

The Effect of Project-Based Learning on Students' Mathematics Learning in Indonesia: A Systematic Literature Review

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Abstract

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Project-based Learning (PjBL) is one of the learning models relevant to the Indonesian 2013 Curriculum which emphasizes developing 21st century skills. Hence, the aim of this study was to perform a systematic literature reviews (SLR) concerning the effect of the PjBL model on students' mathematics learning in Indonesia. The reporting of this SLR is in accordance with the standards of the Preferred Reporting Items for systematic reviews and Meta-Analyses (PRISMA) statement. Article searches through database, namely Scopus and Google Scholar, found 44 articles after being filtered according to the established criteria. The finding showed the effect of PjBL model on learning achievement, higher order thinking skills, conceptual understanding, learning motivation, creative thinking skills, and critical thinking skills. The findings also revealed that most of the studies employed quasi-experimental, pre-experimental, action research, and case studies as research design and PjBL module as learning materials. Additionally, majority of the studies were carried out for the mathematics topics such as statistics, linear equations, and geometry. Further PjBL studies are needed in other mathematics topics as well as their effect on other variables.

Keywords: Project-Based Learning, Mathematics Learning, Systematic Literature Review

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INTRODUCTION

Learning achievement refers to students' academic success or progress in the form of knowledge, skills, and abilities as a result of teaching in schools that is typically measured by classroom assessments, classroom evaluation, and achievement tests (Kpolovie et al., 2014; Keller et al., 2017; Azizah & Widjajanti, 2019; Saputra et al., 2021). However, there are several obstacles that are still widely discussed in the field of education, namely low students' achievement in mathematics. The report of the Indonesian National examination result for the upper secondary school showed the average scores in mathematics is below 50 points for the years 2016 to 2019 and decline for 2016 to 2017 (see Table 1). Despite a rise in scores in 2018 and 2019, they remain associated with low students' achievement.

Table 1. National Examination Results Report

Year	Result
2015	53.97
2016	42.25
2017	37.61
2018	39.37
2019	46.56

Note. Adapted from <https://bit.ly/3ntjPAV>. Copyright 2018 by Pusat Penilaian Pendidikan (Education Assessment Center).

Conventional learning methods that are still used by many teachers make students to think less and simply follow the steps given by their teachers (Noer & Gunowibowo, 2018). In addition, Devi et al. (2020) stated that teachers often practice memorization of Mathematical facts or formulas. If this happens continuously, the desired learning objectives will not be achieved and learning activities will continue to be teacher-centered. Mathematics teaching and learning that are less meaningful result in students memorizing concepts without understanding how to apply the concepts in daily life. This statement is in line with the National Council of Teachers of Mathematics (NCTM) that explains the deficiencies in mathematics learning are due to students not being guided to relate mathematical concepts to their own experiences (Ulya, 2017). In the 2013 Indonesian curriculum, there are several learning model that are suggested, one of which is the Project-based learning (PjBL) (Pratiwi et al., 2019). PjBL creates an active, collaborative, responsible and problem solving (Harianja, 2020; Aiedah, 2012; Dinantika et al., 2019), able to increase students' self-confidence, critical and analytical thinking and improves students' activities and learning outcomes (Erliadi, 2021; Sulaeman, 2020; Oktavian & Nurrochman, 2015; Azizah & Widjajanti, 2019), and is able to increase students' self-confidence (Latifah & Kuswanto, 2018; Azizah et al., 2019; Ainurrizqiyah et al., 2015; Erliadi, 2021).

The current study is vital because there is a scarcity of research that provides a comprehensive picture of the state of the effect of PjBL in Indonesia. Furthermore, the effect of PjBL on mathematics learning will be discussed. Hence, this study presents a systematic literature review on the effect of PjBL model in mathematics learning in Indonesia. To achieve this goal, the following research questions were raised: (1) What is the state of the art of research on Project Based Learning? (2) What is the effect of Project Based Learning in Mathematics? (3) What are the advantages of Project Based Learning in Mathematics Learning? And (4) What are the disadvantages of Project Based Learning in Mathematics Learning?

RESEARCH METHOD

1. Research Design

This study applied a SLR method that identifies, assesses, and interprets findings on research topics to answer predetermined research questions (Kitchenham & Charters, 2007). Through this method, researchers conducted reviews and identified journals in a structured manner by following the steps that have been set in each process (Triandini et al., 2019). This systematic study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines by Moher et al. (2015). The stages of the PRISMA guidelines consist of identification, screening and eligibility, data abstraction, and analysis.

PRISMA has three advantages, namely 1) clearly define the questions that allow the research to be systematic, 2) identify the inclusion criteria, namely the criteria that need to be met with each member of the population that can be taken as a sample and exclusion criteria for members of the population that cannot be sampled, and 3) and check the literature database largely at a predetermined time (Sierra-Correa & Kintz, 2015).

2. Eligibility Criteria

The method includes searching for articles published in the last 5 years through two main database sources, namely Scopus and Google Scholar. According to Boyle and Sherman (2006), Scopus has a very large database and wide range of records as well as features to perform analysis, tracking, and visualization related to the articles being

searched for. In addition, it also has a diverse cover area with citation data and bibliography data in terms of search and sorting capabilities that similar to Web of Science (Chadegani, et al., 2017). The academic literature of Scopus has been shown to significantly increase the relative ranking of its users, especially academics (Meho & Yang, 2007). Google Scholar has a database that reaches thousands of records, which is more than enough to obtain various information about scientific writings, research reports, articles, and scientific journals (Albantani, 2016).

Table 2 shows the criteria for selecting articles. Articles selected are indicated by (✓), while articles excluded are indicated by (/).

Table 2. Criteria for selecting articles

Type	Criteria	Selected	Excluded
Publishing type	Journal articles	✓	
	Conference Paper	✓	
	Report		
	Dissertation/Thesis		/
	Book		/
Access	Maya	✓	
	Paper	✓	
Publishing period	2018-2022	✓	
Publishing network	In country	✓	
	Overseas	✓	
Study type	Empirical study	✓	
	Theoretical study		/
Study methodology	Qualitative	✓	
	Quantitative	✓	

3. Systematic Review Process

Identification

The review process was carried out in June 2022. *In this case*, the first stage was the selection of keywords used in the search process through the three selected databases. The main keywords used as shown in table 3 were Project-Based Learning, student achievement, and mathematics learning. At this stage, 7 journal articles were discarded due to similarities in searches on Scopus and Google Scholar. 7 journal articles were discarded due to similarities in searches on Scopus and Google Scholar. Then, the researcher expanded the search terms and strategies to identify as many eligible studies as possible. The first 90 articles were found after searching using keywords from the website search process. Table 3 shows the keywords to search for information.

Table 3. Keyword Settings in the Website Search Process

Project-Based Learning	Mathematics Learning
PjBL	Mathematics education
21st century teaching skill	Effect
Teaching Practice	Effectiveness
Active Learning Strategy	Learning Model

Screening and Eligibility

At this stage, researchers set a series of eligibility criteria and exceptions. First, the type of literature selected was journal articles that have empirical data which means the

selected journal articles do not include books, book series, book chapters, workshop description, and thesis. Second, the search focused on journal articles that were published in the last five years. Third, the research carried out is at the level of primary school education to higher education institutions. Final inclusion reviews potential and revised full-text relevant studies in conjunction with other authors. The eligibility process resulted in complete articles, as shown in Figure 1. In this case, 39 journal articles were rejected because they did not meet the requirements and were not relevant to project-based learning. Journal articles that were not relevant including the articles that are not focused on mathematics were also rejected. Eventually, the final stage of the review process resulted in 71 articles.

Data Abstraction and Analysis

As many as 44 articles were studied and examined. Themes and sub-themes were identified appropriately by reviewing the abstract of the article, followed by reading the full and in-depth article. Using qualitative content analysis, themes were identified in 44 articles related to project-based learning in mathematics learning in Indonesia. The researchers then arranged the sub-themes around the main themes, defined by the grouping of things by type or category.

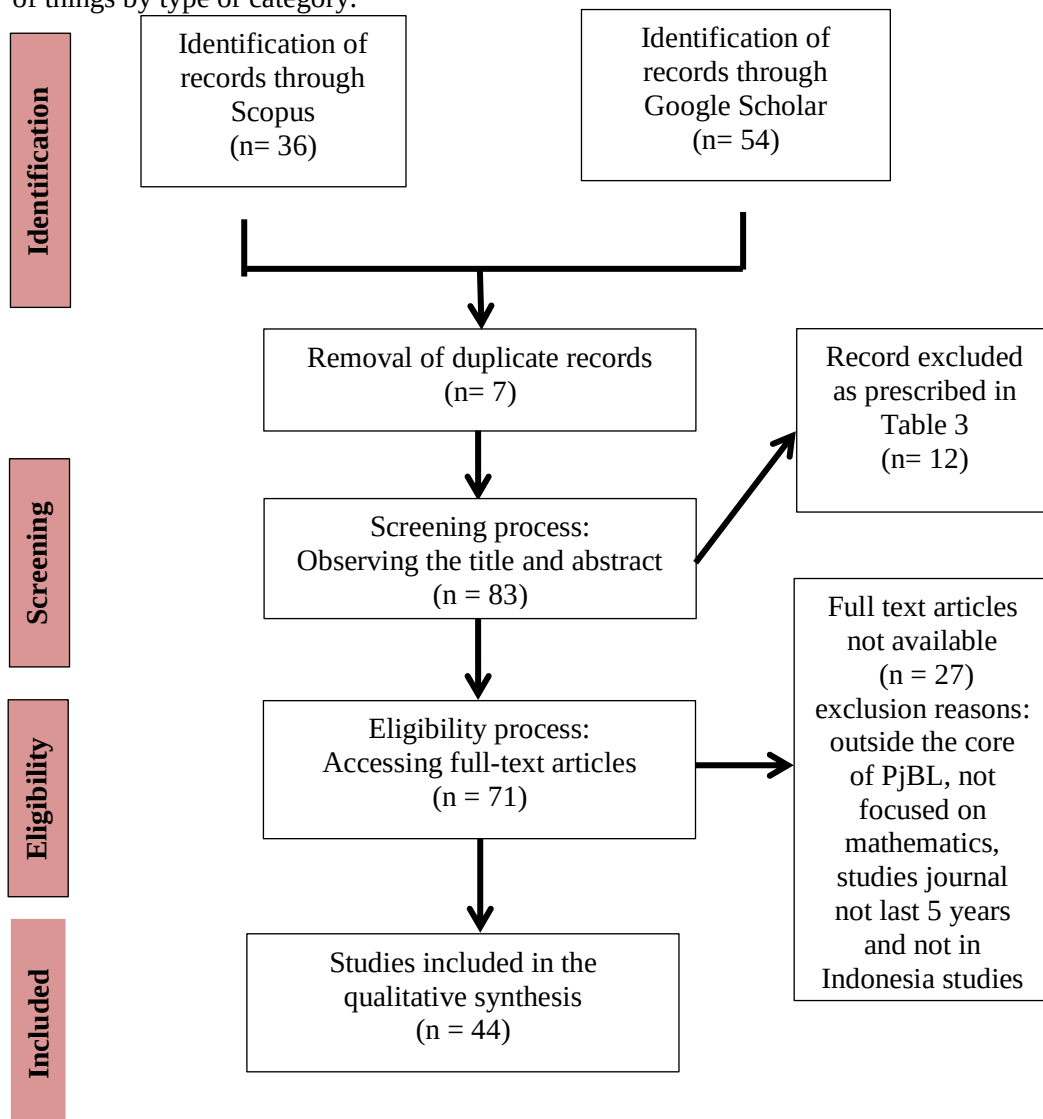


Figure 1. Study flow diagram (Moher et al., 2015)

RESULTS AND DISCUSSION

The following section discusses a review of the effects of project-based learning on mathematics learning in Indonesia. In table 5, an overview of the included studies with more detailed contextual information (eg Learning setting & Participants details (number and age), Location, Education Level, Research Methodology and Study purpose) provided.

1. State of the art of research on Project Based Learning

PJBL is a student-centered learning that provides the students with opportunities for in-depth exploration through real-world exploration, a teaching approach that was built based on activities learning and real-life assignments that provide challenges for students to complete (Condliffe, 2017; Hidayah & Sulistyaningrum, 2019; Billah et al., 2019; Handrianto et al., 2020; Dini, 2022). PjBL is a learning model that focuses on product creation by involving students directly in the learning process (Hapsari et al., 2019, Ardianti et al., 2017). To describe PjBl research journal articles, each publication was analyzed in terms of the learning setting, research location, participant characteristics, education level, research methodology, and research objectives. Table 1 is a summary of the analysis results from articles that have passed the screening stage using the PRISMA process.

Learning Setting

With regard to the learning setting in the research article in table 4, it was found that all the researches were studied in face-to-face classes. Anggrawan (2019), Nissa and Haryanto (2020), and Onde et al. (2021) defined that face-to-face learning has the following advantages:

1. The teacher can control the learning material, thus he can find out to which extent the students master the lesson material presented.
2. This learning is effective if the subject matter that must be mastered by students is broad enough, while the time they have for learning is limited.
3. Students can listen through the delivery of material about a lesson, and at the same time students can see (through the implementation of demonstrations).
4. Face-to-face learning can be used for large numbers of students and class sizes.

Location Research

Indonesia consists of five islands from 34 provinces which are Sumatra, Java, Kalimantan, Sulawesi and Papua. In Table 2, an analysis of the research location was carried out by researchers in selected articles and there are 15 provinces from which researchers studied PjBL. Most locations are in Central Java. Analysis of research locations based on provinces in Indonesia is shown in Figure 2, while the analysis of research locations based on islands in Indonesia is shown in Figure 3.

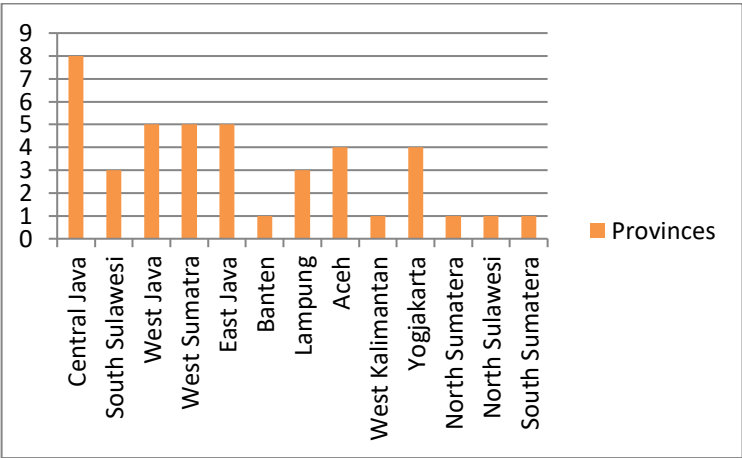


Figure 2. . The analysis of research locations based on provinces in Indonesia

Table 5. The definition of PjBL based on previous researchers

No	Authors	Learning setting & Participants details: Number (N) and age	Location	Education Level	Research Methodology	Study purpose
1	Aisyah et al. (2020)	• Face-to-face classroom • N = 30 students • Age = 14 years	Central Java	Secondary School	• Quantitative approach • Experimental design • One group pretest-posttest • T-test	To determine the effect of PjBL using BOSTIK on mathematics learning achievement on statistical topics.
2	Baharudin et al. (2021)	• Face-to-face classroom • N = 21 students • Age = 11 years	South Sulawesi	Primary School	• Case study • Mixed-method • T-test and observation	To improve the minimum competence of students through the application of PjBL.
3	Durohman et al. (2018)	• Face-to-face classroom • N = 9 students • Age = 11 years	West Java	Secondary School	• Research and Development (R & D) with ADDIE • Quasi-experiment	To develop and test the practicality of student worksheets with a PjBL model.
4	Eliyasni et al. (2019)	• Face-to-face classroom • N = 90 students • Age = ≥ 19 years	West Sumatra	Higher Education Institution	• Quasi-experiment	To determine the effect of Blended Learning and PjBL in improving students' Higher Order Thinking Skills (HOTS).
5	Ramadhana & Hadi, (2022)	• Face-to-face classroom • N = 24 students • Age = 14 years	South Sulawesi	Secondary School	• Quantitative approach • Experimental design • One-Group Pretest-Posttest	To determine the effectiveness of the PjBL model on the higher-order thinking skills.
6	Hapsari et al. (2019)	• Face-to-face classroom • N not specified • Age = 11 years	Central Java	Primary School	• Mixed-method case study	To improve the motivation to learn Mathematics through the application of PjBL.
7	Harianja (2020)	• Face-to-face classroom • N = 5 validator • Age = 13 years	West Java	Secondary School	• Mixed-method case study	To improve the creative thinking skills and mathematical communication students by applying the PjBL model. To find out whether students' creative thinking skills have a positive correlation with students' mathematical communication skill.

8	Hikmiah (2021)	• Face-to-face classroom • N = not specified • Age = 14 years	East Java	Secondary School	• R&D method with 4D (Define,Design, Develop, and Disseminate) • Quasi-experiment • Mixed-method case study	To produce project-based learning tools on data presentation material.
9	Kristiyanto (2020)	• Face-to-face classroom • N = 19 students • Age = 10 years	Central Java	Primary School	• Pre-experimental research • One group pretest-posttest design	To improve critical thinking skills and mathematics learning outcomes with the PjBL model.
10	Niswara et al. (2019)	• Face-to-face classroom • N = 25 students • Age = 10 years	West Java	Secondary School	• Quasi-experiment • One group pretest-posttest design	To determine the effect of learning models in the case of the influence of Puzzle media-assisted PjBL Model on High Order Thinking Skill.
11	Octaviyani et al. (2020)	• Face-to-face classroom • N = 31 students • Age = 13years	East Java	Secondary School	• Quasi-experiment • Non-equivalent research design cluster random sampling	To reveal the students' enhancement in mathematical creative thinking ability by PjBL through STEM approach.
12	Paranduri (2018)	• Face-to-face classroom • N = 30 students • Age = 14 years	Banten	Secondary School	• Quasi-experiment • Random sampling • ANOVA	To determine the final achievement, improvement of critical thinking skills, and mathematical dispositions through PjBL models.
13	Prananda et al. (2020)	• Face-to-face classroom • N = 89 students • Age = 14 years	Lampung	Secondary School	• Quasi-experiment • Posttest only • Non-equivalent control group design • Cluster random sampling technique	To improve HOTS with PjBL model assisted by Geogebra.
14	Ratnasari et al. (2018)	• Face-to-face classroom • N = student (not specified) • Age = 14 years	Lampung	Secondary School	• R & D approach with 4D (Define,Design, Develop, and Disseminate) • Quasi-experiment • Mixed-method case study	To determine the comparison of students 'mathematical representation ability through the PjBL Model and the students' mathematical representation ability through the conventional model.
15	Sapatri et al. (2019)	• Face-to-face classroom • N = 23 student • Age = 11 years	Central Java	Primary School		To develop student worksheets based on the PjBL model on the material of cube and block nets with a scientific approach.
16	Sediyadi et al. (2018)	• Face-to-face classroom • N = 34 student • Age = 11 years	Central Java	Primary School		To determine the level of student motivation in PjBL model.

17	Setyowati & Mawardi (2018)	• Face-to-face classroom • N = 49 student • Age = 10 years	Central Java	Primary School	• Action Research by using stringer model	To increase the mathematics learning outcomes through the synergy of PjBL.
18	Azizah & Widjajanti (2019)	• Face-to-face classroom • N = 34 student • Age = 13 years	Yogyakarta	Secondary School	• Quasi-experiment	To describe the effectiveness of PjBL statistical material in terms of learning achievement, critical thinking skills, and confidence.
19	Faozi et al. (2020)	• Face-to-face classroom • N = 84 student • Age = 16 years	East Java	Secondary School	• Mixed method • experimental research	To develop and determine effect the mathematics learning device with PjBL which based on Learning Community.
20	Pratiwi et al. (2020)	• Face-to-face classroom • N = 60 student • Age = 13 years	Lampung	Secondary School	• Quasi-experiment	• To find out how the PjBL affects students' communication skills • To know the influence of learning styles on student communication skills • To know the learning model interactions between PjBL and learning style to the communication skills.
21	Rahmadani & Yulia (2020)	• Face-to-face classroom • N = 60 student • Age = 17 years	North Sumatra	Secondary School	• R & D with ASSURE model • Quasi-experiment	To improve the statistical thinking skills students.
22	Sofiyan et al. (2020)	• Face-to-face classroom • N = 25 teacher	Aceh	Higher Education Institution	• R & D with ADDIE model • Quasi-experiment	To develop mathematics teaching materials based on a PjBL model that help improve students' Higher-Order Thinking Skill (HOTS) and character.
23	Mumu et al. (2021)	• Face-to-face classroom • N = 9 student • Age = 14 years	North Sulawesi	Secondary School	• R & D with ADDIE model	To develop learning tools on flat-sided building materials with PjBL in order to produce valid, practical and effective tools.

24	Setiawan et al. (2020)	• Face-to-face classroom • N = 60 student • Age = 14 years	Yogyakarta	Secondary School	• Mixed-method case study	To develop the student's creativity through the implementation of Science, Technology, Engineering and Mathematics (STEM) approach using PjBL.
25	Dja'man et al. (2021)	• Face-to-face classroom • N = 34 student • Age = 14 years	South Sulawesi	Secondary School	• Mixed-method case study	To develop, implement, and evaluate the use of the PjBL model in improving students' creativity in building their own city using mathematics (geometry, area, and volume).
26	Sumarni et al. (2020)	• Face-to-face classroom • N = 24 teacher	West Java	Higher Education Institution	• Experimental research	To describe the role of PjBL to improve mathematics knowledge for the learning of prospective mathematics teachers.
27	Shalihah et al (2020)	• Face-to-face classroom • N = 19 student • Age = 10 years	East Java	Primary School	• Experimental research	To analyze PjBL teaching materials can improve students' creative thinking skills.
28	Sari et al. (2020)	• Face-to-face classroom • N = 34 student • Age = 13 years	South Sumatra	Secondary School	• Validation studies	To determine students' abilities after learning mathematics with the PjBL model.
29	Rohmah et al. (2020)	• Face-to-face classroom • N = 28 Students • Age = ≥ 19 years	Central Java	Higher Education Institution	• Descriptive	to find out PjBL can improve student learning activities
30	Hadiyanti et al. (2021)	• Face-to-face classroom • N = student (not specified) • Age = 15 years	East Java	Secondary School	• R & D approach with 4D (Define,Design, Develop, and Disseminate)	To improve the mathematical literacy skills.
31	Lusiana et al. (2020)	• Face-to-face classroom • N = student (not specified) • Age range is 13 to 18 years	West Sumatra	Secondary School	• R & D with ADDIE model	To produce LKPD based on PjBL equipped tracker application for simple harmonic motion experiment, with a valid, practical and effective criteria.
32	Lainufar et al. (2021)	• Face-to-face classroom • N = 32 student • Age = 16years	Aceh	Secondary School	R & D with Plomp model.	To develop learning instrument with PJBL model and GeoGebra AR for geometry topic.

33	Eja et al. (202)	• Face-to-face classroom • N = 34 student • Age = 14years	West Java	Secondary School	• Quantitative • Descriptive • Purposive sampling	To obtain a profile of students' critical thinking ability in PjBL integrated with STEM (Science Technology Engineering and Mathematics).
34	Fitriani & Rohman (2021)	• Face-to-face classroom • N = 52 Students • Age = ≥ 19 years	Central Java	Higher Education Institution	R & D with ADDIE model	To determine the increase in mathematical communication skills using mathematics teaching materials that apply PjBL through vlogs based on unity of sciences.
35	Farokhah et al. (2021)	• Face-to-face classroom • N = 63 student • Age = 14 years	West Java	Secondary School	• Quasi-experiment • non-equivalent group design	To describe whether the improvement of mathematical communication ability of students who learn through PjBL using mind map technique.
36	Sarwi et al. (2021)	• Face-to-face classroom • N = 78 student • Age = 11years	Central Java	Primary School	• Pre-experimental • pretest-posttest one group design	To analyze the improvement of the problems solving abilities by implementing PjBL using a STEM approach.
37	Gerhana et al (2017)	• Face-to-face classroom • N = 31 student • Age = 16 years	Yogyakarta	Secondary School	• Quasi-experiment	To explore the effectiveness of PjBL with scientific approach viewed from interpersonal intelligence toward students'achievement learning in mathematics.
38	Husna et al. (2021)	• Face-to-face classroom • N = 6 student • Age = 16 years	Aceh	Secondary School	• R & D with with Plomp model.	To develop an ethnomathematics based trigonometry project worksheet through the PjBL model that met the valid criteria.
39	Laelasari (2018)	• Face-to-face classroom • N = student (not specified) • Age = ≥ 19 years	West Java	Higher Education Institution	• Qualitative Case Study	To determine the stage of student achievement after going through project-based learning.
40	Safarani (2019)	• Face-to-face classroom • N = 36 student • Age = 17 years	Jakarta	Secondary School	• Descriptive qualitative	To describe how students' collaboration skills develop through PBL in statistics.
41	Kusuma et al. (2021)	• Face-to-face classroom • N = student (not specified) • Age = ≥ 17 years	Jakarta	Higher Education Institution	• Quasi-experiment	To determine the impact of PjBL on mathematical problem solving abilities.

Based on figure 3, the analysis of research locations on 5 islands in Indonesia found that the most research was found on the island of Java as much as 56%. Meanwhile, in Papua Island, no research was found on the effects of project-based learning on mathematics learning in Indonesia.

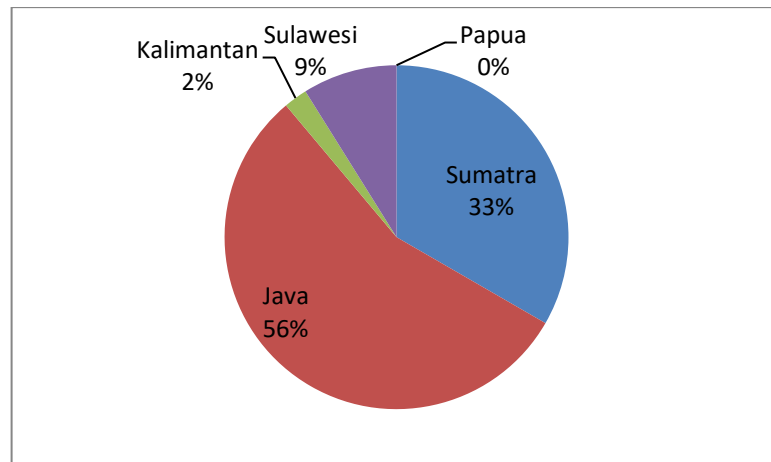


Figure 3. The analysis of research locations based on islands in Indonesia

Participant Characteristics

In the research mentioned in table 5, there were 1,566 samples involved. However, there were 6 studies that do not report the number of samples. The age of the sample in these researches was varied and further divided into three, where 8 articles samples were at the age range of 7 to 12 years, 29 articles samples were at the age range of 13 years to 18 years, and 7 studies samples were at the age range of 19 years and over.

Education Level

Furthermore, based on Table 5, the level of education in the research articles found that, the level of education in the research articles was found mostly in high school as many as 29 articles. Therefore, it can be concluded that PjBL is widely researched and is also implemented for all educational level. However, PjBL studies are rarely found in early childhood.

Research Methodology

Most of the researches were conducted through quasi-experimental with a total of 17 research articles using quantitative methods, 8 studies using research and development (R&D) method, and 8 research articles using case studies with mixed methods. Furthermore, there were 5 research using experiments, one study using action research, one article using pre-experimental research.

2. The Effects of Project Based Learning in Mathematics

The second research question is to determine the the effects of project-based learning in mathematics learning in Indonesia. After the analysis, there were six categories of project-based learning effects, namely: (1) Learning Achievement; (2) Higher Order Thinking Skill; (3) Learning Motivation; (4) Creative Thinking Skill; (5) Critical Thinking Skill; (6) Problem Solving Ability, (7) Mathematical Communication, and (8) Other Effects.

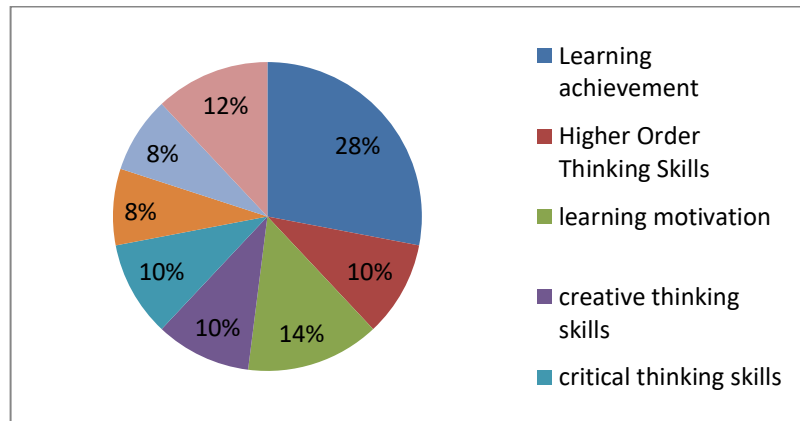


Figure 2. The Effects of Project Based Learning

Learning Achievement

Achievement can be understood as the success of the academic progress of students in the form of knowledge, skills, and abilities as a result of teaching in schools, which are usually measured by class assessments, point assessment scores, and achievement tests. Meanwhile, achievement in learning mathematics is the ability to classify mathematical objects, interpret ideas or concepts, find examples of a concept, and restate mathematical concepts in their language (Mumu et al., 2020; Sumarni et al., 2020; Sari et al., 2020; Lusiana et al., 2020; Lainufar et al., 2021; Gerhana et al., 2017; Husna et al., 2021; Laeslasari, 2018; Herlina et al., 2021).

Aisyah et al. (2020) examined the effect of using the PjBL model was conducted on grade 2 secondary school students using BIOSTIK tools on statistic topics that help students to improve student learning achievement. Another study was further conducted by Baharudin et al. (2021) on 21 students consisting of 10 female students and 11 male students of elementary schools in South Sulawesi, Indonesia, found that PjBL can improve student achievement in memorization and mathematical literacy skills (Rahman et al., 2022). The result of this research is that there is an increase in learning achievement after using PjBL. In addition, the study conducted by Durohman et al. (2018) on grade 5 elementary school students it was found that PjBL can also improve mathematics learning achievement in statistical material. A study conducted on 71 high school students in West Java, Indonesia on mathematics learning found an increase in post-test results after PjBL was implemented. In addition, action research was also carried out using a stringer learning model based on a project on 49 elementary school students in Central Java, Indonesia, that also found an increase in learning achievement in mathematics.

Higher Order Thinking Skill

Higher Order Thinking Skills (HOTS) is a student's thinking activity that involves the high-level cognitive hierarchy of Bloom's taxonomy, which includes analyzing, assessing, and creating them (Eliyasni et al., 2019; Ramadhana & Hadi, 2022; Niswara et al., 2019; Prananda et al., 2020). In the era of the industrial revolution 4.0, students are required to have high-level abilities, and teacher are required to create learning that can fulfill 21st-century learning. The study conducted by Eliyasni et al. (2019) on 90 Higher Education Institution students in West Sumatra, Indonesia concluded that there was an increase in the HOTS ability of students who were taught using PjBL rather than using

only Blended Learning. This study used PjBL and found that it can improving students' higher order thinking skills. This study implies that the use of PjBL model is an alternative to improve Higher Order Thinking Skills (HOTS).

In a study conducted by Ramadhana and Hadi (2022) on 24 students in grade 2 junior high school found that PjBL could improve students' higher-order thinking skills. Furthermore, research conducted by Niswara et al. (2019), namely PjBL-based mathematics learning carried out by elementary school students using teaching aids using puzzle props can also improve higher-order thinking skills criteria for students critical thinking. According to Prananda et al. (2020), a study conducted on 89 secondary school students also found an increase in HOTS with the Geogebra-assisted PjBL model. In addition, the study conducted by Sofiyan et al. (2020) of 25 Higher Education Institution teachers in Aceh found that PjBL-based teaching materials can improving HOTS.

Learning Motivation

According to Hapsari et al. (2019), Sediyadi et al. (2018), and Sianturu et al. (2020), motivation is the need to do well or try to succeed. It is proven by persistence and effort in the face of adversity. The case study conducted by Hapsari et al. (2019) for elementary school students stated that learning motivation is divided into six indicators, *including*: 1) desire to succeed; 2) hopes and ideals; 3) encouragement and need for learning; 4) reward while studying; 5) interesting learning activities, and 6) a supportive learning environment. Students learning motivation in learning mathematics can be increased by applying the PjBL model. This is indicated by showing the percentage in the first cycle of 77% and an increase in the second cycle to 85%, the results show that the PjBL learning model has been proven to increase students' motivation to learn mathematics. Then, the study conducted by Sediyadi et al. (2018) also found an increase in learning motivation in learning mathematics after carrying out PjBL.

Creative Thinking Skill

Creative thinking skills are students' intelligence which includes analytical, creative, and practical aspects (Harianja, 2020; Octaviyani et al., 2020; Rahmazatullaili et al., 2017). Study is carried out by Harianja (2020) by developing a mathematical board game performed for high school students, showed that through mathematics board games project activities, students enjoyed the learning process by implementing PjBL. Some students said that with such a learning model, they had the opportunity to be more creative in learning mathematics, could exchange ideas in groups and better understand mathematical concepts that so far are still difficult to understand for them. In line with that, a similar study was also carried out by Setiawan et al. (2020) on 34 students at a secondary school in South Sulawesi, researchers developed a PjBL design with STEM in the form of innovative food made from salak by integrating the topic of 'ratio' in mathematics.

In addition, the study conducted by Dja'man et al. (2021) found that students who carried out PjBL with the application of mathematical concepts had good creativity in the dimensions of resolution, elaboration, and novelty, as much as 91% of the creativity results obtained which are included in the very good category. According to Salihah et al. (2021) and Rohmah et al. (2020), creative skills have several benefits, namely being optimistic, being a good problem solver, and fostering various innovations.

Critical Thinking Skill

Critical thinking ability is the ability to understand, analyze, and make decisions (Kristiyanto, 2020; Paranduri, 2018; Sianturu et al., 2020; Azizah & Widjajanti (2019). Research conducted by Kristiyanto (2020) on 19 elementary school students found

an increase in critical thinking skills after carrying out PjBL. Data analysis was carried out in three cycles, namely pre-cycle of 10%, cycle I of 63.16%, and cycle II of 84.21% it was found that the implementation of PjBL was effective in improving students' critical thinking skills and could improve mathematics learning achievement.

Meanwhile, research conducted by Paranduri (2018) on high school students in Banten, Indonesia found that: (1) the final achievement of mathematical critical thinking skills among students after implementing PjBL that was included in the very high category was better than students who received scientific learning which is included in the medium category; (2) the improvement of mathematical critical thinking skills in students who get a PjBL that is included in the high category is better than students who get scientific learning which is included in the medium category. Meanwhile, the study conducted by Octaviani et al. (2020) found that for 31 students running PjBL with a STEM approach in learning mathematics can improve critical thinking skills. Further study conducted by Rahmazatullaili et al. (2017) found that the application of PjBL could improve students' critical thinking and problem solving in mathematics learning for second graders in secondary schools in Aceh, Indonesia.

Problem Solving Ability

Research conducted by Hikmiyah (2021) shows that the development of learning tools with the help of MINITAB for junior high school students in East Java can improve problem solving skills on statistical topics. In addition, research conducted by Sarwi et al. (2021) and Kusuma et al. (2021) found that problem-solving skills were improved by implementing STEM integrated PjBL.

Mathematical Communication

A quasi-experimental study conducted by Farokhah et al. (2021) and Pratiwi et al. (2020) in secondary schools found that PjBL can improve students' Mathematical Communication. Meanwhile, research by Fitriani & Rohman (2021) on students at the State Islamic University of Semarang. The results showed that there was an increase in students' mathematical communication skills using PjBL through vlog teaching materials in mathematics learning.

In addition to the effects of project-based learning on mathematics learning in Indonesia above, there are still many learning effects found as summarized in table 6.

Table 6 effects of project-based learning on mathematics learning in Indonesia

No	Effect	Authors
1	Learning Achievement	Aisyah et al. (2020), Baharudin et al. (2021), Durohman et al., 2018, Saputri et al. (2019), Sedyadi et al. (2018), Mumu et al. (2020), Sumarni et al. (2020), Sari et al. (2020), Lusiana et al. (2020), Lainufar et al. (2021), Gerhana et al. (2017), Husna et al. (2021), Laeslasari (2018)
2	Higher Order Thinking Skills	Eliyasni et al. (2019), Ramadhana & Hadi (2022), Niswara et al. (2019), Prananda et al. (2020), Sofiyan et al. (2020)
3	Learning Motivation	Hapsari et al. (2019), Sedyadi et al. (2018) and Sianturu et al. (2020)
4	Creative Thinking Skills	Harianja (2020), Octaviani et al. (2020), Rahmazatullaili et al. (2017), Setiawan et al. (2020),

		Dja'man et al. (2021), Shalihah et al. (2021), Rohmah et al. (2020)
5	Critical Thinking Skills	Kristiyanto (2020), Paranduri (2018), Sianturu et al. (2020), Azizah & Widjajanti (2019), Eja et al. (2020)
6	Problem Solving Ability	Hikmiyah (2021), Faozi et al. (2020), Sarwi et al. (2021), Kusuma et al. (2021)
7	Communication skills	Harianja (2020), Pratiwi et al. (2020), Fitriani & Rohman (2021), Farokhah et al. (2021), Ratnasari et al. (2018)
8	Mathematical Representation Ability	
9	Mathematical Disposition	Paranduri (2018)
10	Statistical Thinking Skill	Pratiwi et al. (2020), Ramadhani & Yulia (2020),
11	Mathematical Literacy	Hadiyanti et al. (2021)
12	Collaboration Skill	Safarani (2019)

3. The advantages of Project Based Learning in Mathematics

Compared to other models, PjBL can improve the quality of student learning in certain materials and improve student learning achievement using problems related to certain materials in real situations (Amanda et al., 2014). PjBL is a contextual learning model because the model is expected to be able to change student learning styles more individually by increasing learning motivation, as well as student creativity in working, generating creative ideas, and practicing critical thinking, in dealing with problems faced at school. The PjBL model involves several aspects of the environment where students are and learn by involving creativity that is manifest in students (Dinantika et al., 2019; Musta'in & Handrianto, 2020).

According to Dinantika et al. (2019), PJBL may involve students actively in constructing their own knowledge and involve collective work to produce a project as an application of the principles or concepts that have been obtained (Arafani et al., 2021; Banseng et al., 2021; Ibrahim et al., 2021). PJBL provides opportunities for students to explore materials using various methods (Hafnidar et al., 2021; Ramadhani et al., 2021; Nengsih et al., 2022). Students are given the opportunity to study materials in various ways, engage in problem solving, and engage in product design activities. It is hoped that the skills and understanding of students can be developed more so that students better understand the material being studied.

Furthermore, Dewi (2021) stated that this model is different from the conventional model which is widely used so far. In the PJBL model, the teacher acts as a facilitator for students to get answers to the guiding questions, while in conventional classes, the teacher plays a role in mastering the entire material and all information is given directly to students. In the classroom, students will be accustomed to working collaboratively; assessments are carried out authentically, and learning resources can be highly developed (Handrianto et al., 2021; Utami et al., 2021). Therefore, the PJBL model is different from conventional classes which are used to individual classroom situations. The assessment carried out is more dominant in the aspect of results rather than process. Nurfitriyanti (2016) states that this model has the following advantages:

1. Increasing students' motivation to learn promotes.

2. Increasing the ability to solve problems.
3. Making students more active and successful in solving complex problems.
4. Increasing cooperation.
5. Encouraging students to develop and practice communication skills.
6. Improving students' skills in managing resources.
7. Providing students with learning and practical experience in managing projects and making allocations of time and other resources such as equipment for preparing assignments.
8. Involving students to learn to take information and demonstrate their knowledge, then implement it in the real world.
9. Making the learning atmosphere fun, so that students and educators enjoy the learning process.

4. The disadvantages of Project Based Learning in Mathematics Learning

According to Harianja (2020), Nurhayati (2017), Baharudin et al. (2021) and Durohman et al. (2018) apart from having various advantages, the implementation of project-based learning also has several weaknesses, namely:

- 1) It takes a lot of time to solve the problem.
- 2) Many teachers feel comfortable with traditional classrooms, where the teacher plays a major role in the classroom.
- 3) The amount of equipment that must be provided is a lot.
- 4) Students who have weaknesses in experiment and information gathering will have difficulty.
- 5) Students are less active in group work.

This statement is evidence of concern that students cannot understand PJBL as a whole. However, PJBL is an alternative offered in the 2013 curriculum (Wardianti, 2021). There are many types of projects that can be done by teachers and students (Handrianto & Salleh, 2019; Pernantah et al., 2022). Projects can increase student interest because of the involvement of students in solving valid problems, working with groups, and building solutions to real problems. The project is still considered to have the potential to improve in-depth abilities because students need to get and ask for information, concepts, and principles during learning (Nurhayati, 2017; Octaviani et al., 2020; Rahmazatullaili et al., 2017). Students also have the potential to improve their competence in thinking (learning and metacognition) as students are assigned to plan, progress and assess completion. The existence of the latest technology is needed in realizing creative projects. The relationship between mathematics and technology and other sciences cannot be separated in mathematics learning. Science, Technology, Engineering, and Mathematics (STEM) which are integrated in PjBL will be able to foster 21st century learning in preparing the younger generation (Sianturi et al., 2020).

CONCLUSION

In the 2013 Indonesian curriculum, there are many ideal models to meet the educational goals of the 21st century, one of which is the Project-Based Learning (PjBL) model. PjBL focuses on the concept of Learning by doing, which is the process of obtaining learning results by performing specific actions that suit the objective. The PjBL model can also connect students' critical thinking skills. In addition, PjBL is able to involve students directly and actively will produce more effective learning compared to an approach that only conveys knowledge. Pupils

can build and build their own knowledge which can improve learning achievement, conceptual understanding, Higher Order Thinking Skills (HOTS), learning motivation, creative thinking skills, and critical thinking skills.

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