon completion of a project, students experience a sense of accomplishment and ownership over the final outcome. This sense of ownership is a crucial factor in fostering active engagement. By perceiving the project as a reflection of their own efforts, students develop a sense of pride and motivation to persist in future endeavors (Rochman & Murdiono, 2024).

Connections with the Real World: Projects Relevant to Everyday Life Help Students Understand the Practical Applications of Geometry

One of the key advantages of project-based learning (PBL) is its capacity to bridge the gap between theoretical knowledge and its practical applications. This is particularly pertinent in the context of geometry learning, where such a connection can facilitate a deeper understanding of concepts that are often perceived as abstract. By engaging with projects that are relevant to everyday life, students not only gain a comprehensive understanding of the theoretical aspects of geometry but also gain insights into its real-world applications.

Geometry, as a branch of mathematics, has a wide range of applications in various fields, including architecture, civil engineering, art, and even technology. However, in traditional educational settings, the teaching of geometry is often limited to theoretical approaches, such as memorising formulas or solving practice problems, without providing a comprehensive understanding of how these concepts are applied in real-world scenarios. Consequently, students may find it challenging to grasp the relevance of geometry in their lives (Owen & Irion-Groth, 2024).

Project-based learning (PBL) facilitates the realisation of a connection with the real world by providing projects that challenge students to apply geometry concepts in a practical context.

The advantages of real-world based projects for students

- This approach enhances the relevance and motivation of the learning process.
- The correlation between geometry and its practical applications instills in students a sense of relevance, prompting them to perceive the value of their learning in a tangible manner. This, in turn, enhances their motivation to learn, as they recognize the real-world applicability of the knowledge they are acquiring.
- It fosters the development of problem-solving abilities.
- The undertaking of projects with real-world relevance presents students with the opportunity to engage in critical and creative thinking. They are required to identify solutions to complex problems, which frequently necessitate the simultaneous application of diverse geometric concepts.
- This approach serves to reinforce conceptual understanding.

The application of theoretical knowledge in practical situations facilitates a more profound comprehension of the underlying geometry concepts. In comparison to rote-based learning, practical experience enables students to retain and integrate the concepts more effectively.

The undertaking of real-world projects frequently entails collaborative endeavours, which fosters the development of students' abilities to engage in collective discourse and to disseminate their ideas. This also facilitates the acquisition of social competencies that are crucial for their future personal and professional lives (Yeshanew et al., 2024).

CONCLUSION

Project-based learning (PBL) has the potential to significantly enhance students' comprehension of geometry concepts at the secondary school level. This approach fundamentally alters the manner in which students learn by integrating theoretical and practical elements through the utilisation of authentic projects that are pertinent to the real world. In the context of teaching geometry, PBL has been demonstrated to be an effective pedagogical approach, as it facilitates the integration of abstract concepts with their practical applications in real-world scenarios. PBL provides a meaningful learning experience, as students are not merely passive receivers of information; rather, they are actively engaged in the learning process through exploration, collaboration and problem-solving. This experience has been demonstrated to enhance students' comprehension of fundamental geometric concepts, including shape, size, angle, and spatial relationships. Additionally, it fosters the development of critical thinking, problem-solving, and creative abilities. Moreover, project-based learning fosters students' active engagement in the learning process. By engaging students with

intriguing and demanding projects, educators can facilitate their assumption of responsibility for their own learning processes. Furthermore, students learn to work together in groups, discuss ideas, and seek solutions, which collectively contribute to the formation of social and collaborative skills. Furthermore, students who are more actively involved in the learning process tend to exhibit greater motivation, which in turn improves their learning outcomes. Another advantage of project-based learning is its capacity to connect geometry concepts with the real world. For instance, in a project to create a building design or geometric model, students can observe first-hand how geometry concepts are utilised in fields such as architecture, engineering or art. This facilitates students' comprehension of the significance of learning geometry and the relevance of these concepts in their lives..

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