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A Review Study on Effectiveness of Project-Based Learning on Mathematical Achievement

Bhawani Pathak

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Author : Bhawani Pathak Email: bhawanipathak2018@mail.com

Abstract

This is a review study based on various selected articles. In this study, literature has been analyzed by the narrative review method. This study focuses on the characteristics of Project-based learning (PBL), steps of Project-based learning, strengths of Project-based learning, and challenges of Project-based learning in mathematics. Project-based learning gives the opportunities to the learner to explore the idea, gather different information and develop new skills and knowledge. PBL supports developing the skill of problem-solving, enhancing collaborative learning, developing the ability to creative thinking and construct new knowledge, developing social interaction and communication skills, and developing the level of confidence to solve the problem.

Keywords: Project-based learning, collaboration, achievement, creative thinking, conceptual learning,

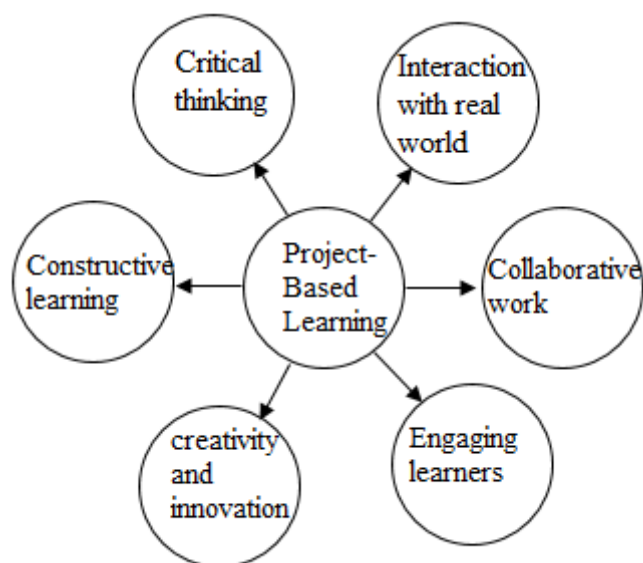
Introduction

Mathematics is considered an important subject from school education to higher study and also important to daily life. Most of the learners feel that mathematics is a difficult and complex subject (Gafoor and Kurukkan, 2015). Mathematics education fails too many children (Gates, 2001, P. 7). It indicates that the achievement of mathematics is

not satisfactory in most of countries in the world. Due to poor learning of mathematics, students take mathematics as a difficult and complex subject. How can mathematics be learned simply and easily when students take it as a difficult and complex subject? It is necessary to give attention to this matter. Achievement in mathematics can be increased by connecting mathematics with real life and involving the active participation of the students in learning. The project-based learning is one of the student-centered instructional methods to increase the active participation of the student. Conceptual learning is essential for a deeper understanding of a subject like mathematics. Project-based learning helps to connect mathematics with real life and promotes conceptual learning. PBL supports engaging learning environments. Through project-based learning or other practical activity, students must learn to use and build their 21st-century ability as they study academic subjects like mathematics (Viro et al., 2020).

Project-based learning

Project-based learning is a teaching strategy that helps to apply own concepts in the learning process. Project-based learning is a student-centered approach that promotes learning by engaging students in an investigation of any topic (Serin, H. (2019). Project-based learning (PBL) constructs the deep understanding of the learners with active participation and conceptual development (Krajcik & Blumenfeld, 2006). Project-based learning has been explored from primary school to higher education in a different context which leads to the active involvement of students with independency, constructive learning, collaboration, sharing, and reflection in practical application (Kokotsaki et al., 2016). PBL encourages the students for more intrinsically motivated, to develop significantly higher critical thinking skills, and to appreciate peer learning (Serin, 2019). During the project-based learning process, students might work alone or in groups. Learner actively creates meaning based on experiences and interactions with others in the real world (Krajcik & Blumenfeld, 2006). Students can integrate project-based learning and mathematics education to improve their understanding of math ideas. Students create an in-depth understanding of the subject matter and a higher ability for innovative methods by being allowed to explore ideas through projects. It increases the student's engagement in their particular work or subject. Creativity and innovation, analytical thinking and problem-solving, interaction, and cooperation are all aspects of project-based learning (Viro et al., 2020). According to the above definitions and descriptions, we can illustrate project-based learning as shown in the diagram.



Project-based learning in mathematics

It is difficult to make real-life connections between mathematics and everyday life. By applying the Project Based Learning approach, students can connect their mathematics learning to daily life situations (Djam'An, 2021). PBL is shown to be a crucial teaching strategy (Rezio et al., 2022., Kokotsaki et al., 2016) that arrange mathematics teaching-learning around problem-solving with collaborative activities while also encouraging students to think critically, think with their creative technique and idea, and mathematically interaction with friends (Krajcik & Blumenfeld, 2006., Rezio et al., 2022). The PBL model can improve the creativity of students in mathematics (Djam'An, 2021).

Creative thinking is very crucial in this competitive world. Critical and logical thinking can develop creative ideas. Project-based learning in mathematics is one of the teaching strategies that develop logical, systematic, and critical thinking abilities (Hossein et al., 2021). There is great role of the Project-based learning model in problem-solving ability and creative thinking skills in mathematics learning (Yunita et al., 2021). Most of the previous studies show that the critical thinking ability of the students is low. Pjbl learning develops the student's critical thinking ability at a high level (Eja et al., 2020). The project-based learning approach gives chance to the students to find solutions to mathematical problems from self-idea and logic. Students can use their talents and develop them through project-based learning activities. Students' participation in project-based learning may enhance their critical thinking, creativity, and cognitive abilities. Pjbl

supports enhancing constructive and logical thinking in mathematics (Jumaat et al., 2017).

From the previous study on project-based learning in mathematics, it can be concluded that students can get a deeper comprehension of mathematical ideas, improve their problem-solving skills, and see the real-world applications of mathematics through project-based learning. Despite the beginning as a new instructional method, PBL is revealed to be a significant teaching method (Rezio et al., 2022). Teachers and students both have an important role in PBL Method. (Fisher et al., 2020). There are many steps to implement the PBL, that Teachers have a significant role to instruct the student and students have greater consciousness to complete the project.

Objectives

To identify the characteristics of project-based learning in mathematics.

To find the steps of project-based learning in mathematics.

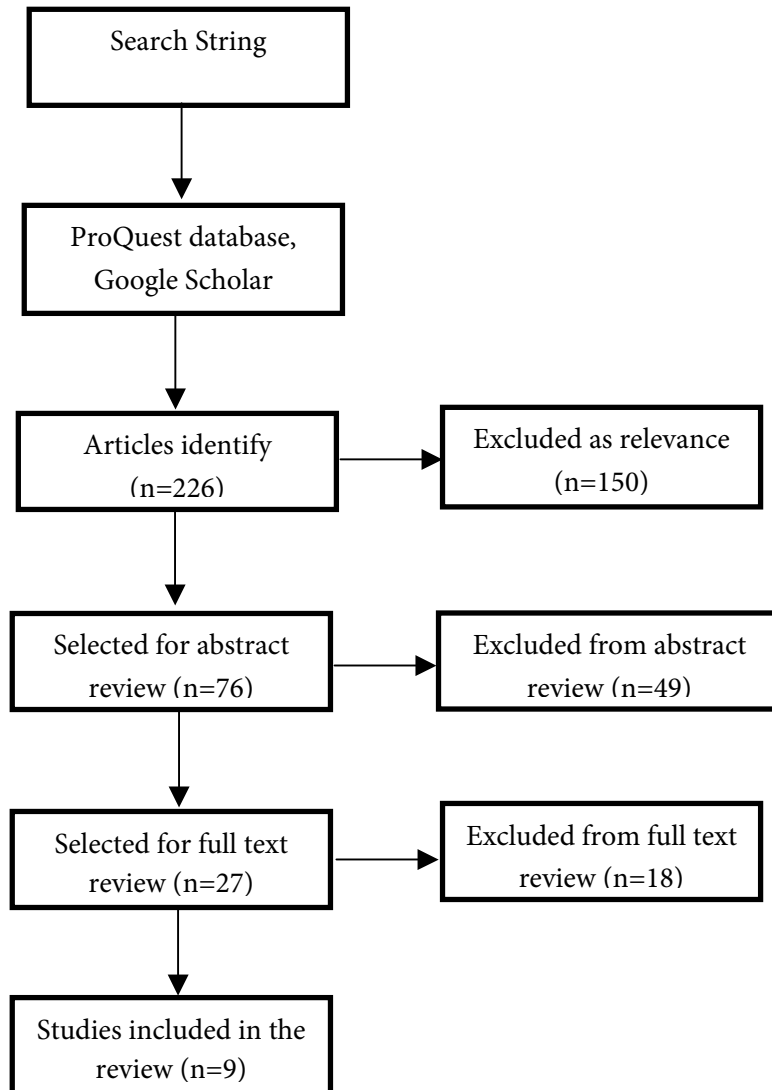
To identify the strengths and challenges to implement PBL in mathematics.

Methodology

This is a review study based on the literature on Project-based learning in mathematics education. The keywords such as 'project-based learning', 'mathematics learning', and 'mathematics education', 'methods of mathematics learning' had been used in the ProQuest database and Google Scholar while searching the literature. 12 articles were selected for the review study. The selection criteria for the literature were identifying the title according to the keywords, examining the abstract related to the objective, and reading the full text of the eligible literature. All the part of selected literature has been reviewed one by one in detail and determines the theme. The past reviewed literature also has been studied in-depth which helped to better understand to complete this review study. The journal articles, books chapter, Thesis, dissertations, and conference papers on the English language are the literature that has been studied. The Findings and conclusion of previous research have been analyzed in detail to generate different themes and related ideas were discussed on those themes. The result has been explored descriptively by the narrative review approach. A narrative review includes a critical evaluation of the literature found in printed and electronic journal articles, and that literature is described and discussed from a theoretical and contextual perspective (Rother, 2007). The context should be introduced at the beginning of a narrative review, and the important conclusions should be discussed at the end (Pautasso, M. (2019).

Article Selection Process

The flowchart of the step of articles selection is shown in the diagram below.



PRISMA flow diagram of article selection 2020

A list of selected articles is given in the table below.

Author	Date	Title
Chistyakov et al	2023	Exploring the characteristics and effectiveness of project-based learning for science and STEAM education
A D Safitri and Suparwoto	2018	Enhancing senior high school students' creative thinking skills using project-based e-learning
Rézio et al	2022	Problem-Based Learning and Applied Mathematics
Hamdi Serin	2019	Project-Based Learning in Mathematics Context
Rohmah et al	2020	Project-based learning to improve student learning activeness
Fisher et al	2020	Project-based learning in mathematics: A literature review
Elina et al	2020	Teachers' Perspectives on project-based learning in Mathematics and Science
Gerhana et al	2017	The effectiveness of project-based learning in trigonometry
Telegina et al	2019	Use of project-based learning in teaching mathematics

Characteristics of project-based learning :

Most of the school projects are not regarded as PBL because PBL is frequently defined more clearly through its distinctive traits (Thomas, 2000). Larmer and Mergendoller (2012) explain the characteristics of PBL in eight different steps. Significant content, a need to know, a driving question, student voice and choice, 21st-century competency, In-depth inquiry, critique and revision, and public audience are the feature of PBL. These features can effectively promote PBL. Similarly, (Krajcik, 2014) explains the about six features as key characteristics of PBL: driving questions, learning goals, scientific practices, collaboration, using technological tools, and creating an artifact. Due to these characteristics, PBL can improve student learning outcomes in mathematics learning (Chistyakov, 2023). Research conducted by Teodoro and Andrade (2022) has explained

the three characteristics of project-based learning. 1) the Role of a tutor as a facilitator 2) the responsibilities of students to be self-regulated and 3) the learning problem as the driving force. Thus, from the detailed study of the previous articles it can be concluded that active learning, collaboration, teamwork, active participation, self-regulation, problem-solving, and critical thinking are the characteristics of project-based learning. Project-based learning increases student involvement, critical thinking, problem-solving techniques, teamwork, and the practical application of information. By incorporating these features, PBL provides a dynamic and effective approach to teaching and learning.

Steps of project-based learning :

The project-based learning can be conducted in several steps. Rohmah et al (2020) suggested six steps of PBL such as project determination, planning step for completing tasks, preparation of project implementation schedules, completion of assignments with facilities and monitoring of lecturer, preparation of report and presentation of result and evaluation of project process and result. In the study of Fisher (2020), there is given the step of project-based learning as developed by The George Lucas Educational Foundation consist of 1) Beginning with essential questions 2) The planning rules of the project 3) making a schedule of activities 4) monitoring student project development 5) evaluation of students' work and 6) evaluation of students' learning experiences. The study of Gerhana et al (2017) described the step of PBL in six different ways. These steps are 1) Theme/ Project topic determination 2) Determination of fundamental questions 3) Design project plan 3) Schedule arrangement 5) Compilation and Preparation of project and report 6) Evaluation of project. From that model, the researcher got the conclusion that project-based learning is more effective than the classical model. From the study of previous it can be concluded that selecting a topic, planning the project, organizing the students' team, developing the action plan, implementing the project, monitoring the progress, and evaluating the result is the step for project-based learning.

Strengths of project-based learning :

With the help of project-based learning, students can engage in learning that is more meaningful to them and build their expertise by completing project activities in an organized manner. Project-based learning increases student learning engagement by involving them directly in all activities (Rohmah et al., 2020). The advantages of PBL may be analyzed from two perspectives: content learning and motivation, which includes students' self-efficacy and self-regulation in mathematics learning (Filcik et al., 2012). PBL gives students the chance to display and promote their work to real audiences and develop the level of confidence the learner (Thomas, 200). PBL is effective to enhance the student's

creative thinking skills (Safitri & Suparwoto, 2018). Therefore, it can be said that PBL makes the student more active, able, and capable to solve the mathematical problem. PBL improve the students' outcomes, problem-solving skill, and critical thinking (Chistyakov). Larmer et al 2015; Kokotsaki et al.,2016 & Thomas, 2020 emphasize that PBL motivates students to build their conceptual understanding of subjects and link that knowledge with its application by using real-world questions and situations. Through inquiry-based and constructive investigation, students are motivated to complete tasks. PBL is a method of instruction where the students are responsible and actively participate.

Challenges of project-based learning :

Project-based learning organizes learning by the project work (John & Thomas,2000). The PBL method places a major emphasis on cooperation, reflection, and concept discussion between teachers and students ((Rezio et al., 2022). Teachers consider technical issues and collaboration as significant challenges in PBL (Markula & Aksela, 2022). Students demonstrated competence in creating plans and following procedures. However, They have problems with the complexity of questions, time management, sufficient ideas, teamwork, and collaboration (Thomas,2000). Good project ideas can make project work easier But a lack of project ideas can make it challenging to start a project. The implementation of PBL can be difficult by the lack of instructor's expertise and motivation, lack of project ideas, lack of the student's readiness for the project, lack of interactions between students and the teacher, collegial support, schedule flexibility, and curriculum (Virvo et al., 2020). So, there are lots of challenges to conducting project-based learning. Detailed pre-plan and readiness of the facilitator and learner are essential for the successful implementation of project-based learning.

Conclusion

In conclusion, project-based learning and mathematics proficiency work well together to give students opportunities for meaningful learning that are both interesting and relevant. Students can better understand the subject matter and develop higher-level critical thinking abilities by having the chance to investigate mathematics concepts through practical inquiry and project-based learning. PBL has more significance to improve the achievement of learning. PBL supports developing the skill of problem-solving, enhancing collaborative learning, developing the ability to critically thinking and construct new knowledge, developing social interaction and communication skills, and developing the level of confidence to solve the problem.

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