Jurnal Elemen, 11(1), 133-152, January 2025
https:/doi.org/10.29408/jel.v11i1.27622

e- ISSN: 2442 - 4226

The impact of project-based learning on mathematics interest and self-efficacy among senior high school students

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Abstract

This research sought to explore how the Project-Based Learning (PjBL) model affects the learning interest and self-efficacy of eleventh-grade students in Senior High School. Employing a quantitative quasi-experimental design, the study utilized a sample of eleventh-grade students selected through simple random sampling. Data were gathered using questionnaires and observational methods and analyzed using a multivariate analysis of variance (MANOVA) test. The results underscored the notable influence of the PjBL model in enhancing learning interest and self-efficacy. The PjBL approach positively affected these variables in the experimental group of 28 students. The robustness of these results was confirmed by Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root tests, each demonstrating F-values with a significance level of 0.000, well below the threshold of 0.05. Moreover, the Coefficient of determination (R^2) revealed that the PjBL model accounted for 73.5% of the variance in learning interest and 90.2% in self-efficacy, with the remaining variance being attributable to other factors not addressed in this study.

Keywords: learning interest; project-based learning; self-efficacy

How to cite: Rahman, A. A, Usalmy, N. W., Suárez, C. A. H., & Refugio, C. N. (2025). The impact of project-based learning on mathematics interest and self-efficacy among senior high school students. *Jurnal Elemen, 11*(1), 133-152. https://doi.org/10.29408/jel.v11i1.27622

Received: 29 September 2024 | Revised: 2 December 2024
Accepted: 12 December 2024 | Published: 1 February 2025

Introduction

Mathematics learning is essential for preparing high-quality human resources to face the era of globalization (Ahuja, 2006; Rahman et al., 2024). This potential can be fully realized by enabling students to master essential mathematical concepts. As a foundational subject, mathematics is crucial for entering higher education and navigating the demands of the globalized world (Shahjahan et al., 2022). The development of science and technology is intrinsically linked to mathematics, which can improve logical, orderly, and systematic thinking (Broadley, 2015). Given the importance of mathematics in knowledge acquisition, its learning must be packaged and delivered in an engaging manner that captures students' attention and promotes active engagement . This focus, driven by interest, allows students to participate actively and understand the material.

Interest is often seen as a crucial foundation for success in the learning process. When students are genuinely interested, they are more motivated to actively participate and immerse themselves in the learning experience from beginning to end (Ryan & Deci, 2020;Sadoughi & Hejazi, 2023). This interest plays a pivotal role in determining the Influenceiveness of the learning process, as it directly influences students' enthusiasm and commitment to engaging with the material. Ultimately, students' level of interest is a crucial determinant in their willingness to invest in and interact with the content being taught. Students learning interests are necessary for the learning process to achieve its full potential. According to the research conducted by (Brunet & Müller, 2024), learning interest is a high tendency towards learning that arises from both felt and unfelt needs or desires. In this context, learning interest refers to a natural curiosity and eagerness to obtain information, knowledge, and experiences through educational activities. Oudeyer et al. (2016) also defines learning interest as a sense of pleasure, statements of preference, curiosity, intrinsic motivation, active engagement, and focused attention. Similarly, Sun & Hsieh (2018) explains that it is reflected in students' pleasure, curiosity, attention, and engagement in learning activities.

A notable issue regarding students' interest in learning mathematics has been observed at the high school level in Aceh. According to an interview with one of the mathematics teachers, students' interest in topics such as linear equation systems could be improved. This is indicated by the lack of enthusiasm during the learning process, with many needing more commitment. For instance, some students pay less attention when teachers explain the lesson material, do not take notes, and do not respond to the material because they are talking and laughing with their deskmates. When asked, students frequently needed to respond appropriately, causing teachers to repeat the lesson. Furthermore, some students are unhappy and feel reluctant when given mathematical assignments, which impacts their seriousness in participating in the learning process. The interview also found that several students were quiet and could have responded more favorably during learning, leading to a lack of confidence when asked to work in front of the class.

In addition to learning interest, self-efficacy is an essential internal factor in the learning process. Williams & Rhodes (2018) defines self-efficacy as individuals' belief in their ability to carry out tasks or actions necessary to achieve specific outcomes. Similarly, Showers et al.

(2015) identifies the internal factor as an aspect of self-knowledge that is most influential in human life. This is because individuals' self-efficacy influences their actions in achieving a goal, including estimates of possible problems. According to Panadero et al. (2017), the internal factor is a self-assessment concerning the ability to perform actions accurately, Influenceively, and in line with expectations. Based on these viewpoints, self-efficacy is a cognitive process in which individuals believe in their competence and ability to handle all tasks, behaviors, and situations to achieve desired objectives and results (Endris et al., 2018; Farmer et al., 2021; Horcajo et al., 2022; Mehmood, 2019). This internal factor is closely related to learning interest. For instance, students who have self-efficacy in dealing with mathematical problems will undoubtedly be interested in learning because they feel confident and capable of solving problems. Students' self-efficacy is obtained through successful classroom experiences, observation of others, verbal persuasion, and pleasant psychological conditions. The learning process will be highly successful when great self-effacing is supported with genuine interest.

Individuals with high self-efficacy are more inclined to take proactive steps and demonstrate resilience when facing challenges. According to Wolf et al. (2018), people with high self-efficacy exert significant effort when confronted with unresponsive or difficult situations. In contrast, those with low self-efficacy tend to become apathetic, resigned, and helpless under similar circumstances. Hwang et al. (2016) further observed that students with elevated levels of self-efficacy tend to perform better on assigned tasks, as they are more likely to employ Influenceive learning strategies and possess more vital self-monitoring abilities.

In problem-solving situations, students needing more confidence tend to reduce their effort and abandon the task altogether (Covington, 2014; Liljedahl, 2018). On the other hand, those with high self-efficacy view failure as a result of insufficient effort, motivating them to try harder. In contrast, students with low self-efficacy interpret failure as reflecting their inherent lack of ability (Brown et al., 2016; Woodcock & Faith, 2021). Low self-efficacy is often characterized by avoiding problems, exerting minimal effort, focusing on deficiencies and obstacles, and anticipating poor performance (Mustafa et al., 2019; Trautner & Schwinger, 2020).

Moreover, students who overestimate their abilities may engage in activities beyond their capabilities, leading to frustration and failure. Conversely, those who underestimate their abilities might miss out on valuable opportunities for growth and success as they shy away from challenges that could otherwise lead to rewarding experiences. This underscores the importance of fostering a balanced and accurate sense of self-efficacy to enable students to approach tasks with appropriate confidence and determination.

Given the above description, the learning process should incorporate a model that enhances students' interest and self-efficacy in mathematics. One such model is project-based learning (PjBL), which engages students in long-term activities such as designing, creating, and displaying products to solve real-world problems (AlAli, 2024; Chen et al., 2021; Fiteriani et al., 2019; Kokotsaki et al., 2016). Learning is a process that occurs continuously without age limits, and meaningful learning activities occur when children successfully achieve the desired learning objectives.

Learning innovation is needed in increasing students' interest in learning and confidence in learning mathematics, because it can help students solve mathematical problems from an affective perspective and help students to encourage their abilities to achieve maximum results. Several previous studies on students‘ learning interest and self-efficacy have been conducted, including Latifah & Ratnaningsih (2022), Laili (2021), Ningsih & Hayati (2020), Ismayati et al (2022), Dewi et al (2022) found that learning interest and self-efficacy greatly affect students' ability to think at a high level of mathematical learners, learning independence so that students can find their own concepts, develop students' mathematical thinking skills. There is a need for a learning process that supports the creation of the required abilities by fostering students' interest in learning and self-efficacy, namely by learning that involves students in projects and collaboration between peers by taking into account the local conditions of the culture and learning environment of students.

The PjBL model is process-centered, time-bound, and problem-focused, including concepts from several fields. In the model, students collaboratively work in heterogeneous groups, which increases their self-efficacy and interest in learning. The PjBL has the potential to significantly improve students' thinking skills by promoting collaborative learning and peer teaching at each stage while positioning teachers as mediators or facilitators. The PjBL focuses on driving questions that help students to use concepts and principles through hands-on experience. Finally, the model allows students to learn from their experiences and use their knowledge daily. Based on this background, the problem formulations in this study are:

1. Is there an influence between PjBL on learning interest?
2. Is there an influence between PjBL on Self-Efficacy?
3. Do PjBL simultaneously affect students' interest in learning and self-efficacy?
4. How much impact (percentage) do PjBL have on student interest and self-efficacy?

Methods

This research was conducted as a quasi-experimental study to determine the influence of particular treatments on other variables within a controlled environment. The study sought to examine how these treatments could affect the outcomes, ensuring that conditions were managed to isolate the Influence of the variables under investigation. By utilizing this method, the research aimed to provide a clearer understanding of the causal relationships between the treatments and the observed changes in the targeted variables. A posttest-only control group design was adopted, where the treatment group only received a post-test containing a questionnaire on students' learning interests and self-efficacy. The quasi-experimental design only had a single experimental group without any comparison counterparts. The experimental treatment was conducted in eleventh-grade, specifically on two-variable linear equations using the PjBL model. However, external factors that might influence the dependent variables were not completely controlled.

Population and sample

The study includes all relevant human and natural entities that exhibit specific characteristics relevant to the study. The study population consisted of all eleventh-grade at senior high school students. A simple random sampling method was used, giving each individual in the population an equal chance of being selected, regardless of any subgroup within the population. As a result, eleventh-grade students from a high school in Aceh with learning problems were selected, 28 students as the experimental group.

Data collection methods and research instruments

Data collection for the study utilized two distinct methods to ensure a comprehensive analysis of the variables involved. First, questionnaires were administered, utilizing a Likert scale to measure students' learning interest (Y1) and self-efficacy (Y2). These questionnaires aimed to capture the students' attitudes, motivations, and confidence levels related to their learning experiences. Second, observations were conducted throughout the learning process to gather qualitative data on implementing the Project-Based Learning (PjBL) model (variable X). These observations focused on documenting student activities, interactions, engagement, and the teacher's instructional strategies and facilitation techniques. Combining these two methods, the research aimed to provide a robust understanding of how the PjBL model influenced student interest and self-efficacy within the educational setting.

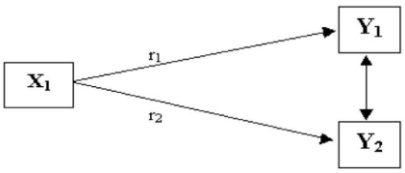

Figure 1. Study design

Description: X1 = Project-Based Learning; Y1 = Learning Interest; Y2 = Self-Efficacy

Data analysis methods

Data analysis involved organizing and synthesizing data from questionnaires and observations to identify patterns, extract relevant information, and draw meaningful conclusions. In this quantitative research, data analysis commenced after collecting all data from respondents and other sources. The process encompassed grouping data by variables and respondent types, tabulating the data, presenting variable-specific results, and employing statistical methods to test hypotheses through calculations. This research specifically utilized two types of data analysis: instrument testing (assessing validity and reliability) and multivariate analysis of variance (MANOVA) testing.

Hypothesis testing

The data analysis process in this research was meticulously designed to yield results that are not only orderly and structured but also meaningful and insightful. A key focus was utilizing statistical analysis techniques to thoroughly calculate and interpret the quantitative data collected from the field. This approach ensured that the findings were grounded in rigorous empirical evidence. Specifically, hypothesis testing was conducted using the MANOVA. This robust statistical method allowed for examining relationships between multiple independent variables and one or more dependent variables. By employing MANOVA, the research assessed the combined Influences of the independent variables on the dependent outcomes, providing a nuanced understanding of the underlying dynamics. This method was precious in identifying how different variables interacted and contributed to the observed changes, ultimately leading to a more comprehensive interpretation of the research results.

Prerequisite test

Several prerequisites need to be fulfilled before conducting the hypothesis testing using the MANOVA test. One such requirement was the Homogeneity Test, executed using the SPSS 22 program. This test involved selecting a statistic based on the average score and analyzing the results. The hypotheses tested in this study included the following:

Ho: Variation in each group was homogeneous

Ha: Variation in each group was not homogeneous

Data interpretation was based on the significance level in the output in the Sig. Column. To determine homogeneity, the significance level guideline of α=0.05 was used. When the significance value was more significant than α, the variance of each sample was homogeneous. However, when the significance obtained was less than α, the variance of each sample was not homogeneous.

MANOVA test

The influence of the PjBL model on students learning interest in senior high school

The MANOVA an advanced extension of the traditional Analysis of Variance (ANOVA), was employed to simultaneously assess the impact of independent variables on multiple dependent variables (Schutz & Gessaroli, 1987). Unlike ANOVA, which is limited to examining the Influences of a single dependent variable, MANOVA enables the analysis of several dependent variables simultaneously. This capability is crucial for understanding how the PjBL model influences multiple outcomes simultaneously rather than in isolation.

In this study, MANOVA was utilized to investigate the Influences of the PjBL model on independent and dependent variables, which were measured on nominal and ratio scales. Specifically, the MANOVA test was applied to address the research's first, second, and third hypotheses. These hypotheses explored the influence of the PjBL model on students' learning interests and self-efficacy, both individually and in combination.

The criteria for evaluating the hypotheses were based on significance values: if the significance value was less than 0.05, the null hypothesis (Ho) was rejected, indicating a statistically significant Influence. Conversely, if the significance value was greater than 0.05, the null hypothesis was accepted, suggesting no significant Influence. By applying these criteria, the study aimed to provide a rigorous assessment of the PjBL model's impact on the targeted variables, offering valuable insights into its Influenceiveness and interactions.

Ho : The PjBL model do not affect students' interest.

H1 : The PjBL model do affects students' interest.

The influence of the PjBL on students' self-efficacy

In this research, the second hypothesis was evaluated using the MANOVA technique, focusing on examining the Influence of the PjBL model on students' self-efficacy. The specific hypothesis under investigation was:

Ho : The PjBL model do not affect students' self-efficacy.

H2 : The PjBL model do affect students' self-efficacy.

The influence of the PjBL model on students' learning interest and self-efficacy

The third hypothesis, analyzed using MANOVA, sought to determine whether the PjBL model influenced both students' learning interests and self-efficacy simultaneously. The hypothesis examined was:

Ho : The PjBL model do not affect students' learning interest and self-efficacy.

H3 : The PjBL model do affect students' learning interest and self-efficacy.

The coefficient of determination

The R^2 value, or the Coefficient of determination, quantifies the degree to which the PjBL model accounts for the variability in the dependent variables, which in this study are students' learning interests and self-efficacy. This value ranges from 0 to 1, measuring how well the independent variables explain the variations observed in the dependent variables.

A low R^2 value indicates that the independent variables have limited explanatory power regarding the variations in the dependent variable, suggesting that other factors might be influencing the dependent variable that is not accounted for by the model. Conversely, an R^2 value nearing one implies that the independent variables explain almost all the variability in the dependent variable, demonstrating a solid relationship and indicating that the PjBL model substantially impacts the outcomes being measured. This measure is crucial for understanding the Influenceiveness of the PjBL model, as it reflects how much of the change in students' learning interest and self-efficacy can be attributed to the model relative to the total variation in these outcomes.

$$KD = r^2 \times 100\% \quad (1)$$

Description: KD = Determinant Coefficient; R = Correlation Coefficient

Results

This research gathered data on students' learning interests and self-efficacy through questionnaires. The interest questionnaire had 20 statements, while the self-efficacy questionnaire had 40 statements, with 20 positive statements and 20 negative statements. As a post-test, questionnaires were sent at the end of the treatment. They were used to determine the extent of student's learning interest and self-efficacy after using the PjBL model related to the specified topics. Questionnaires that had been tested for validity were administered to the experimental group to determine students' learning interests and self-efficacy on the topic.

Validity test

Before distributing the questionnaires to the experimental group, a validity test was conducted to ensure the accuracy and relevance of the questions designed to assess students' learning interests and self-efficacy. This process involved construct validation to determine if the items on the questionnaire effectively measured the intended constructs, thereby ensuring that the results truly reflected the students' abilities and confirming the validity of each question.

To facilitate data analysis, the Microsoft Excel program was utilized to validate the questionnaires on students' learning interests. These questionnaires comprised 20 statements, as detailed in Table 1. The use of Excel enabled a systematic approach to checking the validity of the responses, ensuring that the data collected accurately represented the constructs being measured. This validation process was critical for confirming that the questionnaire was reliable for evaluating the students' learning interests and self-efficacy.

Table 1. Validity test of the learning interest questionnaire

Item Number	r_{count}	r_{table}	Description
1	0.498	0.468	Valid
2	0.541	0.468	Valid
3	0.523	0.468	Valid
4	0.551	0.468	Valid
5	0.483	0.468	Valid
6	0.782	0.468	Valid
7	0.573	0.468	Valid
8	0.556	0.468	Valid
9	0.582	0.468	Valid
10	0.755	0.468	Valid
11	0.575	0.468	Valid
12	0.771	0.468	Valid
13	0.514	0.468	Valid
14	0.803	0.468	Valid
15	0.638	0.468	Valid
16	0.594	0.468	Valid
17	0.488	0.468	Valid
18	0.708	0.468	Valid
19	0.602	0.468	Valid
20	0.673	0.468	Valid

The Pearson validity test compared the r_{count} value with the r_{table} value, and the criteria used to determine the validity included the following.

- When the r_{count} value > r_{table} = valid
- When the r_{count} value < r_{table} = invalid

With a sample size of 20 students and 5% significance level, the statistical distribution yielded an r_{table} value of 0.468. This led to the validity of all questionnaire items related to students' learning interests. Additionally, the validity test for the self-efficacy questionnaires, consisting of 40 statements, was conducted using the Ms. Excel program, with the results presented in Table 2.

Table 2. Validity test of students' self-efficacy questionnaire

Item Number	r_{count}	r_{table}	Description
1	0.763	0.468	Valid
2	0.647	0.468	Valid
3	0.837	0.468	Valid
4	0.687	0.468	Valid
5	0.797	0.468	Valid
6	0.578	0.468	Valid
7	0.737	0.468	Valid
8	0.768	0.468	Valid
9	0.768	0.468	Valid
10	0.726	0.468	Valid
11	0.799	0.468	Valid
12	0.768	0.468	Valid
13	0.602	0.468	Valid
14	0.654	0.468	Valid
15	0.687	0.468	Valid
16	0.768	0.468	Valid
17	0.763	0.468	Valid
18	0.647	0.468	Valid
19	0.837	0.468	Valid
20	0.687	0.468	Valid
21	0.763	0.468	Valid
22	0.647	0.468	Valid
23	0.837	0.468	Valid
24	0.687	0.468	Valid
25	0.529	0.468	Valid
26	0.687	0.468	Valid
27	0.687	0.468	Valid
28	0.529	0.468	Valid
29	0.768	0.468	Valid
30	0.687	0.468	Valid
31	0.481	0.468	Valid
32	0.687	0.468	Valid
33	0.763	0.468	Valid
34	0.647	0.468	Valid
35	0.837	0.468	Valid
36	0.687	0.468	Valid

Item Number	r_{count}	r_{table}	Description
37	0.763	0.468	Valid
38	0.647	0.468	Valid
39	0.837	0.468	Valid
40	0.687	0.468	Valid

The Pearson validity test compared the r_{count} value with the r_{table} value, and the criteria used to determine the validity included the following.

- When the r_{count} value > r_{table} = valid
- When the r_{count} value < r_{table} = invalid

For a sample size of 20 students (n = 20) and 5% significance level, the statistical distribution resulted in a r_{table} value of 0.468, considering all the questionnaire items in self-efficacy to become valid.

Reliability test

The reliability test was employed to assess whether the items within the students' interest and self-efficacy questionnaire statements were reliable, ensuring they consistently yielded the same measurement results. This test was conducted utilizing MS Excel and the Cronbach alpha formula. The reliability of the instrument was categorized into five levels: 0.00-0.20 (Very unreliable), 0.21-0.40 (unreliable), 0.41-0.60 (quite reliable), 0.61-0.80 (reliable), and 0.81-1.00 (very reliable).

Table 3. Reliability data of learning interest questionnaires

Item Number	Item Variant Value	Number of Item Variants	Total Number of Variants	Reliability
1	1.063	23.453	174.5263	0.91118
2	0.576			
3	0.450			
4	1.145			
5	0.737			
6	1.713			
7	1.103			
8	0.976			
9	0.642			
10	1.566			
11	0.800			
12	1.211			
13	1.579			
14	1.358			
15	2.211			
16	0.958			
17	0.747			
18	1.292			
19	1.326			
20	2.000			

Based on the Cronbach alpha test conducted using MS Excel, the 20-item interest questionnaire demonstrated a reliability level of 0.91118, placing it firmly within the "very reliable" category. This high reliability indicates that all the statement items within the questionnaire were dependable for measuring students' learning interests. Furthermore, a reliability test was performed on the self-efficacy questionnaires, utilizing the Cronbach alpha test in MS Excel. The results of this analysis are presented in Table 4.

Table 4. Reliability data for students' self-efficacy questionnaire

Item Number	Item Variant Value	Number of Item Variants	Total Number of Variants	Reliability
1	1.937			
2	1.503			
3	2.095			
4	1.432			
5	1.924			
6	2.737			
7	1.526			
8	1.747			
9	1.747			
10	1.747			
11	2.011			
12	1.747			
13	1.397			
14	1.147			
15	1.432			
16	1.747			
17	1.937			
18	1.503			
19	2.095			
20	1.432	68.587	1380.871	0.90
21	1.937			
22	1.503			
23	2.095			
24	1.432			
25	1.734			
26	1.432			
27	1.432			
28	1.734			
29	1.747			
30	1.432			
31	1.905			
32	1.432			
33	1.937			
34	1.503			
35	2.095			
36	1.432			
37	1.937			
38	1.503			
39	2.095			
40	1.432			

Based on the calculation using the Cronbach alpha test in the MS Excel program, the reliability level of self-efficacy questionnaires consisting of 40 statements was 0.90, indicating it was included in the very reliable category. This suggested that all the statement items of the questionnaires were reliable for measuring students' self-efficacy while learning using the PjBL model.

Hypothesis testing

1. Descriptive statistics

Table 6. Descriptive statistics

Variables	Class	Mean	N
PjBL (Students Activities)	Experimental	54.07	28
Learning Interest		70.14	
Self-Efficacy		64.71	

The average post-test value for the experimental group was 54.07, 70.14, and 64.71 for students' activity (observation), learning interest (interest questionnaire), and self-efficacy (self-efficacy questionnaire), respectively. The experiment was carried out with 28 students from eleventh-grade who were taught about two-variable linear equation systems using the PjBL model.

2. Prerequisite test

Before testing the hypothesis using the MANOVA test, a variance homogeneity test was performed to determine whether the data obtained from the experimental group had the same or different variances. This test used data collected from the group to conduct the homogeneity test by interpreting the significance value. A significance value ≥ 0.05 suggested the same variances, but a significance value ≤ 0.05 implied distinct variances. The homogeneity test in this research was conducted using SPSS 22, and the results were obtained through the Levene test, as shown in Table 7.

Table 7. Results of the variance homogeneity test

Levene's Test of Equality of Error Variances[a]				
	F	**df1**	**df2**	**Sig.**
Learning Interest	.	14	13	.
Self-Efficacy	2.388	14	13	.063

The null hypothesis showed that the error variance of the dependent variable was equal across groups.
a. Design: Intercept + X

Hypothesis:

Ho: Variation in each group was homogeneous

Ha: Variation in each group was not homogeneous

The Levene's test results showed that the significance value for students' learning interest and self-efficacy questionnaires was 0.63. When the significance value was more significant

than 0.05, Ho was accepted, suggesting that the questionnaire data had a homogeneous variance.

MANOVA test

Once the two prerequisites for hypothesis testing were satisfied, the MANOVA test was employed to ascertain whether significant differences existed among several dependent variables across different groups.

Table 8. Results of subject effects with the MANOVA test

Tests of Between-Subjects Effects						
Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	Learning Interest	2916.107[a]	14	208.293	150.434	.000
	Self-Efficacy	4891.714[b]	14	349.408	15.141	.000
Intercept	Learning Interest	82567.863	1	82567.863	59632.346	.000
	Self-Efficacy	71915.549	1	71915.549	3116.340	.000
X	Learning Interest	2916.107	14	208.293	150.434	.000
	Self-Efficacy	4891.714	14	349.408	15.141	.000
Error	Learning Interest	18.000	13	1.385		
	Self-Efficacy	300.000	13	23.077		
Total	Learning Interest	140835.000	28			
	Self-Efficacy	122454.000	28			
Corrected Total	Learning Interest	2934.107	27			
	Self-Efficacy	5191.714	27			

The hypotheses under consideration were:
H0: The PjBL model do not affect students' learning interests.
H1: The PjBL model do affect students' learning interests.
H0: The PjBL model do not affect students' self-efficacy.
H2: The PjBL model do affect students' self-efficacy.

The "Tests of Between-Subjects Effects" table provided the analysis of the relationship between students' activities using the PjBL model and their learning interest scores yielded an F-value of 150.434 with a significance level of 0.000, which is below the threshold of 0.05. This led to the rejection of H0 and the acceptance of H1, indicating that the PjBL model significantly impacts students' learning interests in eleventh-grade of Senior High School, and Similarly, the examination of the effect of the PjBL model on students' self-efficacy produced an F-value of 15.541 and a significance level of 0.000, which is also below 0.05. This result led to the rejection of H0 and the acceptance of H2, showing that the PjBL model significantly influences the self-efficacy of eleventh-grade students in Senior High School.

To gain deeper insights into the effect of the PjBL model on students' learning interest and self-efficacy, additional analyses were performed using Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, as detailed in Table 9. These analyses provided further validation and elaboration on the impact of the PjBL model on these variables.

Table 9. Results of multivariate tests with the MANOVA test

Multivariate Tests[a]						
Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Intercept	Pillai's Trace	1.000	28960.932[b]	2.000	12.000	.000
	Wilks' Lambda	.000	28960.932[b]	2.000	12.000	.000
	Hotelling's Trace	4826.822	28960.932[b]	2.000	12.000	.000
	Roy's Largest Root	4826.822	28960.932[b]	2.000	12.000	.000
X	Pillai's Trace	1.799	8.308	28.000	26.000	.000
	Wilks' Lambda	.001	24.811[b]	28.000	24.000	.000
	Hotelling's Trace	178.312	70.051	28.000	22.000	.000
	Roy's Largest Root	174.193	161.751[c]	14.000	13.000	.000

Hypothesis Test:
H0: The PjBL model do not affect students' learning interest and self-efficacy.
H3: The PjBL model do affect students' learning interest and self-efficacy.

The analysis revealed that the F-values obtained from Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root tests were below the 0.05 significance threshold. This outcome signifies that the F-values for these statistical tests were statistically significant, providing robust evidence against the H0. Consequently, H0 was rejected in favor of the alternative hypothesis (H3).

These results underscore that the PjBL model significantly influence students' learning interest and self-efficacy in eleventh-grade of Senior High School. The consistent significance observed across all the statistical tests further supports the conclusion that the PjBL model is an effective educational strategy for enhancing these key outcomes. The reliability of the findings across multiple analytical methods strengthens the argument that implementing the PjBL model can positively influence students' engagement and confidence in their learning process.

Determination coefficient test

Table 10 presents the R^2 values indicating the impact of the PjBL model on students' learning interest and self-efficacy in eleventh-grade of Senior High School. These results illustrate how well the PjBL model explains the variations in students' learning interests and self-efficacy. The R^2 values provide a quantitative measure of how much the PjBL model accounts for changes in these educational outcomes, offering insights into its effectiveness in enhancing students' engagement and confidence. By analyzing these R^2 values, we better understand how the PjBL model influences the targeted variables, highlighting its potential benefits in the educational context.

Table 10. Results of the PjBL model determination test on learning interest

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.858[a]	.735	.725	5.464

a. Predictors: (Constant), Students Activities

An R^2 value of 0.735 indicates that the PjBL model accounted for 73.5% of the observed variability in students' learning interests. This suggests that a significant portion of the variation in learning interest can be attributed to the PjBL model. However, the remaining 27.5% of the variation is attributed to other factors that were not considered within the scope of this study.

Furthermore, Table 11 comprehensively analyzes the influence exerted by the PjBL model on students' learning interests and self-efficacy among eleventh-grade Senior High School students. This table details the percentage of impact the PjBL model had on these variables, providing an in-depth view of how effectively the model contributed to student engagement and confidence changes. The breakdown in Table 11 enhances our understanding of the PjBL model's overall effectiveness and role in shaping students' educational experiences.

Table 11. Results of the PjBL model determination test on students' self-efficacy

Model Summary				
Model	**R**	**R^2**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.950[a]	.902	.898	4.423

a. Predictors: (Constant), Students Activities

An R^2 value of 0.902 indicates that the PjBL model accounted for a 90.2% variance in self-efficacy among eleventh-grade at Senior High School students. This high R^2 value reflects the model's ability to explain most variability in students' self-efficacy levels. However, the remaining 9.8% of the variance is attributed to other factors not explored in this research. These unexamined factors could include individual differences, external influences, or additional variables not included in the study's scope, which may also contribute to variations in students' self-efficacy.

Discussion

The results of this study have gone through a series of stages. Starting from data collection to data processing through SPSS. One of the most important aspects is data presentation. Based on the presentation of data and data analysis and hypothesis testing, the average value of student interest in learning is 70.14. For the average value of self-efficacy of 64.71. While the independent variable is student activity during the learning process using PjBL with an average value of 54.07. This study used an experimental class without a control class. Students selected as samples are students who have never been exposed to the material of the system of linear

equations of two variables, this is done to ensure the impact of PjBL on students' interest in learning and self-efficacy of students in learning the material.

PjBL helps create a pleasant learning atmosphere so that it can arouse interest in learning mathematics in every student. this will directly affect student self-efficacy. Students who have an interest in learning will believe that mathematics is easy and fun, they will be more active, ask and answer questions compared to students who do not believe in their abilities, they will be more silent and tend to be afraid. by using the MANOVA test, it is proven that PjBL can affect student interest in learning by 73.5% and also affect student self-efficacy by 90.2%, so PjBL can be used as a reference for teachers in high schools on the material of the system of linear equations.

Learning the system of linear equations of two variables implemented using the PjBL process trains students' skills to collaborate with each other, the research findings show that students have different skills, therefore, teachers must be able to see these different skills to unite them in groups to complement each other, this is in accordance with the opinion of Krulatz & Christison (2023) stating that collaboration skills will be maximised if directed to organise groups and determine the skills needed. The findings during learning using PjBL that students discuss and exchange opinions to solve the problems given, students share tasks according to their abilities. In addition. The ability of students to collaborate fosters higher-level thinking skills, such as analysis and evaluation, this is in accordance with the opinion of MA & Rong (2022) that students who have a high interest in learning and are supported by peer assistance and exchanging ideas will be able to solve problems related to problem analysis.

Furthermore, researchers also observed several factors that hindered the learning process and student collaboration while using PjBL, namely there were still some group leaders who were unable to organise their group members to work, this was due to the low ability of students in leadership and sharing, whereas according to Maxwell (2013) that a leader must be able to provide instructions and be easy to understand so that teamwork in solving problems will be easier. Leaders must also be able to motivate their members to achieve common goals. Supported by the opinion of McShane & Glinow (2010) that leaders must be able to provide direction and attract members to work together.

Other abilities such as experience and motivation also affect the success of PjBL, namely communication that is not established between teachers and students, so that students do not dare to express ideas to speak in public. Johnson & Johnson (2018) explained that communication is essential for the success of good co-operative learning. Effective communication can also improve students' collaboration skills. Effective communication is very important in learning, especially in project-based learning. Effective communication helps students understand the material presented, exchange ideas, and solve problems together. When students can communicate effectively, their collaboration skills will improve.

Conclusion

The PjBL model influence of the learning interest of Senior High school students based on the results and discussions presented in the previous section. This is because the PjBL model

activities always activate students to learn together in projects and collaboration with friends so as to generate student learning interest. Therefore, the application of the PjBL model has a positive impact on students who have low learning interest. This may also be due to the fact that mathematics is considered a difficult subject to understand and comprehend, so it is necessary for a variety of learning models to play an important role in creating a pleasant learning atmosphere. From this study it was also found that interest in learning plays an important role in fostering students‘ self-efficacy. because with interest in learning, students’ confidence in completing the learning process also increases. this means that in learning mathematics that the most important thing that teachers must understand is how to create interesting mathematics for students, it can be seen from the determinant coefficient test that as interest in learning increases, self-efficacy also increases. so that the main target of an educator is interest in learning mathematics.

The outline in this study shows that the material of linear equations of two variables taught using PjBL has a positive effect on interest in learning mathematics and self-efficacy through learning to collaborate with group members to solve common goals, but several aspects need to be considered so that learning achieves maximum results, this implies that every teacher who uses project-based learning must continue to monitor the condition of students in the group, the development of students' collaboration skills must be supported by the ability of each member to lead and direct the tasks of each member. Teachers must be able to condition students in groups with diverse individual abilities and tasks designed to explore collaboration skills. Future research is expected to involve technology in PjBL learning so that the learning atmosphere becomes more enjoyable while still paying attention to students' abilities. Given the limited sample, the findings are considered provisional until further verification can be obtained from more extensive research. Nevertheless, these findings provide a rationale for further research on the implementation of teaching the system of linear equations of two variables through PjBL learning, and this study can provide insight into the development of interest in learning mathematics and self-efficacy with its causal factors.

Acknowledgment

The researchers would like to thank the Faculty of Teacher Training and Education, Universitas Muhammadiyah Sumatera Utara, for the support and permission given so that this research can be carried out well, as well as the practitioners, Co-Author and principal for the help and permission given to carry out research at the school.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, multiple publications and/or submissions, and redundancy, have been resolved by the authors.

Funding Statement

This work received no specific grant from any public, commercial, or not-for-profit funding agency

Author Contributions

Arief Aulia Rahman: writing - original draft; **Nyak Wha Usalmy:** Instrument administration; **César Hernández** and **Craig N Refugio:** Validate instrments, analyze the data.

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