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# An empirical analysis: The impact of project-based learning on students' mathematical reflective thinking skills and self-concept

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## ABSTRACT

Mathematical reflective thinking skills and self-concept are essential aspects of 21st-century learning to address global challenges. This study analyzes the effect of Project-Based Learning (PjBL) on students' mathematical reflective thinking skills and self-concept. The experimental research involved 75 tenth-grade students in Bandar Lampung using a posttest control group design. Data were collected through mathematical reflective thinking skills tests and self-concept questionnaires and analyzed using parametric and non-parametric statistical tests. The results showed that the implementation of PjBL did not significantly affect students' mathematical reflective thinking skills and self-concept compared to conventional learning. However, the indicators of mathematical reflective thinking skills achievement in the PjBL class were higher. This study implies the need for a longer implementation of PjBL to achieve significant results and its potential contribution to developing students' collaboration, creativity, and social skills as part of holistic learning.

# *Analisis empiris: Dampak pembelajaran berbasis proyek terhadap kemampuan berpikir reflektif matematis dan konsep diri siswa*

***Kata Kunci:***

*Pendidikan holistik, pembelajaran matematika, kemampuan berpikir reflektif matematis, pembelajaran berbasis proyek, konsep diri*

## *ABSTRAK*

*Kemampuan berpikir reflektif matematis dan konsep diri merupakan aspek penting dalam pembelajaran abad ke-21 untuk menghadapi tantangan global. Penelitian ini menganalisis pengaruh* Project-Based Learning *(PjBL) terhadap kemampuan berpikir reflektif matematis dan self-concept siswa. Penelitian eksperimen melibatkan 75 siswa kelas X di Bandar Lampung dengan desain* posttest control group. *Data diperoleh melalui tes kemampuan berpikir reflektif matematis dan angket self-concept, dianalisis menggunakan uji statistik parametrik dan non-parametrik. Hasil menunjukkan penerapan PjBL tidak memberikan pengaruh signifikan terhadap kemampuan berpikir reflektif matematis dan self-concept siswa dibandingkan pembelajaran konvensional. Namun, indikator pencapaian berpikir reflektif matematis pada kelas PjBL lebih tinggi. Penelitian ini berimplikasi pada perlunya implementasi PjBL dalam jangka waktu lebih panjang untuk hasil signifikan serta dapat berkontribusi mengembangkan keterampilan kolaborasi, kreativitas, dan kemampuan sosial siswa sebagai bagian pembelajaran holistik.*

**Contribution to the literature**

This research contributes to:

- Exploring the impact of PjBL on students' mathematical reflective thinking skills and self-concept.
- This study highlights the unique advantages of PjBL in fostering creativity, collaboration, and real-world problem-solving.
- The study underscores the importance of sufficient time for students to adapt and fully engage with PjBL activities to achieve meaningful outcomes.
- Emphasizes the potential of PjBL to enhance students' character development and social skills, which are essential components of holistic education.

## 1. INTRODUCTION

In the 21st century, the development of science and technology has brought significant changes in various aspects of human life. Education must also continue to innovate to be relevant to the needs of the modern world, especially in fields that play a major role in the advancement of science and technology, such as mathematics. Mathematics underpins advanced technologies, particularly in data science and artificial intelligence, enabling the development of algorithms and models essential for data analysis and decision-making processes [1]. Therefore, mathematics teaching needs to adapt to this new era through innovative approaches that enable students to develop critical thinking skills, collaboration, creativity, and technological literacy. One relevant approach is PjBL, where students learn mathematics through its application in solving real problems, which not only enhances their understanding but also prepares them to contribute to future scientific and technological developments [2].

Learning development in Indonesia is oriented towards higher-order thinking Skills (HOTs) to prepare students to face the 21st century. This learning is a program developed as an effort to improve the quality of graduate learning, which integrates strengthening character education and learning oriented towards higher-order thinking skills [3]. The development of HOT-oriented learning also needs to be applied to mathematics learning [4]. The objective of mathematics learning is mastery of high-level thinking skills, including understanding concepts, mathematical problem solving, mathematical reasoning, mathematical connections, mathematical communication, and other abilities that students will have well if they have good reflective thinking skills [5]. The reflective thinking process is a complex mental process that involves critical and creative thinking processes in reviewing something that has happened or has been done. Therefore, reflective thinking is a high-level thinking skill [6]. This is in line with King *et al.* [7], who state that the ability to think critically, logically, reflectively, metacognitively, and creatively is a high-level thinking skill.

Pamungkas *et al.* [8] said that every student is expected to have good reflective thinking skills because they will have good mathematics learning targets and other abilities if they are able to realize that what they have done is correct, conclude what they should do if you experience failure, and evaluate what has been done. According to Choy [9], reflective thinking is an awareness of what is known and what is needed. This is very important to bridge the gap in learning situations. Several indicators can be used to determine a person's reflective thinking skills. Measuring mathematical reflective thinking skills can be seen from three indicators, namely reacting, comparing, and contemplating [10], [11]. Reacting (reflective thinking for action): in this phase, students are able to mention things that are asked, mention things that are known, and are able to explain that what is known is enough to answer the question. Comparing (reflective thinking for evaluation), in this phase, students do things such as linking the problem being asked to problems they have faced. Contemplating (reflective thinking for critical inquiry), in this phase, students do several things, such as explaining what they are doing, detecting errors, and correcting errors if they occur.

Facts in the field show that students' mathematical reflective thinking skills in Indonesia are still low. Ministry of Education and Culture, Education Assessment Center, shows that the results of the national test scores for mathematics subjects are still very low. Nationally, the average mathematics score is only 38.6 [12]. This value shows that mathematics is the subject with the lowest value compared to other subjects. The characteristics of the national mathematics exam questions measure the metacognitive dimension, which, among other things, reflects the ability to connect several different concepts, solve problems, choose problem-solving strategies, argue, and make the right decisions [13]. This is directly related to indicators of reflective thinking abilities, namely reacting, comparing, and contemplating. This is supported by the opinion of Syadid and Sutiarso [14] that good mathematical reflective thinking skills will be comparable to students' problem-solving abilities. So, when students' problem-solving abilities on national exams are still low, their reflective thinking skills are also low. The low ability to think reflectively also occurs in Lampung Province. The average national exam mathematics score in 2019 showed a score of 36.18. In the Bandar Lampung City area, the average mathematics score is 43.40, which is still considered low. The high school where the research was conducted is a high school that has characteristics similar to high schools in general. The school's math score in the 2019 national exam is also a school with a low score of 37.92. The results of interviews with mathematics teachers show that students' reflective thinking skills are still low. Students have difficulty in providing answers using the information they have obtained. Students also sometimes have difficulty with what method they should choose to solve a math problem. This is related to the indicators of mathematical reflective thinking ability.

Apart from reflective thinking skills, psychological aspects of the mathematics learning process also need to be developed to support the learning process. Learning will be more successful when students' cognitive and psychological abilities are developed together. One of these psychological aspects is self-concept. The self-concept in this research is the self-concept of mathematics (mathematics self-concept). Triana [15] stated that a positive self-concept is needed in the mathematics learning process. The learning goals are to be achieved because self-concept correlates with a person's motivation, achievement, and interest in mathematics. When a student has a high self-concept, he will be interested in studying mathematics, so learning mathematics will be fun. Apart from that, students will be confident in their mathematical skills, so they will be optimistic about being able to solve the mathematical problems given. Therefore, students need to develop a self-concept in learning mathematics.

Currently, the government has changed the curriculum from the 2013 curriculum to the Merdeka curriculum. The Merdeka Curriculum encourages teachers to implement PjBL, which aims to ensure that students have complete competencies (including soft skills, hard skills, and character) so that they can face the challenges of the 21st century. Ministry of Education and Culture's decision number 56 of 2022 concerning Guidelines for Curriculum Implementation in the Context of Learning Recovery in the Independent Curriculum states that: "Learning at school requires project activities to strengthen the profile of Pancasila students which can be allocated around 30% (thirty percent) of the total JP per year, where teachers can carry out PjBL in learning activities in subjects (extracurricular)." Apart from that, the PJBL learning model really needs to be implemented because, through this model, students or learners are invited into a learning situation of remembering, thinking, and linking previous knowledge with new knowledge obtained from the learning process [16].

PjBL refers to a learning model that involves students in constructing knowledge through the task of completing meaningful projects and developing real-world products Guo *et al.* [17]. The advantage of the PjBL model is that it provides students with experience in learning and practicing organizing projects, provides learning experiences that involve students in a complex way, and is designed to develop in the real world, making the learning atmosphere enjoyable. Apart from that, Sastrika *et al.* [18] stated that the PjBL model provides opportunities for students to freely carry out experimental activities, study literature in the library, browse the internet, and collaborate with teachers. Therefore, learning material becomes more open, varied, and fun. In recent years, the number of research on the application of PjBL in mathematics learning in Indonesia has continued to increase, with most research being carried out at the university level and junior high school. At the same time, there is still little research on elementary school and senior high school [19]. Based on the analyzed systematic literature review, it was found that the implementation of Project-based Learning on mathematics learning in Indonesia has a positive impact on student learning outcomes [19], [20]. These are high-order thinking skills, collaboration ability, creative thinking skills, logical-mathematical intelligence, problem-solving skills, mathematical aptitude, interpersonal skills, critical thinking, self-confidence, mathematical communication, and motivation [21]–[24]. Based on this, students' learning experiences in PjBL are also thought to have a positive impact on students' reflective thinking abilities and self-concept. So, it is necessary to comprehensively study and analyze students' reflective thinking skills and self-concept in PjBL in senior high school.

Several studies have revealed that many learning models/approaches can be used to improve students' mathematical reflective thinking skills, including the collaborative inquiry learning model [25], the discovery learning model [26], guided discovery learning [27], [28], group investigation learning model assisted by open-ended questions [29] and scientific approach [30]. However, these studies generally focus on enhancing cognitive abilities without considering affective aspects such as self-concept. This study aims to analyze the effect of PjBL on mathematical reflective thinking skills while also developing students' self-concept through project-based learning involving collaboration, creativity, and real-world problem-solving. The results of this study provide a new contribution by offering a holistic learning approach that not only supports cognitive skill development but also strengthens students' affective aspects while opening opportunities for PjBL implementation in various educational contexts.

## 2. METHOD

This research is an experimental study with a population of 75 students of the tenth-grade Science class, which was divided into three classes in one of the Bandar Lampung high schools in the 2022/2023 academic year. The samples were selected using a purposive sampling technique, with class X IPA 2 (27 students) as the experimental class and X IPA 3 (22 students) as the control class. After receiving approval, the research was conducted.

A preliminary study was carried out by conducting interviews with teachers and students, analyzing students' midterm exam results, and observing the mathematics learning process to determine students' initial characteristics and abilities as well as the learning applied. After receiving consent from parents and students, the research was conducted. Sampling in this study used a purposive sampling technique. Sampling was carried out by selecting two classes that had almost the same mean midterm exam scores to ensure that both groups had relatively similar characteristics at the beginning of the study. The experimental research design used was a posttest control group design. The experimental class used a PjBL model, while the control class used conventional learning. After the treatment was completed, both groups were given the post-test to measure reflective thinking skills and self-concept. This experimental design was used because it allowed the researcher to identify the cause-and-effect relationship between the application of PjBL and students' reflective thinking ability and self-concept. In this experiment, a control group that did not receive PjBL served as a comparison that allowed the researcher to conclude that the application of PjBL caused the observed changes. In addition, experimental research with a control group increases the reliability of the results due to the direct comparison between two separate groups. The steps in this research are presented in the research flow chart in Figure 1.

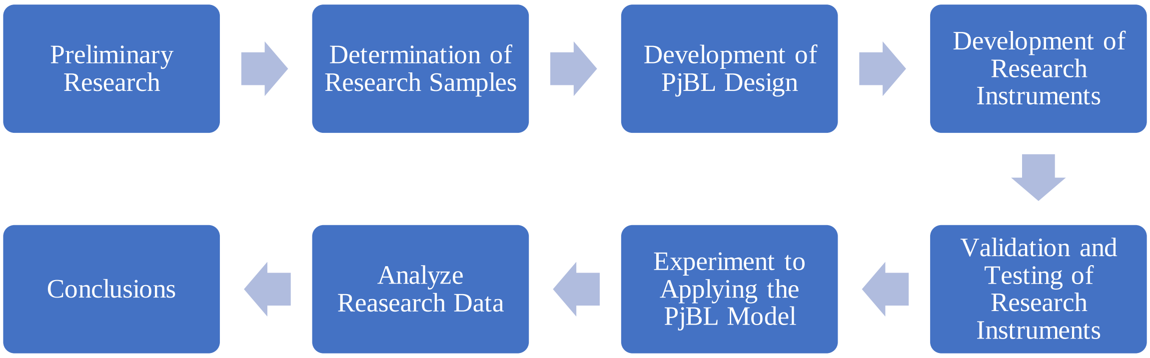


**Figure 1.** Research Procedures

Mathematical reflective thinking skills tests and self-concept questionnaires were used to obtain the data for this research. Self-concept questionnaires are compiled using a Likert scale with four choices: strongly agree (SA), agree (A), disagree (DA), and strongly disagree (SDA), with no neutral option. Experts have validated the mathematical reflective thinking skills test and self-concept questionnaires, and the test questions have been tested. Each item of the test instrument is valid and reliable, and power and level of difficulty are differentiated according to the criteria. Mathematical reflective thinking skills indicators reacting, comparing, and contemplating [10], while three dimensions of self-concept: self-knowledge, self-expectations, and self-evaluation were developed from the concept of self-concept indicators by Calhoun dan Acocella [15].

The data analysis technique in this research is that the preliminary study data is analyzed descriptively as a background for the need to apply PjBL. Data from the validation questionnaire of learning tools, reflective thinking ability test instruments, and student self-concept questionnaires were analyzed descriptively, qualitatively, and quantitatively. Qualitative data in the form of comments and suggestions from validators were described quantitatively as a reference for improving the learning model, learning tools, reflective thinking ability test instruments, and student belief questionnaires. Qualitative data from material experts and media experts are described quantitatively. Then, the learning effectiveness test data were analyzed using statistical tests to see the effect of the application of project-based mathematics learning on improving students' mathematical reflective thinking skills and self-concept. Before analyzing the statistical test, a prerequisite test was carried out, namely the normality test using the Shapiro-Wilk test using SPSS. Based on the test results, it is known that the data on students' reflective thinking ability comes from a normally distributed population, so a two-average comparison test using the t-test is carried out. Meanwhile, self-concept data comes from a population that is not normally distributed, so a non-parametric test is carried out, namely the Mann-Whitney U test. In this article, only the results of the effectiveness test of the application of the learning model will be presented.

## 3. RESULTS AND DISCUSSION

This research aims to examine the mathematical reflective thinking skills of students who received PjBL and those who received conventional learning. After processing the posttest data for students in the experimental group and control group, the lowest score, highest score, mean score, and standard deviation were obtained, which are presented in full in Table 1.

**Table 1.** The Data of Mathematical Reflective Thinking Skills

| Data | Posttest | |
|---|---|---|
| | **Experiment class** | **Control class** |
| N | 22 | 22 |
| $x_{min}$ | 61.11 | 58.33 |
| $x_{max}$ | 100.00 | 97.22 |
| Mean | 82.45 | 76.01 |
| s | 9.67 | 12.99 |

Based on Table 1, the mean score of students' mathematical reflective thinking skills in the experimental class is higher than the students' mathematical reflective thinking skills in the control class. In addition, the standard deviation of experimental class data is smaller than the standard deviation of control class data. This shows that the distribution of data on students' mathematical reflective thinking skills in the control class is more diverse than in the experimental class. From the data described in Table 1, several hypotheses related to students' mathematical reflective thinking skills were tested. For this purpose, a normality test was first carried out on the two groups of data. The results of the normality test calculations are presented in Table 2.

**Table 2.** Recapitulation of Data Normality Test for Mathematical Reflective Thinking Skills Scores

| Class | Sig. Shapiro Wilk | Test Decision | Interpretation |
|---|---|---|---|
| Experiment | 0.787 | $H_0$ accepted | Sample data from a normally distributed population |
| Control | 0.127 | $H_0$ accepted | Sample data from a normally distributed population |

Based on Table 2, the results obtained are sig > 0.05 in the experimental class and control class, so $H_0$ is accepted. Thus, the experimental class and control class come from a normally distributed population. Next, the homogeneity of variance of the data in the experimental class and control class will be tested using the Levene test. Table 3 presents the results of the data homogeneity test.

**Table 3.** Recapitulation of Data Homogeneity Test for Mathematical Reflective Thinking Skills Scores

| Sig. Levene Test | Test Decision | Interpretation |
|---|---|---|
| 0.047 | $H_0$ rejected | The two groups of data have unequal variances |

Based on Table 3, the value obtained is 0.047 < 0.05 so that $H_0$ is rejected. Thus, the data on reflective thinking skills for the experimental class and control class have different variances or come from non-homogeneous populations. Next, hypothesis testing was carried out using the Independent Sample T-Test to test whether there were differences in mathematical reflective thinking skills between experimental class students and control class students. The results of the hypothesis test for reflective thinking skills can be seen in Table 4.

**Table** 4. Recapitulation of Hypothesis Test Results Data on Students' Mathematical Reflective Thinking Skills

| **Learning Factors** | **Skor Posttest** | | |
|---|---|---|---|
| | **Mean** | **t** | ***Sig.* (2-tailed)** |
| PjBL | 82.45 | 1.865 | 0.07 |
| Conventional Learning | 76.01 | | |

After testing the hypothesis of students' mathematical reflective thinking skills with the test criteria, H0 is accepted if the sig (2-tailed) value is > 0.05. The obtained sig (2-tailed) value is 0.07 > 0.05, so $H_0$ is accepted. The conclusion is that the students' mathematical reflective thinking skills in PjBL were the same as the students' mathematical reflective thinking skills in PjBL.

Analysis of mathematical reflective thinking skills scores was carried out to determine the achievement of mathematical reflective thinking skill indicators after treatment in the experimental class and control class. The results of the analysis of the achievement of each indicator of students' mathematical reflective skills are presented in Figure 2.

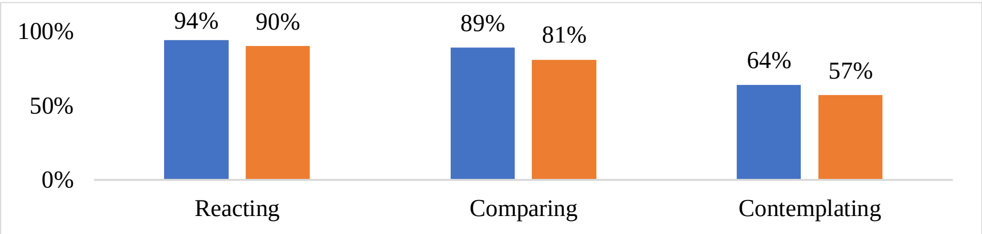


**Figure 2**. Bar Chart Percentage of Student Reflective Thinking Skill Indicator Achievement

After receiving learning using PjBL and conventional learning models, the percentage of achievement of each indicator of mathematical reflective thinking skill for students in the experimental class was higher than in the control class. The average achievement indicator for students' mathematical reflective thinking skills in the experimental class was 82%, while in the control class, it was 76%. Overall, the average achievement of the experimental class students' mathematical reflective thinking ability indicators was higher than that of the control class, with an average difference of 6%. Based on Figure 1, each percentage of achievement of indicators of students' reflective thinking skills in PjBL classes is always higher than in conventional classes.

This research also aims to examine students' self-concept in PjBL classes and conventional classes. After processing the student self-concept questionnaire data in the experimental group and control group, the lowest score, highest score, mean score, and standard deviation were obtained, which are presented in full in Table 5.

**Table 5.** Data of Self-concept

| **Data** | **Posttest** | |
|---|---|---|
| | **Experiment Class** | **Control Class** |
| N | 22 | 22 |
| $x_{min}$ | 40.00 | 62.00 |
| $x_{max}$ | 105.00 | 102.00 |
| Mean | 72.86 | 72.77 |
| s | 13.27 | 9.57 |

Based on Table 5, the mean self-concept score of students in the class was relatively the same as the mean self-concept score of students in the control class. Apart from that, the standard deviation of the experimental class data was greater than the standard deviation of the control class data. This shows that the distribution of self-concept data for experimental class students was more diverse than that of the control class. From the data described in Table 5, several hypotheses related to students' self-concept were tested. For this purpose, a normality test was first carried out on the two groups of data. The results of the normality test calculations are presented in Table 6.

**Table 6.** Recapitulation of Normality Test of Self-concept Score Data

| Class | Sig. Shapiro Wilk | Decision Test | Interpretation |
|---|---|---|---|
| Experiment | 0.48 | $H_0$ rejected | Sample data from a population that is not normally distributed |
| Control | 0.10 | $H_0$ rejected | Sample data from a population that is not normally distributed |

Based on Table 6, the results obtained are sig < 0.05 in the experimental class and control class, so H0 is rejected. Thus, the experimental class and control class come from populations that are not normally distributed. Next, hypothesis testing was carried out using self-concept data with the Mann-Whitney U Test to test whether there were differences in students' self-concept in PjBL classes and conventional classes. The results of the self-concept hypothesis test can be seen in Table 7.

**Table 7**. Recapitulation of Mann-Whitney U Test Results of Student's Self-concept

| Learning Factors | Skor Posttest Self-concept | | |
|---|---|---|---|
| | Average Ranking | Z | *Sig*. (2-tailed) |
| PjBL | 22.75 | 0.129 | 0.897 |
| Conventional Learning | 22.25 | | |

After testing the student's self-concept hypothesis with the test criteria, $H_0$ is accepted if the sig (2-tailed) value is > 0.05. The obtained sig (2-tailed) value is 0.897 > 0.05, so $H_0$ is accepted. The conclusion is that the student's self-concept in PjBL was the same as the student's self-concept in PjBL. Self-concept analysis was also carried out to determine students' self-concept achievements after treatment in the experimental class and control class. The results of the analysis of the achievement of each self-concept indicator are presented in Figure 3.

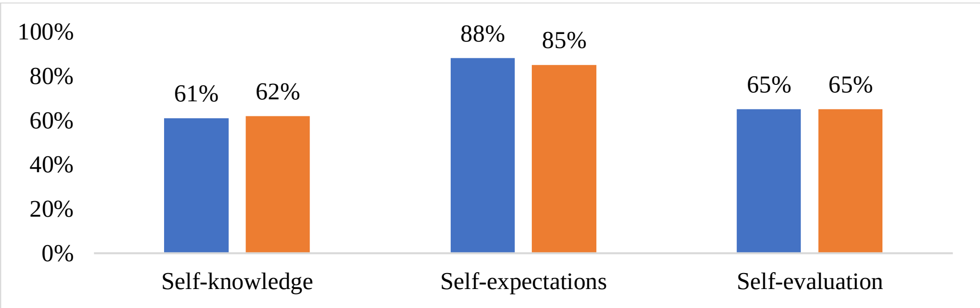


**Figure 3.** Bar Chart Percentage of Student Self-concept Indicator Achievement

The average achievement of the experimental class students' self-concept indicators was 70%, while in the control class, it was 71%. Overall, the average achievement of the experimental class students' self-concept indicators is relatively the same as that of the control class, with an average difference of only 1%. This shows that the achievement of the experimental class students' self-concept indicators is the same as that of the control class.

Based on the research results, it was found that the students' mathematical reflective thinking skills in PjBL were the same as the students' mathematical reflective thinking skills in conventional learning. This allegedly occurred due to limited time in the research, so the influence of the PjBL model on mathematical reflective thinking skills was not yet significant. The PjBL model tends to take a long time to have a significant impact. Time limitations in the PjBL model result in a lack of time to study the material, which is caused by group learning and requires more class management and time [31]. Projects are complex tasks based on challenging questions or problems that involve students in design, problem-solving, decision-making, or investigative activities. They give students the opportunity to work independently for long periods and lead to a realistic product or presentation [32].

Although based on the results of the difference between the two means, it was concluded that the students' reflective thinking skill in PjBL was the same as the reflective thinking skill of students in conventional learning, the percentage of achievement of each indicator of students' mathematical reflective thinking skill in the class with PjBL higher than classes with conventional learning. This is because, at each stage of learning with the PjBL model, students are trained to write down the information they know correctly and completely, are able to provide solutions correctly and systematically, and can relate according to the information provided with the right steps and evaluate or check the correctness. An argument is based on concepts that are used appropriately to conclude. This activity is a form of indicator of mathematical reflective thinking skills, which includes reacting, comparing, and contemplating.

The final result of the project, which was in the form of a mathematics wall magazine with the help of the Canva application, received a positive response from students. Students are involved in designing activities, expressing all their creativity, and presenting and showing off their group's work in front of the class. This is certainly different from students' experiences in classes with conventional learning. According to Novianti [33], through the PjBL model, students are required to show creativity in their learning. Students produce creative thinking, are critical, and are skilled in investigating conclude the material, as well as connecting with real-world problems and authentic issues [34].

PjBL begins with students receiving stimulus in the form of basic questions. Learning begins with questions packaged in a project guide that students must complete in groups. At this stage, students will analyze the questions and then use the internet and books to obtain information to answer the questions given in the project guide. This will stimulate students' curiosity. According to Arum and Wijayanti [35], students who act with a sense of curiosity (curiosity in solving problems) are called the reaction phase in students' mathematical reflective thinking skills. This is in accordance with the opinion of Noer *et al.* [27] that one effort to improve reflective thinking skills is through the learning process by providing problems that arouse curiosity.

Although the learning implementation using the PjBL model is generally carried out well, there are several obstacles. At the first meeting, students had difficulty working on the project guide that the teacher provided, even though the working mechanism had previously been explained to them. The teacher overcomes this problem by approaching each group and providing more detailed directions so that students can work on the project guide given. In this case, scaffolding needs to be carried out by the teacher, namely providing full assistance to the child in the early stages of learning, which is then gradually reduced and giving the child the opportunity to take over greater responsibilities as soon as he is able to do so [36]. Apart from that, some groups also haven't focused on teamwork and do other things outside of lessons, such as chatting, completing other lesson assignments, and so on. Students also still tend to work individually and do not set targets with the group. In this situation, the teacher's role is very important to direct students to focus on working on the given project.

At the second meeting, each group focused on continuing the tasks in the project guide to gather information and organize strategies. Rahmazatullaili et al. state that planning contains activities for determining activities and selecting strategies for completing projects [37]. This will hone reflective thinking skills on reaction indicators, as stated by Samad et al., which state that one of the indicators of reflective thinking is in the form of determining problem-solving strategies [38]. The obstacle experienced during learning is that students have difficulty finding appropriate information, but with mentoring from the teacher, students can choose information that is valid and easy to understand. As stated by Aminullah [39], one of the things that must be considered in implementing the PjBL model is monitoring students' progress. In the opinion of Hapsari *et al.* [40], PjBL is about discovering and building students' knowledge so that it can become an important part that students will always remember. Fisher et al. stated that students find understanding in the process of investigating relevant to their needs and interests [34]. So, even though students find it difficult to find information at first, it will become an important impression when they understand what they found. Students have also prepared targets and plans to put their answers on the wall magazine. At this meeting, the teacher began to introduce the Canva application as a tool that would be used to create a mathematics wall magazine.

At the third and fourth meetings, the student activity was designing a wall magazine on the Canva application. The results displayed on the wall magazine are students' answers to the project guide, which were consulted with the teacher during learning and received approval. This activity trains students to explain the results they obtain when consulting with the teacher, which is called comparing in mathematical reflective thinking. This is in line with the opinion of Jantiawati [41] that reflective thinking is thinking with strong effort, using clear reasons that support the conclusion of the solution to the problem. In line with the opinion of Rosmaya and Noer [42], students will compare by analyzing and clarifying what individual experiences believe by comparing them with other experiences that refer to theory. Some students experienced difficulty accessing it because it was their first time using this application. Mentoring activities are very beneficial for students in this process because they often forget the design methods that the teacher has conveyed. Students also experienced several problems regarding font types for mathematical symbols that were not supported by the application, so a combination with Microsoft Word was needed to complete the font types that were not supported by the Canva application. However, despite all the complaints expressed, they are very enthusiastic about learning how to design this. This is in line with Supianti's [43] opinion that the learning process using applications is believed to be more active, productive, and enjoyable for students.

At the fifth meeting, the project results, in the form of a wall magazine, were presented in class, and other student groups then gave responses. Students can review, check the correctness and conclude together the results obtained from the project preparation activities that have been carried out. In the ability to think reflectively, this is called an indicator of contemplating. This is in line with the opinion of Pamungkas *et al.* [8] that one form of mathematical reflective thinking is the ability to evaluate and check the truth of an argument based on the concepts used. The obstacle experienced at this stage was that the classroom atmosphere was not conducive because some students wanted to convey their responses. As a result, there was not enough time for all groups to make presentations. Only groups 1-4 can convey the results of their group's work. Groups 5 and 6 presented the results of their project work at the sixth meeting. The sixth meeting, which was supposed to be a meeting for evaluation between teachers and students, had less time. However, overall, the material was well received by the students, and the teacher answered all the students' questions. The students' work in the form of a mathematics wall magazine has also been handed over to the school as a keepsake and also as a learning medium. The teacher gives appreciation for the hard work of each group. According to Thorndike's theory of the law of consequences, satisfaction that arises from rewards from teachers will provide satisfaction for children, and they will tend to try to do or improve what they have achieved [44].

Even though PjBL provides students with opportunities to develop their reflective thinking skills, it turns out that students are not used to working on projects. This is because it is the first time students are studying with PjBL, so students experience several obstacles in completing the given project. All of this is thought to have an impact on students' assessments of their abilities. Students will feel less able to complete the project that has been given, so the assessment of their abilities decreases, and students will need a relatively long time for students to be able to adapt to learning with PjBL. Project-based learning emphasizes collaboration, exploration, and creative problem-solving, which require students to work through complex tasks and make connections to real-world applications. These processes take time to unfold, and a short-duration PjBL may not allow students to fully develop these skills. Studies show that for PjBL to be effective, students need enough time to engage meaningfully with the material and reflect on their learning experiences [45].

Nirmalawati stated that the formation of self-concept is due to self-experience and interaction with the people around them. Its formation is through several parts, each part of which must be balanced in order to create an individual with a good self-concept [46]. A good self-concept is formed over a relatively long time and develops through certain stages. Based on the opinions above, it can be concluded that in order for students to have a good self-concept, learning is needed, where students learn with their activities, such as PjBL. However, forming a good student self-concept takes a relatively long time because students have to get used to the learning and go through certain stages.

This study was conducted in a relatively short period, so the time spent in PjBL at school was also quite short. Even though the researcher tried to minimize possible weaknesses in this research, due to limitations in providing the time needed for the student adaptation process with PjBL, PjBL did not have a significant effect on self-concept. Based on the results of this research, PjBL cannot improve students' self-concept, but it does not rule out the possibility that it can improve affective aspects, namely students' character and skills. This was seen at the second meeting; students' collaboration skills had begun to develop well, and students and their group of friends worked together to gather information and organize strategies in accordance with the project guidelines. The character of never giving up is shown by the attitude of students who try to complete the project, and if they have difficulty completing it, they ask the teacher. Then, students showed creative character by designing wall magazines using the Canva application and creating various creations.

Furthermore, the students demonstrated the skills of being a good listener and asking questions. When presenting the results of the discussion by one of the groups, other students listened to their friends' explanations. They had the opportunity to respond and ask questions if their friends' explanations were not understood. Based on the results of observations, the students' character and social skills developed better from the first meeting to the last meeting. However, the improvement in the students' affective aspects cannot be known with certainty because the researchers did not develop instruments to measure them. Initially, the researchers only focused on reflective thinking skills and psychological aspects, namely self-concept.

The main limitation of this study is the short duration of the study, which only lasted for six meetings, which may have precluded a clear observation of the long-term effects of PjBL on students' reflective thinking skills and self-concept. This limitation may have influenced the findings, suggesting that the impact of PjBL may take longer to be achieved. Based on this research, recommendations that can be given in implementing PjBL include: 1) It is recommended that future research be conducted over a longer period (more than six meetings) to better capture the long-term effects of PjBL on reflective thinking and self-concept. Further studies should also consider examining the affective aspects of learning, such as character development and social skills, and develop appropriate instruments to measure these aspects. 2) Project work guidelines should be prepared in as much detail as possible so as to reduce the possibility of students experiencing problems when doing projects that will hinder the time for carrying out research so that the use of time can be more optimal. These recommendations can provide valuable insights for educators aiming to enhance student's learning experiences through project-based approaches and offer a foundation for further studies to explore the broader impacts of PjBL in various educational contexts.

## 4. CONCLUSION

Based on the research, it was found that the implementation of PjBL did not have a significant effect on students' mathematical reflective thinking skills and self-concept, as there was no significant difference in reflective thinking ability and self-concept between students in the PjBL class and those in the conventional learning class. However, the results showed a higher percentage of achievement in the indicators of students' mathematical reflective thinking skills in the PjBL class, with an average difference of 6% compared to the conventional learning class. This study has implications for the need for PjBL implementation over a longer period to achieve significant results and can contribute to developing students' collaboration skills, creativity, and social skills as part of holistic learning.

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## AUTHOR CONTRIBUTION STATEMENT

SHN contributed to the conceptualization of the study, designing the methodology, supervising the research process, and leading the manuscript writing and revisions. MT contributed to data collection, statistical analysis, and the interpretation of findings, as well as drafting sections of the manuscript. PG contributed by providing expertise in project-based learning, designing the intervention, and offering critical insights during manuscript preparation. RA contributed to supporting data collection, facilitating participant engagement, and assisting in reviewing and refining the manuscript. WV contributed to conducting the literature review, developing the theoretical framework, managing references, and proofreading the final draft. All authors contributed to the preparation of the final manuscript, approved its content, and agreed to be accountable for the integrity and accuracy of the work.

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