The effectiveness of the Project-Based Learning (PjBL) model in students’ mathematical ability: A systematic literature review

Y Yunita\(^1\), D Juandi\(^2\), Y S Kusumah\(^2\) and S Suhendra\(^2\)

\(^1\) Program Studi Pendidikan Matematika, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
\(^2\) Departemen Pendidikan Matematika, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*E-mail: yunita1996nita@upi.edu

Abstract. One of the learning models recommended in the 2013 Curriculum is Project Based-Learning (PjBL) model with the demands for the skills required in the 21st century. This learning model can be applied to enhance students’ mathematical ability. This study aims to determine and evaluate the effectiveness of the PjBL model process to foster mathematical ability. This study used a systematic literature review method, including planning, implementing, and reporting. The data were analyzed based on data inclusion criteria, and then the data were extracted, resulting in 26 studies. The findings indicated that an increase in mathematics abilities through mathematics learning using PjBL could occur if students are directly involved in the learning process with clear directions, and they pay attention to essential aspects, such as learning activities, optimal use of time, and mathematical ability. Another finding revealed that the large percentage of the number of studies discuss the influence of the PjBL model on problem-solving and creative thinking skills. There is also an increase in publications, especially those indexed by Scopus every five periods and many studies using random research sampling. Thus, the PjBL model is appropriate for achieving learning objectives, especially in mathematical ability.

1. Introduction

Competencies required in the 21st century include critical skills, communication, collaboration, creativity, and innovation [1]. One of the competencies demanded in the 21st century is mathematical competence. According to the National Council of Teachers of Mathematics (NCTM), mathematical competencies include understanding, problem-solving, critical, creative, and communication skills [2], [3]. To master these various abilities, of course, is not easy. It requires hard and smart efforts, one of which is education. One of the hard and smart efforts in education is using the Project Based-Learning (PjBL) model for improving mathematical abilities. PjBL is a learning model that involves students directly according to their experience and abilities in building a mathematics completion process through real projects [4], [5]. Student-centred learning and support activity is learning contained in the 2013 curriculum [6]. Hence, the learning model recommended by the 2013 curriculum is the PjBL model. The PjBL model has an arrangement of processes that can be carried out, including creating a project with a conceptual pattern that is owned, then displaying it by explaining the project carried out systematically [7]. A literature review of the PjBL implementation has been proven effective in...
learning science. Still, there has been no research that has reviewed the literature on the effectiveness of applying the PjBL model in mathematics learning [8]. To prove how the PjBL model is effectively used in mathematics learning to improve mathematical competence, the researchers conducted a study using the literature study method.

Based on the explanation above, this study aims to determine and evaluate the effectiveness of the project-based learning model in students' mathematical ability by reviewing the findings from the body of literature to obtain information that can be used by teachers and researchers to apply in the learning process.

2. Methods
2.1. Research Design
This study used a systematic literature review (SLR) method. SLR is a method with inclusiveness, transparency, heuristics, and explanations without being subjective to avoid bias in identifying, selecting, and analyzing secondary data [9]. The stages were systematically carried out in this study. The first stage includes observing the structure based on the research context, defining the review protocol and formulating questions based on PICOC, namely (Population, Intervention Comparison and Context). The second stage performs tracing and data extraction by categorizing data items. As a result, the third stage reports the results of the research discussion [10].

2.2. Inclusion Criteria
The inclusion criteria of this study are literature studies using Indonesian or English published from January 1, 2010, to August 31, 2020, indexed by Scopus and non-Scopus, categorized as proceedings and journals, having full access, and categorized as mathematics and mathematics education fields.

2.3. Literature Search and Coding Data
The sources of the electronic literature machines used are Portal Garuda, Google Scholar, Semantic Scholar, IOP Science, ProQuest, Science Direct, SAGE Journals, Wiley Online Library, AIP, IEEE Explore, Emerald Insight, Taylor & Francis Online, SpringerLink, and Institute of Education Science (ERIC), resulting in 163 studies. The questions were then posed to assess the research quality aspects with the answer scoring Yes = 3, Partial = 2, or No = 0. After passing the PICOC and inclusion criteria, data extraction was carried out; thus, we obtained 26 suitable studies.

3. Results and Discussion
3.1. What is project-based learning?
A process of learning activities by making a project plan and putting it into practice to foster students' imagination is known as a PjBL model [11]. Students' thinking patterns have been trained from the beginning to the end of the lesson. In the learning process of PjBL, students will have no difficulty solving a mathematics problem. The PjBL learning provides various options in the problem-solving process and can drive students' challenge [5]. It is such an enjoyment for students to learn freely, but the learning still adheres to the learning objectives agreed upon between the teacher and students. Some of the definitions of PjBL are presented in Table 1.

| Author(s) | Poses Problem | Real World | Use of time | Student activity | Project product |
|-----------|---------------|------------|-------------|-----------------|-----------------|
| Evans, Friedman, McGrath, Myers & Ruiz (2017) | ✓ | ✓ | ✓ | | |
| Çevik (2018) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Craig & Marshall (2019) | ✓ | ✓ | ✓ | ✓ | ✓ |
Table 1 provides an update on the definition of PjBL by previous researchers. The steps of the PjBL model include (1) students design ideas to solve problems; (2) students make temporary hypotheses using their logical-mathematical intelligence in the form of projects; and (3) students present their work regarding the projects that have been made so that they understand the shortcomings and advantages over the project [7].

PjBL is considered as cooperative learning, which is usually carried out individually or in groups. Group collaboration is often used by students to lighten their workload. Thus, their work could be completed well and punctually. Through the PjBL model, collaboration skills provide a sense of responsibility, substantially joint decision-making, and interdependence of products-projects [12]. In the learning process, there is a system of knowledge transfer between teachers and students and between students and students. However, knowledge transfer requires a long time to explore, investigate, and find solutions to complex challenges [13]. If the PjBL model is implemented by prioritizing students’ active participation while the teacher facilitates and helps students at the right time, learning will go as well as expected [14]. The PjBL model can be integrated with STEM (science, technology, engineering, and mathematics) with engineering principles that improve problem-solving and communication skills [15].

3.2. Project-based learning on mathematical ability?
PjBL model activities involve various abilities that help students develop a problem-solving strategy. Various mathematical problems faced by students require mathematical abilities. Mathematical abilities embedded in the PjBL model include conceptual understanding skills, problem-solving abilities, critical thinking skills, creative thinking skills, reasoning skills, connection skills, and communication skills. The ability to understand mathematical concepts is an ability that students possess in presenting mathematical problems to be simpler so that they are easy to understand and interpret and apply them [16]. Problem-solving ability is a thinking process that requires high concentration in understanding, planning, completing according to what was initially planned, and looking back at the end of the task [17]. Critical thinking ability on mathematics is the ability to analyze in detail and thoroughly but specific and bring the logic of thinking towards the goal to be achieved perfectly [18]. Mathematics creative thinking ability is a thought process by developing other ways to solve problems, but logical correctness can be accepted [19]. Mathematical communication skills convey mathematics information in diagrams, tables, symbols, and other media to clarify a mathematical problem [20]. Students need these mathematical abilities to develop and produce a project based on the learning plan and objectives.

The percentage of studies that discuss the PjBL model based on mathematical ability is shown in Figure 1.

![Figure 1](image-url)
Figure 1 shows the percentage of studies using the PjBL model on the conceptual understanding ability (15%), problem-solving ability (24%), critical thinking ability (13%), creative thinking ability (26%), and communication ability (22%). Many studies have researched the PjBL model of critical thinking and creative thinking skills. This can be followed up by conducting a meta-analysis of the effectiveness of the PjBL model in developing critical thinking and creative thinking skills to evaluate the size of the effect in detail.

3.3. Why is project-based learning effective on mathematical ability
Mathematical skills have a crucial role in PjBL. The relationship between mathematical ability and the learning model to achieve learning objectives planned between the teacher and students is shown in Figure 2.

**Figure 2.** The relationship between mathematical ability and the project-based learning model.

Figure 1 shows one aspect of the mathematical ability connected to the PjBL activity process. The learning that combines various abilities and learning styles is most likely found in the PjBL model [21]. The ability to understand concepts and think critically arises when students experience learning in the real world, which is then absorbed and linked to the students’ previous knowledge. Students look for strategies and solve problems without eliminating collaboration among students to enrich students’ knowledge in various ways that creativity is generated. The resulting project must be presented and explained and understandable.

Some aspects that must be considered as improving the PjBL model include learning activities and student abilities [8]. Moreover, it is essential to pay attention to the effectiveness of the PjBL model in mathematical ability, such as the use of appropriate time to create an atmosphere for the PjBL activities because the basic principle of PjBL is to make products which require optimal, sufficient time so that the use of the PjBL model positively impacts students’ mathematical ability.

Several previous researchers studied the effectiveness of the PjBL model in mathematical ability based on statistical data analysis. Overall, the PjBL model significantly influences mathematical abilities, such as conceptual understanding, problem-solving, creative thinking, critical thinking, and
mathematical communication skills. There are also differences shown in the experimental class using PjBL and the control class with conventional learning.

The related studies published at the national and international levels are shown in Figure 3.

Figure 3 shows that the number of studies examining the effectiveness of PjBL model to foster mathematical ability has increased in publication every five periods, both journals indexed by Scopus and non-Scopus. Only one study was published in journals indexed by Scopus in the 2010-2015 period, while there are 18 studies published in the 2016-2020 period. On the other hand, one study was published in the non-Scopus indexed journals in the 2010-2015 period, and six studies were in the 2016-2020 period. Thus, studies on the PjBL model have been developed throughout the period.

Regarding research sampling techniques, two sampling techniques, including random sampling and purposive sampling, were utilized in the previous studies, as shown in Figure 4.

In Figure 4, 24 studies use random sampling techniques, and two studies employ a purposive sampling technique. The random sampling technique is the best way to make decisions and reduce research bias [22]. Meanwhile, purposive sampling uses a sample following the specific characteristics of the
research objectives. This technique highly depends on existing knowledge in the field and the targeted member relationships [23]. Most of the studies use research samples that avoid publication bias to maintain the accuracy of the research.

4. Conclusion
The improvement of mathematical ability through mathematics learning using PjBL can occur if students are directly involved in the learning process with clear directions, and they focus on essential aspects, such as learning activities, optimal use of time, and mathematical ability. Another aspect that supports this finding is the large percentage of studies that discuss the effect of the PjBL model on problem-solving and creative thinking skills of students and an increase in publications, especially those indexed by Scopus every five periods. This finding suggests that the PjBL model affects mathematical abilities. Besides, many studies use random research sampling techniques so that the effectiveness of PjBL model in mathematical ability is maintained and its accuracy is protected, and research bias is avoided. Therefore, the PjBL model is appropriate for achieving learning objectives, especially in fostering mathematical ability.

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