JPPIPA 11(6) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Influence of STEAM Integrated PjBL Learning Model on Communication Skills, Critical Thinking Skills and Problem-Solving Skills of Students in Biology Subject

Iin Anugrahsari[1]*, Nurhayati B[1], Syamsiah[1]

[1]Biology Education, Faculty of Mathematics and Natural Sciences, Makassar State University, Makassar, Indonesia.

Received: April 19, 2025
Revised: June 15, 2025
Accepted: June 25, 2025
Published: June 30, 2025

Corresponding Author:
Iin Anugrahsari
Iinanugrahsari2013@ac.id

DOI: 10.29303/jppipa.v11i6.11411

Abstract: 21st century education requires students to be more independent in learning. However, the integration of Project Based Learning (PjBL) with STEAM has not been widely explored. This study aimed to examine the effect of the STEAM-integrated PjBL model on students' communication, critical thinking, and problem-solving skills. Using a quasi-experimental design with a pretest-posttest control group, the experimental class was taught using PjBL-STEAM, while the control class used Direct Instruction. Results showed that the experimental class had a greater improvement than the control. In critical thinking, 16 of 33 students in the experimental class were in the very high category, compared to only 3 in the control class. In problem-solving, 3 students in the experimental class were in the very high category and 27 in the high category, while the control class had none in the very high and only 12 in the high category. Observation of communication skills showed 30% of the experimental class were in the very high oral category and 18% in written, while only 3% in the control class reached this level. In conclusion, the PjBL-STEAM model positively influences students' communication, critical thinking, and problem-solving skills.

Keywords: Communication Skills; Critical Thinking; PjBL; STEAM; Problem Solving

Introduction

The quality of education in Indonesia is still relatively low compared to other Asian countries. The Political and Economic Risk Consultant (PERC) survey ranked Indonesia 12th out of 12 Asian countries, even below Vietnam. The World Economic Forum also reported that Indonesia's competitiveness is only ranked 37th out of 57 countries, and is only considered a follower in mastering technology. The low quality of education is influenced by various factors such as the effectiveness and efficiency of teaching, the quality of facilities and infrastructure, the low quality of teachers, and the lack of relevance of education to the needs of the times (Hidayat, 2012).

The learning system in schools tends to emphasize the quantity of results, not the quality of the process. The curriculum, learning process, and evaluation do not fully reflect the goals of national education (Arsy, 2021). To overcome this, the government developed the Independent Curriculum which emphasizes the importance of developing 21st century skills, such as communication, critical thinking, problem solving, and collaboration. However, the implementation of this curriculum-based learning has not been optimal. The problems that occur start from the low communication skills, critical thinking skills, and problem-solving skills of students. The lack of communication skills of students can be proven from several previous studies, such as research by (Ariani & Sari, 2019) at SMA Plus Negeri 7 Bengkulu City showing that many students still lack confidence in communicating. Problems with communication skills at the junior high school level also occur, according to (Nurlailasari et al., 2018) students' communication skills in science learning are still relatively low. Although learning activities have been designed referring to student activities, there are still students who are passive in discussions. Another study

How to Cite:
Anugrahsari, I., Nurhayati B, N. B., & Syamsiah, S. (2025). The Influence of STEAM Integrated PjBL Learning Model on Communication Skills, Critical Thinking Skills and Problem-Solving Skills of Students in Biology Subject. *Jurnal Penelitian Pendidikan IPA*, *11*(6), 670–687. https://doi.org/10.29303/jppipa.v11i6.11411

conducted by (Aris Pangestu et al., 2023) showed that students were less active in speaking in the learning process and had to be encouraged or assisted by the teacher so that they were willing and brave enough to speak or convey their ideas and thoughts.

Other problems such as low critical thinking skills of students can also be seen in research conducted by (Alawiyah, Nida; Marlina, 2019) which stated that students' ability to interpret was 48.80% in the very low category. The cause of low interpretation skills of students is because students are not used to interpreting information in the form of graphs or images and the lack of critical thinking practice questions given to students. These results are in line with previous research by (Fithriyah et al., 2016), which shows that students with low critical thinking skills are often only able to understand information partially without being able to link various relevant concepts.

Meanwhile, the problem of low problem-solving ability was revealed by the results of (Karmana, 2015), that the biology problem-solving ability of students at SMAN 3 Mataram, SMAN 6 Mataram, and SMAN 8 Mataram was still categorized as lacking. Students' problem-solving ability is still low. This can be proven by the number of students who have low category problem-solving ability of more than 50%.

In fact, these three things are important and interrelated in supporting the learning process. Problem-solving skills are closely related to critical thinking skills and communication skills. The higher a person's critical thinking skills, the more they are able to solve problems by utilizing a deep knowledge base. Meanwhile, when students' problem-solving skills are honed, it also affects the improvement of reasoning skills related to critical thinking skills (Su et al., 2016). Not only critical thinking skills, communication skills are also closely related to problem-solving skills. Communication skills acquired through classroom activities will make it easier for them to solve problems (La'ia & Harefa, 2021). The explanation above clearly shows that critical thinking and communication skills are essential in improving problem-solving skills. This has an impact on the methods and solutions a person chooses when solving problems.

Observation results that have been carried out at SMA Negeri 18 Makassar also show low communication skills, critical thinking, and problem solving due to the implementation of learning that has not used a certain model in a structured manner. An effective learning process is greatly influenced by the learning model and teacher personality (D. J. Putri et al., 2017). Models such as Project Based Learning (PjBL) provide opportunities for students to be active, independent, and collaborative in producing real products. PjBL can be increased in effectiveness through integration with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach which encourages creativity, problem solving, and meaningful learning in real contexts (Arsy, 2021).

The STEAM-based PjBL approach emphasizes the collaborative design and problem-solving process through five stages: reflection, research, discovery, application, and communication (Nurhayati B et al., 2023). This approach is very relevant to be applied in environmental change materials that require conceptual understanding and high-level thinking skills. The application of the STEAM-integrated PjBL model has been proven to improve students' collaboration, communication, critical thinking, and problem-solving skills (Arisya et al., 2022) dalam (Fitriyah & Ramadani, 2021). Based on this background, this study aims to determine the effect of the STEAM-integrated PjBL learning model on students' communication skills, critical thinking skills, and problem-solving skills in biology subjects phase E at SMA Negeri 18 Makassar.

Method

Type of Research and Research Design

The research conducted was Quasi experiment. The design of this study used pretest-posttest control group design.

Time and Place of Research

This research was conducted in August 2024-March 2025. The proposal preparation stage in August 2024, the Validation stage of learning devices and instruments in November 2024. The Research Stage January-March 2025 in the second semester (even) of the 2024/2025 Academic Year. This research was conducted at SMAN 18 Makassar, precisely in Komp. Mangga Tiga Permai Daya, Paccerakkang, Kec. Biringkanaya, Makassar City, South Sulawesi 90241.

Population and Sample

The population taken in this study were all students of class X of SMA Negeri 18 Makassar and the samples used were classes X.5 and X.9. The collection of research data was carried out by conducting pretest-posttest tests which were used to measure students' critical thinking and problem solving skills and to measure the communication skills of the students themselves, the researcher used a communication skills observation sheet.

Research Stages

The learning stage begins with experimental class treatment and the control class is given an initial test (pretest) which aims to determine the initial abilities of

students towards the material. Furthermore, students in the experimental class will be taught by applying the PjBL-STEAM learning model and for the control class itself will be taught with the Direct Instructiron model. At the discussion stage, students will be assessed by 2 observers to determine how the students' communication skills are. The final stage, both classes, namely the experimental and control classes, are given a posttest to determine how the critical thinking and problem-solving skills of students from both classes are.

Data Analysis

Data analysis was conducted using descriptive statistical analysis and inferential statistical analysis. Descriptive statistical analysis aims to describe students' communication skills, critical thinking skills, and problem-solving skills obtained by students both through the application of PjBL-STEAM and Direct Instruction learning which consists of mean value, standard deviation, highest value (maximum), and maximum value lowest (minimum) using the Statistical Package for Social *Science*(SPSS) Version 23.0. Analysis of test results and observations was conducted to determine students' critical thinking and problem-solving skills and communication skills. This was done by calculating the percentage of initial test scores (pretest) and final test scores (post test) uses the formula as follows:

$$\text{Percentage} = \frac{skor\ jawaban\ benar}{skor\ maksimal}\ x\ 100\% \quad (1)$$

The results obtained from the observation sheet are then interpreted in category of student activity percentage. The percentage of student activity can be seen in Table 1.

Table 1. Student Communication Skills Score Category

Score	Category
x ≥ 90	Very high
75 ≤ x < 90	Tall
60 ≤ x < 75	Currently
40 ≤ x < 60	Low
x < 40	Very Low

Source: (Rachman, 2012)

The value obtained from the essay test is used for Measuring students' critical thinking skills can be categorized as follows (Table 2).

Table 2. Critical Thinking Skills Categories

Assessment Interval	Category
81-100	Very high
61-80	Tall
41-60	Currently
21-40	Low
0-20	Very Low

Source: (Wayudi, Mauliana; Suwatno; Santoso, 2020)

The value obtained from the essay test is used for Measuring students' problem-solving abilities can be categorized as follows (Table 3).

Table 3. Categorization of Problem-Solving Skills

Mark	Category
0 < x ≤ 40	Very Low
40 < x ≤ 50	Low
50 < x ≤ 70	Currently
70 < x ≤ 90	Tall
90 < x ≤ 100	Very high

Source: (Nuryana & Rosyana, 2019)

Meanwhile, inferential statistical analysis is used to test hypotheses. research through the Statistical Package for Social Science (SPSS) version 23 system with parametric statistical analysis for communication skills, critical thinking skills, and problem solving skills. The parametric statistical analysis used was ANACOVA. Before testing the hypothesis, a normality test and a variance test are first carried out. homogeneity. The normality test is used to determine the distribution of samples. used in the study. The normality test was conducted using Kolmogrov-Smirnov analysis using the Statistical Package for Social Science version 23 for Windows with the test criteria, namely the research sample is normally distributed if the significant value (2-tailed) > α 0.05 and for the research sample is not normally distributed if the significant value (2-tailed) < α 0.05.

The homogeneity test is carried out to determine the level of homogeneity of the data. obtained from both treatment groups. Homogeneity test using Levene *Statistics*with the criteria if the Levene Statistic value > 0.05 then it can be said that the data variation is homogeneous and if the Levene Statistic < 0.05 then the data variation not homogeneous. Data that has been proven to be normally distributed and has a variance homogeneous will then be tested using t-test analysis, to Hypothesis testing. Hypothesis testing is carried out to find out whether There is an influence of the implementation of the PJBL model on student learning outcomes. The data tested is the difference between the pretest and posttest scores in the experimental class and the control class control using the Statistical Package for Social Science program (SPSS) version 23 for windows. The test criteria are if sig (2-tailed) > a, then H0 is accepted and H1 is rejected, which means there is no the influence of the PjBL-STEAM model on communication skills, critical thinking skills, and problem-solving skills of students and if sig (2-tailed) < a, then H0 is rejected and H1 is accepted which means there is there is an influence of the PjBL model on student activities and learning outcomes.

Results and Discussion

The results of this study show differences in communication skills, critical thinking skills, and problem-solving skills of students through the Project Based Learning learning model (experimental class), the Direct Instruction learning model (control class) at SMA Negeri 18 Makassar.

Descriptive Statistical Analysis Results
Oral Communication Skills

The assessment of students' oral communication skills was measured using an oral communication skills observation sheet. The oral communication skills observation sheet consists of 5 indicators, then the observer was asked to provide a score that was available on the observation sheet when the students made a presentation in front of the class. The results of the oral communication skills data acquisition can be seen in Table 4.

Table 4. Distribution of Descriptive Statistical Values of Students' Oral Communication Skills

Statistics	Student Oral Communication Skills Score	
	PjBL-STEAM Model	Direct Instruction Model
Lowest Value	65.00	50.00
The highest score	95.00	90.00
Average	81.97	69.68
Standard Deviation	8.10	11.18
Number of Samples	33	33

Based on Table 4, it shows that the highest score in the class taught with the PjBL-STEAM model is 95.00 and the highest score in the class taught with the Direct Instruction model is 90.00. While the average score in the class taught with the PjBL-STEAM model is 81.97 ± 8.10 and the average in the class taught with the Direct Instruction model is 69.68 ± 11.18. The results of these averages can show that the class taught with PjBL-STEAM has a higher score than the class taught with the Direct Instruction class. Based on the overall value of oral communication skills obtained by students, it can be categorized in Table 5.

Table 5. Distribution and Percentage of Students' Oral Communication Skills

Interval	Category	PjBL-STEAM Model		Direct Instruction Model	
		F	%	F	%
x ≥ 90	Very high	10	30	1	3
75 ≤ x < 90	Tall	20	61	14	43
60 ≤ x < 75	Currently	3	9	11	33
40 ≤ x < 60	Low	0	0	7	21
x < 40	Very Low	0	0	0	0
	Amount	33	100	33	100

F: Frequency
%: Percentage

Table 5 shows that students in the class taught with PjBL-STEAM have oral communication skills that are in the very high category and most of them are in the high category. This is proven by 30% of students being in the very high category and 61% of students being in the high category. While in the class taught with Direct Instruction, it shows that only 3% of oral communication skills are in the very high category and 43% are in the high category. The frequency data can be seen more clearly in Figure 1.

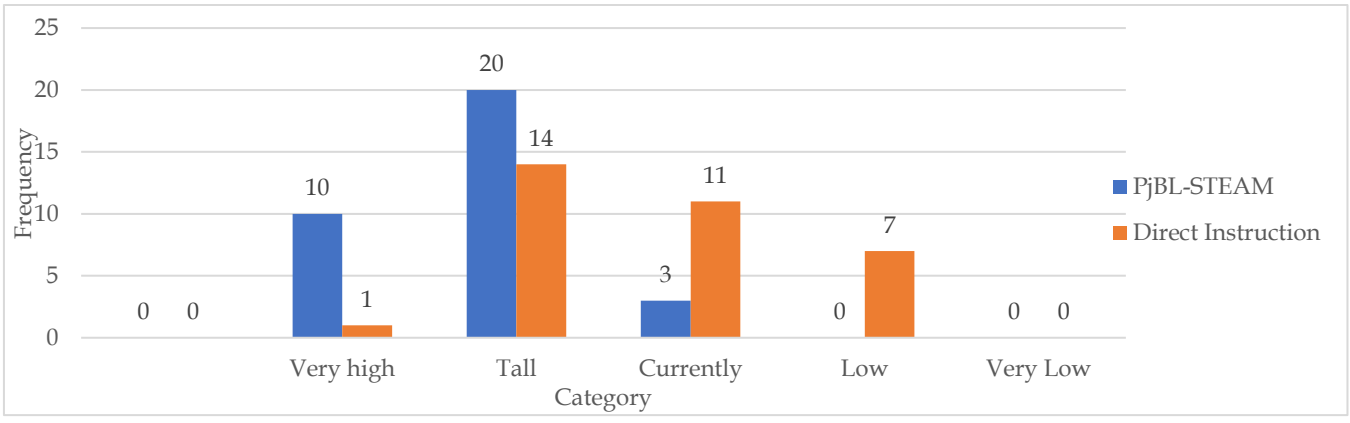

Figure 1. Frequency Distribution Diagram of Students' Oral Communication Skills

Based on the graph in Figure 1, it can be seen that there is a difference in the range of oral communication skills scores in classes taught using the PjBL-STEAM model and classes taught using the Direct Instruction model. In the PjBL-STEAM class, the scores are dominated by those in the high category and there are no students who have scores in the low category. While in the Direct Instruction class, although the scores are also dominated by those in the high category, they are not as many as in the class taught using PjBL-STEAM and there are still many students who are in the medium category.

Written Communication Skills

The assessment of students' written communication skills was measured using a written communication skills observation sheet. The written communication skills observation sheet consists of 4 indicators, then the observer was asked to give a score on the observation sheet that had been given when checking the reports that had been worked on by the students. The results of the communication skills data acquisition in the experimental class can be seen in Table 6.

Table 6. Distribution of Descriptive Statistical Values of Students' Written Communication Skills

Statistics	Student Written Communication Skills Score	
	PjBL-STEAM Model	Direct Instruction Model
Lowest Value	56.00	50.00
The highest score	94.00	94.00
Average	81.11	72.35
Standard Deviation	9.36	10.83
Number of Samples	33	33

Based on Table 6, it shows that the highest value in the class taught with the PjBL-STEAM model is 94.00 and the highest value in the class taught with the Direct Instruction model is 94.00. While the average value in the class taught with the PjBL-STEAM model is 81.11 ± 9.36 and the average in the class taught with the Direct Instruction model is 72.35 ± 10.83. The results of these averages can show that the class taught with PjBL-STEAM has a higher value than the class taught with the Direct Instruction class. Based on the overall value of written communication skills obtained by students, they can be categorized in Table 7.

Table 7. Distribution and Percentage of Students' Written Communication Skills

Interval	Category	PjBL-STEAM Model		Direct Instruction Model	
		F	%	F	%
x ≥ 90	Very high	6	18	1	3
75 ≤ x < 90	Tall	23	70	16	49
60 ≤ x < 75	Currently	3	9	12	36
40 ≤ x < 60	Low	1	3	4	12
x < 40	Very Low	0	0	0	0
	Amount	33	100	33	100

F: Frequency
%: Percentage

Table 7 shows that students in classes taught with PjBL-STEAM have written communication skills that are in the very high category and most of them are in the high category. This is proven by 18% of students being in the very high category and 70% of students being in the high category. While in classes taught with Direct Instruction, it shows that only 3% of oral communication skills are in the very high category and 49% are in the high category. The frequency data can be seen more clearly in Figure 2.

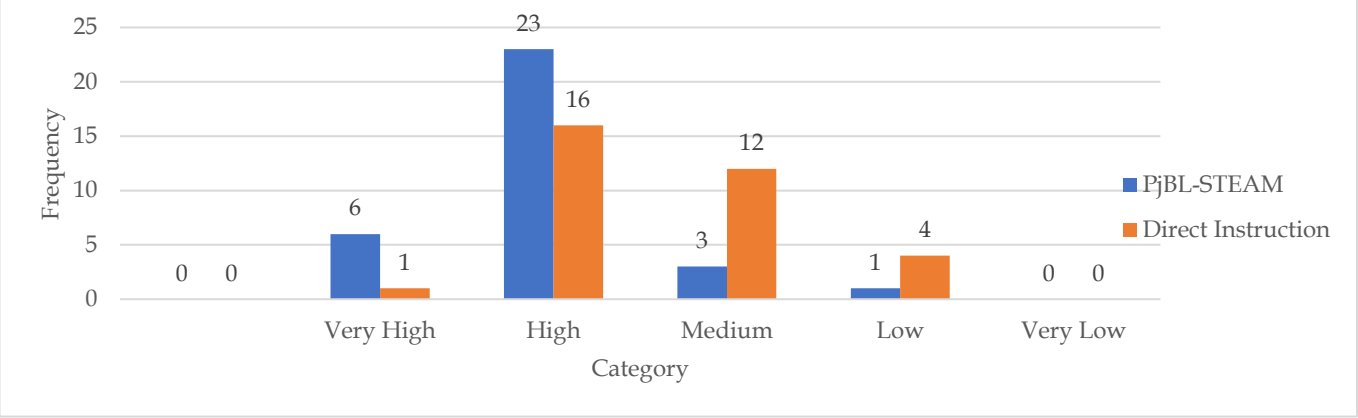

Figure 2. Frequency Distribution Diagram of Students' Written Communication Skills

Based on the graph in Figure 2, it can be seen that there is a difference in the range of written communication skills scores in classes taught using the PjBL-STEAM model and classes taught using the Direct Instruction model. In the PjBL-STEAM class, the scores are dominated by those in the high category and only a few students have scores in the low category. While in the Direct Instruction class, although the scores are also dominated by those in the high category, they are not as many as in the classes taught using PjBL-STEAM and there are still many students in the medium category.

Critical Thinking Skills of Students

The assessment of students' critical thinking skills used before and after learning is measured using a critical thinking skills test. The critical thinking skills test consists of 5 questions in the form of essays, then students are asked to provide answers where each answer is given a score. The results of the critical thinking skills test data can be seen in Table 8.

Table 8. Results of Descriptive Analysis of Students' Critical Thinking Skills

Statistics	Critical thinking ability value of students			
	PjBL-STEAM Model		Direct Instruction Model	
	Pretest	*Posttest*	*Pretest*	Posttest
Lowest Value	30.00	65.00	20.00	45.00
The highest score	65.00	95.00	55.00	90.00
Average	45.76	81.97	42.12	70.91
Standard Deviation	8.11	8.19	7.61	10.11
Number of Samples	33	33	33	33

Table 8 shows that the highest score in the class taught by PjBL-STEAM is 95.00 and the highest score in the class taught by the Direct Instruction model is 90.00. While the average score in the class taught by PjBL-STEAM is 81.97 ± 8.19 and the average in the class taught by the Direct Instruction model is 70.91 ± 10.11. The results of these averages can show that the class taught by PjBL-STEAM has a higher score than the class taught by Direct Instruction. Based on the overall critical thinking ability scores obtained by students, they can be categorized as in Table 9.

Table 9. Frequency Distribution and Percentage of Critical Thinking Ability Value Categories of Students

Interval	Category	PjBL-STEAM Model				Direct Instruction Model			
		Pretest		Posttest		Pretest		Posttest	
		F	%	F	%	F	%	F	%
81-100	Very high	0	0	16	48	0	0	3	9
61-80	Tall	1	3	17	52	0	0	23	70
41-60	Currently	21	64	0	0	16	49	7	21
21-40	Low	11	33	0	0	16	48	0	0
0-20	Very Low	0	0	0	0	1	3	0	0
Amount		33	100	33	100	33	100	33	100

F: Frequency
%: Percentage

Table 9 shows that students in the experimental class who initially obtained scores that were mostly in the low category in the pretest obtained high scores after receiving treatment in the form of being taught with the PjBL-STEAM model. This is evident from 33% of students who were in the low category, after being taught with the PjBL-STEAM model experienced an increase, namely 48% of students were in the very high category, 52% were in the high category, and there were no students in the medium or low categories.

As for students in the control class, from 48% of students who initially obtained grades in the low category, after being taught with the Direct Instruction model, 9% were in the very high category, 70% were in the high category, and 21% were in the medium category. This was obtained after students were taught with the Direct Instruction model. The frequency distribution graph of critical thinking skills can be seen in Figure 3.

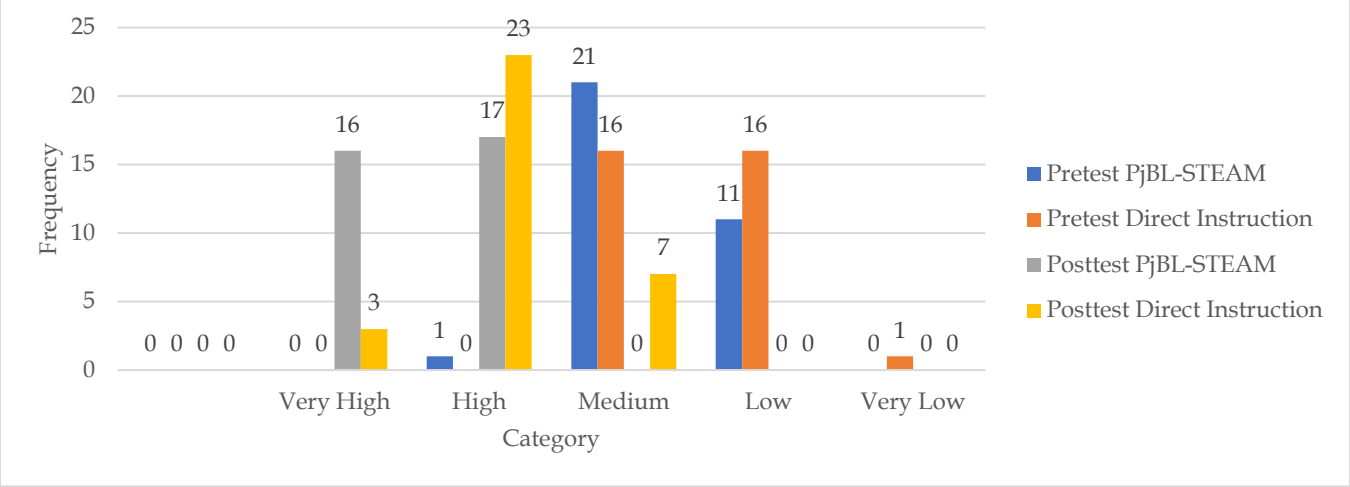

Figure 3. Frequency Graph of Students' Critical Thinking Skills

Based on the graph in Figure 3, it can be seen that there is a difference in the range of critical thinking ability values in the experimental class using the PjBL-STEAM model and the critical thinking ability values in the control class using the Direct Instruction model. In the experimental class after being taught with the PjBL-STEAM model, the values dominated by the very high and high categories. While in the control class after being taught with the Direct Instruction model, the values dominated by the high and medium categories.

Students' Problem-Solving Ability

Assessment of students' problem-solving abilities used before and after learning is measured using a problem-solving ability test. The problem-solving ability test consists of 5 questions in the form of essays, then students are asked to provide answers where each answer is given a score. The results of the critical thinking ability test data can be seen in Table 10.

Table 10. Results of Descriptive Analysis of Students' Problem-Solving Abilities

Statistics	Student Communication Skills Value			
	PjBL-STEAM Model		Direct Instruction Model	
	Pretest	Posttest	Pretest	Posttest
Lowest Value	15.00	65.00	15.00	45
The highest score	65.00	95.00	55.00	85
Average	37.12	81.97	36.82	67.27
Standard Deviation	9.44	8.19	8.08	10.01
Number of Samples	33	33	33	33

Table 10 shows that the highest score in the class taught by PjBL-STEAM is 95.00 and the highest score in the class taught by the Direct Instruction model is 85.00. While the average score in the class taught by PjBL-STEAM is 81.97 ± 8.19 and the average in the class taught by the Direct Instruction model is 67.27 ± 10.01. The results of these averages can show that the class taught by PjBL-STEAM has a higher score than the class taught by Direct Instruction. Based on the overall problem-solving ability scores obtained by students, they can be categorized as in Table 11.

Table 11. Frequency Distribution and Percentage of Categories of Students' Problem-Solving Ability Values

Interval	Category	PjBL-STEAM Model				Direct Instruction Model			
		Pretest		Posttest		Pretest		Posttest	
		F	%	F	%	F	%	F	%
0 < x ≤ 40	Very Low	23	70	0	0	24	73	0	0
40 < x ≤ 50	Low	9	27	0	0	8	24	3	9
50 < x ≤ 70	Currently	1	3	3	9	1	3	18	55
70 < x ≤ 90	Tall	0	0	27	82	0	0	12	36
90 < x ≤ 100	Very high	0	0	3	9	0	0	0	0
Amount		33	100	33	100	33	100	33	100

F: Frequency
%: Percentage

Table 11 shows that students in the experimental class who initially obtained scores that were mostly in the low category on the pretest obtained high scores after receiving treatment in the form of being taught with the PjBL-STEAM model. This is evident from 70% of students who were in the very low category, after being taught with the PjBL-STEAM model experienced an increase, namely 9% of students were in the very high category, 82% were in the high category, and 9% were in the medium category.

As for students in the control class, from 73% of students who initially obtained scores in the very low category, after being taught with the Direct Instruction model, there were no students in the very high category, but as many as 36% were in the high category, 55% were in the medium category, and 9% were in the low category. This was obtained after students were taught with the Direct Instruction model. The frequency distribution graph of problem-solving ability can be seen in Figure 4.

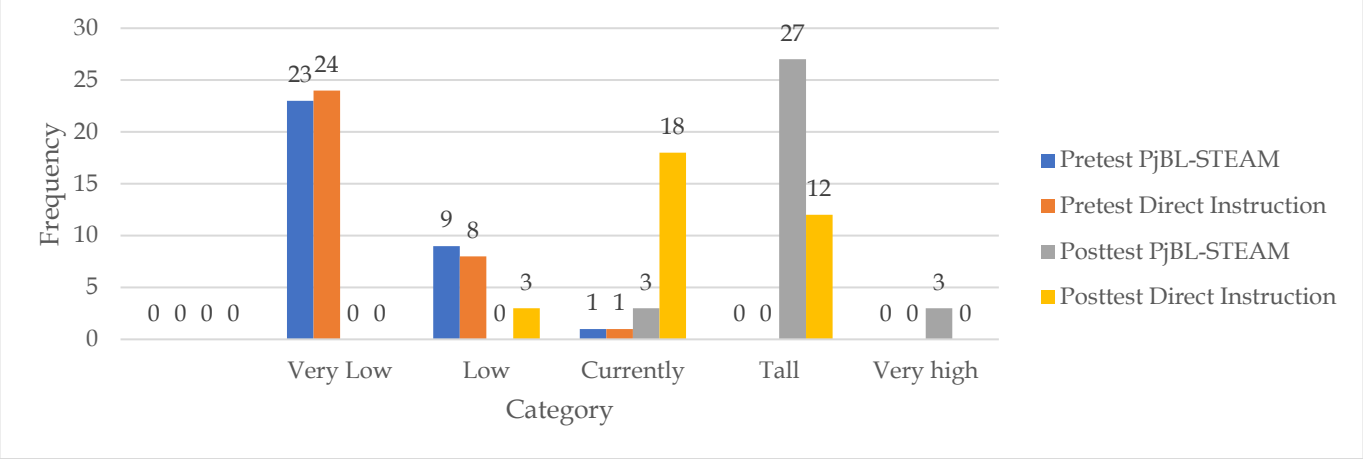

Figure 4. Frequency Graph of Students' Problem-Solving Abilities

Based on the graph in Figure 4, it can be seen that there is a difference in the range of problem-solving ability values in the experimental class using the PjBL-STEAM model and the problem-solving ability values in the control class using the Direct Instruction model. In the experimental class after being taught with the PjBL-STEAM model, the high category values dominate. While in the control class after being taught with the Direct Instruction model, the medium category values dominate.

Inferential Statistical Analysis Results

Inferential statistical analysis on the three dependent variables, namely communication skills, critical thinking, and problem solving, is explained as follows.

Oral Communication Skills of Students
Normality Test

The normality test was conducted on the data of oral communication skills results in classes taught with the PjBL STEAM model and the DI model. The normality test was used to determine whether the data was normally distributed or not. The results of the normality test on students' oral communication skills can be seen in Table 12.

Table 12. Normality Test of Students' Oral Communication Skills

Variables	Sig	Information
Oral Communication Skills Experimental Class	.087	Normal
Oral Communication Skills Control Class	.092	Normal

Based on Table 12, the results of the normality test using the Kolmogorov-Smirnov test obtained a significant value of the oral communication skills of the experimental class with the PjBL STEAM learning model, namely 0.087> α = 0.05, meaning that the value of oral communication skills can be stated as normally distributed. While the value of the oral communication skills of the control class with the Direct Instruction model has a significant value of 0.092> α = 0.05. This means that oral communication skills in the control class can be stated as normally distributed.

Homogeneity Test

Homogeneity tests are conducted to determine whether the sample variance is the same or not. Homogeneity test is conducted as one of the prerequisites in conducting hypothesis analysis. If the sample has the same variance, then both are said to be homogeneous. The results of the homogeneity test on

students' oral communication skills can be seen in Table 13.

Table 13. Homogeneity Test of Students' Oral Communication Skills

		Levene Statistics	df1	df2	Sig.
Mark	Based on Mean	2.911	1	64	.093
	Based on Median	2.628	1	64	.110
	Based on Median and with adjusted df	2.628	1	61.399	.110
	Based on trimmed mean	2.841	1	64	.097

Based on Table 13, the results of the homogeneity test of oral communication skills of students in the experimental class with the PjBL-STEAM model and the control class with the Direct Instruction model show that the data obtained have a significance value Based on Mean, namely 0.093> α = 0.05, so it can be concluded that the group variance in the experimental and control classes is the same or homogeneous.

Hypothesis Testing

Data from the results of hypothesis testing on students' oral communication skills can be seen in Table 14.

Table 14. Hypothesis Test of the Effect of the STEAM Pjbl Model on Students' Oral Communication Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2485.227a	1	2485.227	26,986	.000
Intercept	379545.833	1	379545.833	4121.341	.000
learning model	2485.227	1	2485.227	26,986	.000
Error	5893.939	64	92.093		
Total	387925.000	66			
Corrected Total	8379.167	65			

Based on Table 14, the hypothesis test of students' oral communication skills can be seen that the significance value for the influence of the learning model is 0.000. Referring to the hypothesis testing criteria, if the significance value is less than α = 0.05, then H0 is rejected and H1 is accepted. So, it can be concluded that there is an influence of the PjBL-STEAM model on oral communication skills.

Students' Written Communication Skills

Normality Test

The normality test was conducted on data of written communication skills in classes taught with the PjBL STEAM model and the DI model. The normality test was used to determine whether the data was normally distributed or not. The results of the normality test on students' written communication skills can be seen in Table 15.

Table 15. Normality Test of Students' Written Communication Skills

Variables	Sig	Information
Written Communication Skills Experimental Class	.087	Normal
Written Communication Skills Control Class	.088	Normal

Based on Table 15, the results of the normality test using the Kolmogorov-Smirnov test obtained a significant value of the written communication skills of the experimental class with the PjBL STEAM learning model, namely 0.087> α = 0.05, meaning that the value of written communication skills can be stated as normally distributed. While the value of the written communication skills of the control class with the Direct Instruction model has a significant value of 0.088> α = 0.05. This means that the written communication skills in the control class can be stated as normally distributed.

Homogeneity Test

The homogeneity test is conducted to determine whether the sample variance is the same or not. The homogeneity test is conducted as one of the prerequisites in conducting hypothesis analysis. If the samples have the same variance, then both are said to be homogeneous. The results of the homogeneity test on students' written communication skills can be seen in Table 16.

Based on Table 16, the results of the homogeneity test of written communication skills of students in the experimental class with the PjBL-STEAM model and the control class with the Direct Instruction model show that the data obtained has a significance value Based on Mean, namely 0.336> α = 0.05, so it can be concluded that the group variance in the experimental and control classes is the same or homogeneous.

Table 16. Homogeneity Test of Students' Written Communication Skills

		Levene Statistics	df1	df2	Sig.
Mark	Based on Mean	.939	1	64	.336
	Based on Median	.606	1	64	.439
	Based on Median and with adjusted df	.606	1	61,877	.439
	Based on trimmed mean	.876	1	64	.353

Hypothesis Testing

Data from the results of hypothesis testing on students' written communication skills can be seen in Table 17.

Table 17. Hypothesis Test of the Effect of the STEAM Pjbl Model on Students' Written Communication Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1265.470a	1	1265.470	12,352	.001
Intercept	388546.909	1	388546.909	3792.510	.000
learning model	1265.470	1	1265.470	12,352	.001
Error	6556.871	64	102,451		
Total	396369.250	66			
Corrected Total	7822.341	65			

Based on Table 17, the hypothesis test of students' written communication skills can be seen that the significance value for the influence of the learning model is 0.001. Referring to the hypothesis testing criteria, if the significance value is less than α = 0.05, then H0 is rejected and H1 is accepted. So it can be concluded that there is an influence of the PjBL-STEAM model on written communication skills.

Critical Thinking Skills of Students

Normality Test

The normality test was conducted on the data of critical thinking skills in classes taught with the PjBL STEAM model and the Direct Instruction model. The normality test was used to determine whether the data was normally distributed or not. The results of the normality test on students' critical thinking skills can be seen in Table 18.

Table 18. Normality Test of Students' Critical Thinking Abilities

Variables	Sig	Information
STEAM PjBL Model Pretest	.174	Normal
Posttest Model PjBL STEAM	.103	Normal
Pretest Direct Instruction Model	.079	Normal
Posttest Direct Instruction Model	.090	Normal

Based on Table 18, the results of the normality test using the Kolmogorov-Smirnov test obtained significant values of the pretest and posttest values of the problem-solving ability of the experimental class with the PjBl STEAM learning model. The significance value of the pretest problem-solving ability is 0.174> α = 0.05, meaning that the pretest value of the problem-solving ability can be stated as normally distributed. Furthermore, the significance value of the posttest problem-solving ability is 0.103> α = 0.05, meaning that the posttest value of the students' problem-solving ability is stated as normally distributed.

While the pretest and posttest values of the problem-solving ability of the control class with the Direct Instruction model. The significance of the pretest of problem-solving ability is 0.079> α = 0.05, meaning that the pretest of problem-solving ability can be stated as normally distributed. Furthermore, the posttest value of problem-solving ability obtained a significant value of 0.090> α = 0.05, meaning that the posttest value of students' problem-solving ability is stated as normally distributed.

Homogeneity Test

The homogeneity test is conducted to determine whether the sample variance is the same or not. The homogeneity test is conducted as one of the prerequisites in conducting hypothesis analysis. If the samples have the same variance, then both are said to be homogeneous. The results of the homogeneity test on students' critical thinking skills can be seen in Table 19.

Based on Table 19, the results of the homogeneity test of critical thinking skills of students in the experimental class with the PjBL-STEAM model and the control class with the Direct Instruction model show that the data obtained has a significance value Based on Mean, namely 0.221> α = 0.05, so it can be concluded that the group variance in the experimental and control classes is the same or homogeneous.

Table 19. Homogeneity Test of Students' Critical Thinking Skills

		Levene Statistics	df1	df2	Sig.
Mark	Based on Mean	1.489	3	128	.221
	Based on Median	1.487	3	128	.221
	Based on Median and with adjusted df	1.487	3	123.819	.221
	Based on trimmed mean	1.535	3	128	.209

Hypothesis Testing

Data from the results of hypothesis testing on students' critical thinking skills can be seen in Table 20.

Table 20. Hypothesis Test of the Influence of the STEAM Pjbl Model on Students' Critical Thinking Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1530.912a	2	765,456	7,356	.001
Intercept	14191.498	1	14191.498	136,385	.000
Pretest	167,275	1	167,275	1,608	.209
learning model	1513.688	1	1513.688	14,547	.000
Error	6555.452	63	104,055		
Total	383850.000	66			
Corrected Total	8086.364	65			

Based on Table 20, the hypothesis test of students' problem-solving abilities can be seen that the significance value for the influence of the learning model is 0.000. Referring to the hypothesis testing criteria, if the significance value is less than α = 0.05, then H0 is rejected and H1 is accepted. So it can be concluded that there is an influence of the PjBL-STEAM model on students' critical thinking abilities.

Students' Problem-Solving Skills

Normality Test

The normality test was conducted on the problem-solving ability data in classes taught with the PjBL STEAM model and the DI model. The normality test was used to determine whether the data was normally distributed or not. The results of the normality test on students' problem-solving abilities can be seen in Table 21.

Table 21. Normality Test of Students' Problem-Solving Abilities

Variables	Sig	Information
PjBL-STEAM Model Pretest	.092	Normal
Posttest of PjBL-STEAM Model	.153	Normal
Pretest Direct Instruction Model	.111	Normal
Posttest Direct Instruction Model	.082	Normal

Based on Table 21, the results of the normality test using the Kolmogorov-Smirnov test obtained significant values of the pretest and posttest values of the problem-solving ability of the experimental class with the PjBl STEAM learning model. The significance value of the pretest problem-solving ability is 0.092> α = 0.05, meaning that the pretest value of the problem-solving ability can be stated as normally distributed. Furthermore, the significance value of the posttest problem-solving ability is 0.153> α = 0.05, meaning that the posttest value of the students' problem-solving ability is stated as normally distributed.

While the pretest and posttest values of the problem-solving ability of the control class with the Direct Instruction model. The significance value of the pretest of problem-solving ability is 0.111> α = 0.05, meaning that the pretest of problem-solving ability can be stated as normally distributed. Furthermore, the posttest value of problem-solving ability obtained a significant value of 0.082> α = 0.05, meaning that the posttest value of students' problem-solving ability is stated as normally distributed.

Homogeneity Test

The homogeneity test is conducted to determine whether the sample variance is the same or not. The homogeneity test is conducted as one of the prerequisites in conducting hypothesis analysis. If the samples have the same variance, then both are said to be homogeneous. The results of the homogeneity test on students' problem-solving abilities can be seen in Table 22.

Based on Table 22, the results of the homogeneity test of the problem-solving abilities of students in the experimental class with the PjBL-STEAM model and the control class with the Direct Instruction model show that the data obtained has a significance value Based on Mean, namely 0.549> α = 0.05, so it can be concluded that the group variance in the experimental and control classes is the same or homogeneous.

Table 22. Homogeneity Test of Students' Problem Solvng Abilities

		Levene Statistics	df1	df2	Sig.
Mark	Based on Mean	.708	3	128	.549
	Based on Median	.587	3	128	.652
	Based on Median and with adjusted df	.587	3	123.975	.652
	Based on trimmed mean	.704	3	128	.551

Hypothesis Testing

Data from the results of hypothesis testing on students' problem-solving abilities can be seen in Table 23.

Table 23. Hypothesis Test of the Effect of the STEAM Pjbl Model on Students' Problem-Solving Abilities

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3820.434a	2	1910.217	23,620	.000
Intercept	15024.642	1	15024.642	185,777	.000
Pretest	256,419	1	256,419	3.171	.080
learning model	3529.536	1	3529.536	43,642	.000
Error	5095.096	63	80,875		
Total	376425.000	66			
Corrected Total	8915.530	65			

Based on Table 23, the hypothesis test of students' problem-solving abilities can be seen that the significance value for the influence of the learning model is 0.000. Referring to the hypothesis testing criteria, if the significance value is less than $\alpha = 0.05$, then H0 is rejected and H1 is accepted. So, it can be concluded that there is an influence of the PjBL-STEAM model on students' problem-solving abilities.

Based on the analysis of research data that has been conducted, the discussion of the research is intended to provide an explanation of the research results related to communication skills, critical thinking skills, and problem-solving skills of students. The discussion of the three variables is focused on the suitability between the research objectives and the research hypothesis. Experimental research on the effect of STEAM-integrated PjBL on communication skills, problem-solving skills, and critical thinking skills in Biology lessons on environmental change material for class X of SMA Negeri 18 Makassar. In the experimental class consisting of 9 meetings including 1 meeting for the pretest, 7 meetings for the learning process and 1 meeting for the posttest. While in the control class consisting of 6 meetings including 1 meeting for the pretest, 4 meetings for the learning process and 1 meeting for the posttest.

The Influence of the STEAM Integrated Project Based Learning (PjBL) Learning Model on Students' Communication Skills

Based on the research results that have been discussed previously, the use of PjBL-STEAM is able to improve students' communication skills compared to the application of Direct Instruction. This is shown that in contrast to the application of the PjBL-STEAM and Direct Instruction learning models which found students in the medium category, the combination of the PjBL and STEAM learning models did not find students in the low and very low categories. This is because in the application of STEAM-integrated PjBL there are discussion activities and direct work on a product related to the material. This activity is carried out in groups which stimulate students to convey concepts that are understood both verbally and in writing.

In this study, students were asked to create a product as a form of solution to overcome the problems that students had observed in the first phase, namely providing basic questions. Then from these basic questions, students will design a product by discussing it with their group members, this activity is a phase in PjBL-STEAM. Then entering the third phase, where students prepare a product making schedule together with the researcher (teacher). In the fourth phase, students will be monitored regarding the progress of the product they have made and what obstacles are the problems during the making of the product. The fifth phase tests the results each group will make a presentation in front of the class about the products they have made which is continued with a discussion session between groups. In the material on environmental change, students present products in the form of organic fertilizer, ecobricks, etc. During the presentation and discussion process, the observer makes an assessment by giving a score for the students' oral communication skills that are available on the observation sheet. The sixth phase is the evaluation of learning experiences students together with researchers draw conclusions from the results of the presentations and discussions that have been carried out to reach an understanding so that misconceptions do not occur and collect reports to

observers who will later be given a score on the observation sheet for students' written communication skills.

The process carried out in PjBL-STEAM learning that has been explained above certainly involves students' communication skills both verbally and in writing. This is because students are gradually encouraged at each phase in PjBL-STEAM to express their ideas in verbal form through discussions and presentations carried out in the learning process. Then students are also encouraged to express their written communication skills through reports that are made where of course students will express their understanding of the products they have made through research on several appropriate references into the form of writing. This is what influences why students' communication skills increase when using PjBL-STEAM.

This is in line with the opinion of (W. N. Putri & Ardi, 2023) that students' communication skills can be improved if during the learning process they are facilitated to communicate, discuss, and be able to present the results of what has been communicated, discussed previously in groups. (Nursyamsini, 2023) also explains that the Project Based Learning model has a more interesting and meaningful learning experience for students. Through this learning model, writing learning materials are linked to factual daily life problems. Students are asked to formulate hypotheses and problem solving. In this way, it will train students to think critically, motivate students to be active in learning, and make it easier to express their ideas based on concrete things.

Based on the explanation above, it can be concluded that communication skills can be improved through the PjBL-STEAM learning model or in other words, there is an influence of the PjBL-STEAM model on students' communication skills. This is in accordance with the results of research by (Nugroho et al., 2019) which shows that the Project Based Learning learning model influences students' communication skills in learning science.

The Influence of the STEAM-Based Project Based Learning (PjBL) Learning Model on Students' Critical Thinking Skills

Based on research conducted at SMA Negeri 18 Makassar, it shows that there is a significant influence of the PjBL learning model on the formation of students' critical thinking skills compared to the Direct Instruction learning model. This is shown that the PjBL-STEAM learning model is not included in the categorymedium, low and very low different from the Direct Instruction learning model, namely that there are students who are still in the categoryis good at environmental change material. This is because by using the PjBL-STEAM model, each student is required to provide a solution, so that in the problem-solving process carried out by students, it can form students' critical thinking skills. This can be seen from the student worksheets and direct observations of researchers, where students actively participate in learning to prepare questions, analyze and create answers and are active in expressing arguments, especially in discussion forums. This is in line with the opinion of (Melinda, Vina; Zainil, 2020) that PjBL allows students to be involved in challenging real projects and develop relevant critical thinking, skills and problem solving in real-life contexts. Moreover, with its integration with STEAM where according to (Hadinugrahaningsih et al., 2017) the STEAM approach seeks for students to create their own understanding of the learning process by combining some aspects of the field of study in real life.

The PjBL Learning Model itself makes students active in the learning process through projects that contain tasks from basic questions or problems that are continued with the process of searching, investigating, and so that students find, gain complete knowledge (Pratiwi et al., 2018). This is in line with several indicators of critical thinking where students are asked to be able to provide simple explanations, build basic skills, make conclusions, provide further explanations and organize strategies and tactics.

The first phase in PjBL is giving basic questions through a reflection and research approach. In this phase, students are asked to create a basic question after being shown a problem in the form of a video on the material of environmental change. Basic questions certainly come after determining what the problem is. This is in accordance with the opinion of (Rahayu & Hartono, 2016), namely determining the problem, consisting of identification, analysis and determining the problem. At each stage, students need to focus on identifying and analyzing various problem topics that will be determined to be studied in the project. In addition to focusing, students must also do the work and learn or study at each stage, namely completing each task that has become their responsibility by trying to dig up various information regarding the problem to be studied. This information can be obtained individually or from the surrounding environment. As for the activity of determining the problem, students will become more focused and responsible in identifying, analyzing, evaluating, and finding sources of information to make conclusions for completing the project.

The second phase, designing product planning with a discovery approach. In this phase, students will discuss with their group members to plan a product as a form of solution to the basic questions that arise in the first phase, of course in product planning, critical thinking is needed in building basic skills in students to

draw conclusions about what kind of solution is needed so that existing problems can be handled properly. In line with the opinion of (Hikmah et al., 2016) that in determining the design. requires reason and situation at each stage which of course requires critical thinking in it. Reason is needed so that students are able to provide accurate reasons according to the facts/evidence regarding various kinds of project design designs that will be used to match the initial objectives while the situation is needed so that students understand the key problems that cause the problem situation to be studied so that later students will easily determine the right design for the portfolio project. In addition to reason, students must also try to try, namely trying and trying various strategies to be able to realize the design into a real and quality portfolio. The reason is that the situation and try to try in the process of determining the design can foster students' understanding of the project and encourage students to be more active in exploring various information about the project design from various perspectives, and students are able to learn to be responsible for the design chosen for the project (portfolio).

The third phase, compiling a production schedule with a discovery approach. In this phase, students and teachers compile a product production schedule, which of course must be done carefully in compiling it to minimize errors in the product to be made, so that in this compilation critical thinking is needed. This is in line with the opinion of (Sukisno & Yuniarti, 2016) that it is necessary to do it with inference and overview, namely clarifying and re-checking the design design which is a part of critical thinking. Inference and overview are also needed in terms of implementing individual and group tasks, work schedules, materials & tools, to project completion deadlines in order to determine the accuracy of overview decisions, obey the rules are also needed by students in implementing the design, this is intended so that students can comply with the rules of the game/agreements that have been made so that the project being worked on remains in accordance with the design and does not deviate from the initial goal. Obey the rules is an important indicator because students are required to be responsible for complying with the agreements that have been made both in terms of timeliness and suitability of the material.

The fourth phase, monitoring the ty and development of the project with an application approach. In this phase, students will be monitored to what extent the project has been created by students regarding obstacles or things that need to be considered again so that the project is successful. The fifth phase, testing the results with a communication approach. In this phase, students will present the products they have created in front of the class, this encourages students to provide further explanations. In line with (Trisnadati, 2018) that in this phase critical thinking skills are needed in the form of explanation and clarity, namely activities for students to present the final results of the project and explain the reasons for the conclusions of the project that has been worked on. In addition, paying attention is also needed so that students remain attentive, focused, and consistent with the suitability of the material with the results of the project that will be presented until the conclusion is delivered.

The sixth phase, evaluation of learning experiences with a communication approach. At this stage, students will draw conclusions about the products and discussion results when making presentations which of course will be used as improvement materials to organize tactics and strategies if they are going to make the same product again, this is in line with the indicators in critical thinking, namely organizing strategies and tactics. (Insyasiska et al., 2015) argues that in critical thinking, the self-regulation aspect is the student's activity to thoroughly re-examine the students' understanding of the project presentation results, regarding whether the problems studied have been solved and whether the presentation material has been conveyed well. The aspect of responsibility as something that is given or taken is also needed at this stage so that students are able to have a response to be responsible for all work that has been given or taken, and to be cooperative with the consequences for work that is already their responsibility.

Based on the explanation above, it can be concluded that the use of the STEAM PjBL learning model in each phase greatly influences or PjBL influences students' critical thinking skills. This is in line with research conducted by (Fitriyah & Ramadani, 2021) which found that the application of the STEAM integrated PjBL model influenced students' creative and critical thinking skills.

The Influence of the STEAM-Based Project Based Learning (PjBL) Learning Model on Students' Problem-Solving Abilities

Based on the results of inferential analysis through ANACOVA testing, it was concluded that there is an influence of the PjBL-STEAM model on students' problem-solving abilities. This is reinforced by the results of the descriptive analysis of students' problem-solving abilities on environmental change material which increased from low to very high and high categories. The PjBL-STEAM model influences problem-solving abilities because it is in accordance with the steps of the PjBL-STEAM model.

The first phase, giving basic questions through a reflection and research approach, at this stage students are directed to face situations related to everyday life or

the surrounding reality. Since the beginning of the basic question-giving phase, students are given problems that are directed at STEAM solutions. This study uses several problems that are presented in the form of videos, in the material on environmental change, a video is shown of the accumulation of garbage that is so overflowing and other environmental problems. The purpose of the problems presented to students is to encourage the learning environment to be more active in finding solutions to the problems presented. In this phase, in accordance with the problem-solving indicators, students can identify/understand the problem.

This is in accordance with the opinion of (Larmer et al., 2015) that by emphasizing basic reality and problem solving, it can improve students' critical skills, including the ability to solve problems effectively. In addition, (Mulyani, 2019) also stated that STEAM in learning focuses on solving problems in real everyday life. STEAM shows students how concepts, principles, engineering, science, art, and mathematics are used in an integrated manner to develop products, processes, and systems that are beneficial to human life.

The second phase, designing product planning with a discovery approach, at this stage students who have been formed into heterogeneous groups together exchange opinions to find solutions to problems through student worksheets that have been given. Research helps students by providing suggestions and several sources that are relevant to solutions to problems in environmental change material and after being discussed with their respective group members, students are able to create a design for the product plan that will be made. This phase is the most capable of encouraging students' problem-solving abilities because at this stage they are asked to plan their product designs. The designs made by students are directed to refer to the integration of science, technology, engineering, art, and mathematics. At this phase, in accordance with the problem-solving indicator, namely planning a solution. This is in line with the research conductedby (Cunningham & Lachapelle, 2016) stated that introducing engineering principles through product design activities in schools can improve students' problem-solving abilities.

The third phase, preparing a schedule for making with a discovery approach, at this stage students are asked to prepare a schedule for making a project with their respective group members which will be carried out for one week. At this stage, what is done in addition to guiding students to determine their schedule, also guides students to find out what tools and materials are used in making their projects which are then written on the student worksheet. This is in line with research (Saadah & Mawardi, 2019) also explained that student enthusiasm increased because of project-based learning or interaction between students increased because they worked in groups.

The fourth phase, monitoring the activity and development of the project with an application approach. At this stage each group has designed a solution project to the problem. The activity of monitoring the activity and development of the student project is carried out in one meeting. (Larmer & Mergendoller, 2010) emphasize the importance of continuous assessment and monitoring of the activity and development of student projects in PjBL to ensure that learning objectives are achieved.

The fifth phase, testing the results with a communication approach. At this stage each group presents the results of their project and other groups provide responses to the project. With the discussion activities then continued with presentations, it will provide many opportunities for students to learn to communicate verbally. According to (Azis et al., 2018) that problem-solving skills cannot be obtained simply, they must be supported by active, communicative, and student-oriented learning so that they can help students solve the problems they face.

The sixth phase, evaluation of learning experiences with a communication approach. At this stage, researchers respond to each project produced by each group and then also provide conclusions and reflections on environmental change material. According to (Larmer et al., 2015), effective evaluation of learning experiences in PjBL helps teachers identify areas that need improvement and ensure that students get the full benefit of the project-based learning approach.

Based on the explanation above, it can be concluded that the application of the PjBL-STEAM model through six phases can affect students' problem-solving abilities. This is in line with the opinion of (Triprani et al., 2023) that the application of PjBL-STEAM learning can affect students' problem-solving abilities. The increase in problem-solving abilities occurs because at each meeting, students are trained to identify, analyze, conclude and create a work. Students in STEAM classes are required to solve real-world problems and are involved in ill-defined tasks to become well-defined outcomes through group collaboration (Lumbantobing & Azzahra, 2020).

Conclusion

Based on the research on the influence of STEAM-integrated PjBL on communication skills, critical thinking skills, and problem-solving skills of students, it was found that there was an influence of STEAM-integrated in SMA Negeri 18 Makassar. PjBL on students' communication skills both in oral and written communication skills. This is evidenced by the results of

the anacova test on oral communication skills with a significance value (sig. 2-tailed = 0.000 <0.05) and written communication skills (sig. 2-tailed = 0.001 <0.05), PjBL-STEAM also has an influence on students' critical thinking skills as evidenced by its significance value (sig. 2-tailed 0.001 <0.05) as well as on problem-solving skills as evidenced by the significance value (sig. 2-tailed 0.000 <0.05). The results of this study can be used as a consideration to be applied in the classroom to improve students' communication skills, critical thinking skills and problem-solving skills. However, this study has limitations, such as small sample size and limited coverage of materials. Further researchers can develop this study to further understand the STEAM-integrated PjBL model in various educational settings.

Acknowledgements
Thank you to the teachers and students at SMA Negeri 18 Makassar who accepted me to conduct my research.

Author Contributions
Collect data, analyze data, and prepare articles for publication.

Funding
No funding provider

Conflict of Interest
No conflicts of interest

References

Alawiyah, Nida; Marlina, R. (2019). Analisis Kemampuan Berpikir Kritis Matematis Siswa. *Prosiding Seminar Nasional Matematika Dan Pendidikan Matematika*, 1077. https://doi.org/10.53712/sigma.v8i1.1690

Ariani, W. A., & Sari, W. K. (2019). Analisis Tingkat Keterampilan Komunikasi Siswa Di Sma Plus Negeri 7 Kota Bengkulu. *Psikodidaktika: Jurnal Ilmu Pendidikan, Psikologi, Bimbingan Dan Konseling*, *4*(1), 20. https://doi.org/10.32663/psikodidaktika.v4i1.732

Aris Pangestu, A., Fita Asri Untari, M., & Listyarini, I. (2023). Analisis Kemampuan Bercerita Siswa Kelas Iv Sdn 4 Kertosari Kabupaten Kendal. *Didaktik : Jurnal Ilmiah PGSD STKIP Subang*, *9*(1), 259–272. https://doi.org/10.36989/didaktik.v9i1.699

Arisya, W., Usman, H., & Raihan, S. (2022). Pengaruh Penerapan Project Based Learrning (PjBL) Terhadap Kreativitas Siswa Mebuat Karya Dekoratif. *Global Journal Teaching Professional*, *1*(2), 95–113.

Arsy, I. S. (2021). Pengaruh Pembelajaran Steam (Science, Technology, Engineering, Arts, and Mathematics) Terhadap Kreativitas Peserta Didik. *Biolearning Journal*, *7*(1), 39–43.

Azis, A. A., Lutfi, & Ismail. (2018). Pengaruh project based learning terintegrasi Stem terhadap literasi sains, kreativitas dan hasil belajar peserta didik[The influence of Stem-integrated project-based learning on science literacy, creativity and student learning outcomes]. *Prosiding Seminar Nasional Biologi Dan Pembelajarannya*, 189–194.

Cunningham, C. M., & Lachapelle, P. (2016). Experiences to engage all students. *e d u c a t i o n a l d e s i g n e r Journal Of The International Society For Design And Development In Education*, *3*(9), 1–26.

Fithriyah, I., Sa'dijah, C., & Sisworo. (2016). Analisis kemampuan berpikir kritis siswa kelas IX-D SMPN 17 Malang. *Konferensi Nasional Penelitian Matematika Dan Pembelajarannya*, *Knpmp I*, 580–590.

Fitriyah, A., & Ramadani, S. D. (2021). Penerapan Metode Project Based Learning. *Journal of Education*, *3*(1), 7. https://doi.org/10.26737/jpmi.v1i1.76

Hadinugrahaningsih, T., RahmawatI, Y., Ridwan, A., Budiningsih, A., Suryani, E., Nurlitiani, A., & Fatimah, C. (2017). Keterampilan abad 21 dan STEAM (Science, Technology, Engineering, Art, and Mathematics) project dalam pembelajaran kimia. *LPPM Universitas Negeri Jakarta*, *110*. https://www.scribd.com/document/429700453/Keterampilan-Abad-21-dan-STEAM-Project-dalam-Pembelajaran-Kimia-pdf

Hidayat, A. (2012). Pengelolaan Pendidikan: Konsep, Prinsip, dan Aplikasi dalam Mengelola sekolah dan Madrasah. *Digital Library, Uin Sunan Gunung Djati*, 36. https://etheses.uinsgd.ac.id/30324/

Hikmah, N., Budiasih, E., & Santoso, A. (2016). Pengaruh Strategi Project Based Learning (Pjbl) Terhadap Kemampuan Berpikir Kritis Siswa Kelas XI IPA Pada Materi Koloid. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *1*(11), 2248–2253.

Insyasiska, D., Zubaidah, S., & Susilo, H. (2015). Pengaruh Project Based Learning Terhadap Motivasi Belajar, Kreativitas, Kemampuan Berpikir Kritis, Dan Kemampuan Kognitif Siswa Pada Pembelajaran Biologi. Jurnal Pendidikan Biologi, 7(1), 9–21. https://doi.org/10.17977/jpb.v7i1.713. *Jurnal Pendidikan Biologi Volume*, *7*(1), 9–21.

Karmana, I. W. (2015). Profil Kemampuan Pemecahan Masalah Biologi Siswa SMA di Kota Mataram. *Jurnal Ilmiah Biologi "Bioscientist,"* *2*(1), 54–61.

La'ia, H. T., & Harefa, D. (2021). Hubungan Kemampuan Pemecahan Masalah Matematis dengan Kemampuan Komunikasi Matematik Siswa. *Aksara: Jurnal Ilmu Pendidikan Nonformal*, *7*(2), 463. https://doi.org/10.37905/aksara.7.2.463-474.2021

Larmer, J., & Mergendoller, J. R. (2010). Essentials for

Learning. *Educational Leadership*, *68*(1), 4.

Larmer, J., Mergendoller, J. R., & Boss, S. (2015). Setting The Standard For Project based learning. In *Engineering* (Issues 1–2).

Lumbantobing, S. S., & Azzahra, F. S. (2020). Meningkatkan Kemampuan Berpikir Kreatif Siswa Dalam Menghadapi Revolusi Industri 4.0 Melalui Penerapan Pendekatan STEAM (Science, Technology, Engineering, Arts and Mathematics). *Jurnal Dinamika Pendidikan*, *13*(3), 393–400. https://doi.org/10.33541/jdp.v12i3.1295

Melinda, Vina; Zainil, M. (2020). Penerapan Model Project Based Learning untuk Meningkatkan Kemampuan Komunikasi Matematis Siswa Sekolah Dasar (Studi Literatur). *Jurnal Pendidikan Tambusai*, *4*(2), 1526–1539. https://doi.org/10.36989/didaktik.v8i2.579

Mulyani, T. (2019). Pendekatan Pembelajaran STEM untuk menghadapi Revolusi Industry 4.0. *Seminar Nasional Pascasarjana 2019*, *7*(1), 455–460. https://proceeding.unnes.ac.id/index.php/snpasca/article/download/325/351

Nugroho, A. T., Jalmo, T., & Surbakti, A. (2019). Pengaruh model project based learning (PjBL) terhadap kemampuan komunikasi dan berpikir kreatif. *Jurnal Bioterdidik: Wahana Ekspresi Ilmiah*, *7*(3), 50-58. https://core.ac.uk/download/pdf/289778345.pdf

Nurhayati B, Jamaluddin, F. J., Daud, F., Saenab, S., Hadis, A., Hadis, N. I. R., & Remiza. (2023). An Extraordinary Duet: Integration of PjBL and STEM to Promote Student's Motivation, Scientific Literacy Skills, and Students Learning Outcomes. *European Journal of Education and Pedagogy*, *4*(3), 42–47. https://doi.org/10.24018/ejedu.2023.4.3.639

Nurlailasari, R., Enawaty, E., & Lestari Program Studi Pendidikan Kimia FKIP Untan, I. (2018). Upaya Meningkatkan Keterampilan Komunikasi Siswa Melalui Model Pembelajaran Think-Talk-Write. *Jurnal Pendidikan Dan Pembelajaran Khatulistiwa*, *7*(2).

Nursyamsini, S. (2023). *Penerapan Model Project Based Learning Untuk Meningkatkan Hasil Belajar Bahasa Indonesia Materi Teks Laporan Percobaan Siswa Kelas 9 G SMPN 8 Bandarlampung Semester 1 Tahun Peraturan Menteri Pendidikan dan Kebudayaan Nomor 81A Tahun 2014 tentang mengemban*. *8656*, 265–277.

Nuryana, D., & Rosyana, T. (2019). Analisis Kesalahan Siswa SMK dalam Menyelesaikan Soal Pemecahan Masalah Matematik pada Materi Program Linear. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *3*(1), 11–20.

Pratiwi, I. A., Ardianti, S. D., & Kanzunnudin, M. (2018). Peningkatan Kemampuan Kerjasama Melalui Model Project Based Learning (Pjbl) Berbantuan Metode Edutainment Pada Mata Pelajaran Ilmu Pengetahuan Sosial. *Refleksi Edukatika : Jurnal Ilmiah Kependidikan*, *8*(2). https://doi.org/10.24176/re.v8i2.2357

Putri, D. J., Angelina, S., Claudia, S., & Mujazi, R. M. (2017). *Faktor-faktor yang mempengaruhi minat belajar siswa di kecamatan larangan tangerang*. *9*.

Putri, W. N., & Ardi, A. (2023). Meta-analysis: Menilai Peningkatan Keterampilan Komunikasi Melalui Pendekatan Pembelajaran Discovery, Problem-Based, dan Project-Based. *JRTI: Jurnal Riset Tindakan Indonesia*, *8*(2), 223–233.

Rachman, M. (2012). Konservasi Nilai Dan Warisan Budaya. *Indonesian Journal of Conservation*, *1*(1), 30–39.

Rahayu, E., & Hartono, H. (2016). Keefektifan Model PBL dan PjBL Ditinjau dari Prestasi, Kemampuan Berpikir Kritis, dan Motivasi Belajar Matematika Siswa SMP. *PYTHAGORAS: Jurnal Pendidikan Matematika*, *11*(1), 1. https://doi.org/10.21831/pg.v11i1.9629

Saadah, M., & Mawardi. (2019). Peningkatan kebermaknaan dan hasil belajar siswa melalui desain pembelajaran tematik terpadu alternatif berbasis projek pada siswa kelas 5. *Jurnal Riset Teknologi Dan Inovasi Pendidikan*, *2*(1), 205–218. http://www.journal.rekarta.co.id/index.php/jartika/article/view/261%0Ahttp://www.journal.rekarta.co.id/index.php/jartika/article/download/261/255

Su, H. F. H., Ricci, F. A., & Mnatsakanian, M. (2016). Mathematical teaching strategies: Pathways to critical thinking and metacognition. *International Journal of Research in Education and Science*, *2*(1), 190–200. https://doi.org/10.21890/ijres.57796

Sukisno, T., & Yuniarti, N. (2016). Meneguhkan Peran Penelitian dan Pengabdian Prosiding Seminar Nasional " Meneguhkan Peran Penelitian dan Pengabdian kepada Masyarakat dalam Memuliakan Martabat Manusia " Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) UNY Masyarakat Penelitian. *Prosiding Seminar Nasional*, *May*.

Triprani, E. K., Sulistyani, N., & Aini, D. F. N. (2023). Implementasi Pembelajaran STEAM Berbasis PjBL Terhadap Kemampuan Problem Solving pada Materi Energi Alternatif di SD. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, *2*, 176–187. https://doi.org/10.24246/j.js.2023.v13.i2.p176-187

Trisnadati, I. (2018). Komparasi pendekatan matematika realistik dengan model PBL dan PjBL ditinjau dari kemampuan interpersonal, berfikir kritis, dan prestasi belajar. *Pythagoras: Jurnal Pendidikan Matematika*, *13*(1), 99–109.

https://doi.org/10.21831/pg.v13i1.21219
Wayudi, Mauliana; Suwatno; Santoso, B. (2020). Kajian analisis keterampilan berpikir kritis siswa sekolah menengah atas. *Jurnal Pendidikan Manajemen Perkantoran*, *5*(1), 67–82. https://doi.org/10.17509/jpm.v4i2.18008