



# Application of stem-based project-based learning to improve learning outcomes of simple aircraft material

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## ABSTRACT

The purpose of this study was to determine how well the learning outcomes of students after STEM-based project-based learning on simple aircraft material were used. This study used a quasi-experimental control group design. Quasi experimental design research is a research using experimental classes and control classes. The experimental class and control class will be given a pretest and posttest, the experimental class is a class has treatment that applies STEM-based project-based learning and the control class has treatment using a traditional learning model, namely the lecture and discussion method. The research shows that the use of STEM-based project-based learning and traditional learning can improve student achievement; The use of STEM-based project-based learning is more effective in improving student learning outcomes compared to the use of traditional learning; Student learning outcomes in the experimental class with STEM-based project-based learning are significantly different from student learning outcomes in the control class with traditional learning. It can be said that the learning outcomes for the cognitive component of the class using STEM-based project-based learning.

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## INTRODUCTION

Development in the 21st century is associated with scientific and technological advances in various fields of life, thus affecting the capabilities of the new generation. In this way, we incorporate 21st century education into the learning process. By aligning the principles of Curriculum 2013 with 21st century learning standards, the world of education hopes to produce a generation of Indonesians who are able to live as loyal, productive, innovative and effective human beings. Critical thinking, problem solving, communication and collaboration are key components of success in the 21st century (Rahmawati, 2018).

According to the North Central Regional Educational Laboratory and Materiti Group, there are many different definitions of 21st century skills, but they all agree on one thing: the definition of 21st century skills. Digital literacy, ingenuity, effective communication, and high productivity are the factors underlying the four categories of 21st century skills (Lemke, 2003).

Griffin, P. and Care identified 21st century skills that require everyone to think in certain ways, such as metacognition; mastering decision-making methods; engaging in critical thinking processes; being innovative; and problem solving. Problem-solving skills are essential for students' confidence that they can cope with various problem situations. According to the National Education Law Number 22 of 2006, the purpose of education is to improve learners' ability to understand and solve problems, create problem-solving methods, and interpret problem solving. Problem solving skills affect how well students learn. Student learning outcomes are closely related to problem solving skills; one of these outcomes is student learning in the cognitive aspect (Pratiwi & Fasha, 2015). If the problem-solving ability of a learner is good, it is in line with the results of the learning achievement he gets. Therefore, learning achievement (cognitive aspect ability) has a relationship to problem solving ability. Through the cognitive abilities that students have achieved, it will be known the progress and improvements that have been achieved after going through the learning activities.

The 2013 curriculum in Indonesia has been implemented with a focus on aligning educational practices with 21st century learning standards, particularly in science and technology. The curriculum emphasizes the development of students' critical thinking, problem-solving, creativity, and collaboration skills, which are essential for success in the modern world. To support these goals, the curriculum integrates project-based learning (PjBL) and the STEM (Science, Technology, Engineering, Mathematics) approach. This integration allows students to apply theoretical knowledge to real-world problems, fostering scientific literacy and technological competence. Through PjBL-STEM, students engage in hands-on projects that require them to design solutions to practical challenges, thereby enhancing their understanding of science and technology concepts and preparing them for future challenges in these fields.

Integrating 21st century skills, such as critical thinking and problem solving, into the learning process in Indonesia faces several challenges. One significant challenge is the traditional teacher-centered approach to education, which limits students' active participation and hinders the development of these essential skills. Many classrooms still rely heavily on rote memorization and lecture-based teaching methods, which do not encourage students to engage in critical thinking or problem-solving activities. Additionally, there is often a lack of adequate training for teachers on how to effectively implement PjBL and STEM approaches, leading to inconsistent application across different schools. Furthermore, resource constraints, such as limited access to technology and materials needed for hands-on projects, can impede the successful integration of these skills. Overcoming these challenges requires a shift in teaching practices, increased professional development for educators, and better resource allocation to ensure that all students can benefit from 21st century learning methods.

The project-based learning (PjBL) model is one of the learning models that can help students develop problem-solving skills and develop creativity. This can lead to improved student learning outcomes. This model is a project-based learning model (activity). Afriana et al. (2016) said PjBL learning is proven to improve students' creativity and problem-solving skills. This learning model works best when connected to technology and knowledge in everyday life. The PjBL model can be balanced with the STEM (Science, Technology, Engineering, Mathematics) approach that can help students understand ideas, solve problems, develop character, and improve learning outcomes. construction materials, and other life activities that all utilize technological products. The numerous benefits of technology in life make mastering the knowledge and technology very necessary. Therefore, creative, innovative, quality individuals who can act quickly and accurately are highly needed. To produce quality human resources, the role of education is essential (Lestari et al., 2018; Malina et al., 2021; Pratiwi & Fasha, 2015; Siswanto, 2018).

The Project-Based Learning (PjBL) model is significantly more effective than traditional learning methods in enhancing students' problem-solving skills and creativity. PjBL actively

engages students in real-world projects, fostering critical thinking, collaboration, and innovation. It encourages students to develop practical problem-solving strategies and explore creative solutions, leading to deeper understanding and application of concepts. This hands-on, experiential approach makes PjBL a superior method for cultivating these essential 21st-century skills compared to the more passive, rote-learning focus of traditional education.

The physics curriculum also leads to several teaching and learning strategies, including a STEM approach that centers on contextual learning. STEM integration can put students' experiences and knowledge in their daily lives at the forefront. In realizing this integration, problems in students' daily life about physics can be used as input for their STEM learning to work on STEM projects that can solve their problems. For example, when students have to lift and carry a fairly heavy load, how can they design a tool that can help their activities so that the heavy load can be lifted and carried easily. They can work together to understand the concept of simple aircraft to help their work. This method helps students know how to apply physics concepts to solve problems in daily life (Bunyamin & Finley, 2016).

One of the current problems is that the instruction provided does not involve active participation of students in class (Ramadan & Astuti, 2020). Teaching and learning activities should always be done effectively according to the 2013 curriculum. Lack of interaction with each other will lead to teacher-centered learning and certainly cause students to be inactive and lack understanding of the lesson. This will result in low student learning outcomes. PjBL-STEM learning is the best solution to the problems faced (Nining et al., 2024; Venalia et al., 2022).

STEM-project based learning is very impactful in improving students' creative thinking skills. By implementing STEM-PjBL, students have scientific and technological skills gained from reading, writing, observing, and doing science as well as solving daily life problems related to STEM science fields (Lestari et al., 2018). STEM is a learning concept that integrates math, technology, science, and engineering into one subject (Roberts & Cantu, 2012; Bybee, 2013). STEM goals in 21st-century education: Students should acquire science and technology literacy through reading, writing, observing, and doing science, and develop competencies that they can use to solve problems related to STEM fields in everyday life. Therefore, the PjBL STEM-based learning model, emphasizing the design process, is a great combination that can work together. A systematic approach to developing solutions to problems with clear outcomes is known as the design process. Since the dominant PjBL learning model involves creating projects that can be completed both inside and outside the classroom, it emphasizes solving problems related to everyday life in an interesting and engaging way, resulting in improved student learning outcomes.

## RESEARCH METHODOLOGY

This experiment used a quasi-experimental design combined with a non-equivalent control group design. There were two classes used in this study (Sugiyono, 2017). The experimental class used STEM project-based learning and the control class used traditional learning. The population of this study was class VIII SMP Negeri 5 Pontianak, namely class VIII A, VIII B, VIII C, VIII D, VIII E and VIII F. Randomly selected, and got the samples of class VIII A as an experimental class and VIII D as a control class.

$01 \times 02$

$03 \times 04$

Description:

$0_1$  : Mean pretest of experimental class

$0_2$  : Average of experimental class posttest

$0_3$  : Control class pretest average

$0_4$  : Control class posttest average

× :Treatment using STEM-based project-based learning model

The research was carried out in three stages, namely the preparation stage, the implementation stage, and the final stage which lasted for three weeks and consisted of three meetings. Pre-study activities, problem formulation, preparation of research instruments, instrument validation, instrument testing, and identification of control and experimental classes are elements of the preparation of a study.

In the experimental class using STEM project-based learning, the approach was implemented over three weeks, with sessions lasting 90 minutes each. Students engaged in hands-on activities, including brainstorming, prototyping, and presenting their projects. They utilized a range of materials, including science kits, digital tools, and basic construction materials, to explore real-world problems and develop solutions using STEM concepts. The process emphasized collaborative problem-solving, creativity, and application of STEM principles. In contrast, the control class followed a traditional learning approach, also over three weeks with 90-minute sessions. This method involved teacher-led lectures, individual note-taking, and practice problems from textbooks. Students focused on theoretical understanding with limited interactive or group activities. The traditional approach centered on direct instruction and individual work, leading to a more passive learning experience compared to the active, hands-on nature of the STEM project-based learning.

The research was conducted at the implementation stage. This stage begins with choosing a study schedule, conducting pre-exams, providing treatment, and working on post-test questions. The last step is to make a research report. This stage includes managing and analyzing data from the pretest and posttest results of the experimental and control classes, and summarizing the results.

This research uses test questions in the form of pre-test and post-test questions to determine how well students learn in the cognitive aspect. In addition, this research uses rubrics to evaluate the results of LKPD products as a project-based STEM learning feature. This study found the following findings: validation and reliability of test questions on student learning outcomes; improving student learning outcomes in the cognitive domain; differences in learning outcomes in experimental and control classes; and student project assessment results. Normality test, homogeneity test, Independent Sample t-test and N-Gain Score test were used to analyze student learning performance in experimental and control classes. This analysis is carried out to determine whether there is an increase in student learning outcomes in the control and experimental classes.

The rubric used to assess the LKPD product in STEM project-based learning evaluates five key criteria: content accuracy and relevance, creativity and innovation, problem-solving approach, project design and presentation, and application of STEM concepts. Each criterion is rated on a four-point scale, ranging from exemplary (4) to beginning (1). The rubric aims to measure the depth of students' understanding, their ability to integrate and apply STEM principles, and the overall quality of their project work. The final score reflects the student's proficiency in meeting the learning objectives and effectively applying what they have learned.

## RESULTS AND DISCUSSIONS

### **Students' Learning Outcomes on Simple Airplane Material in Experimental and Control Classes**

This study involved 25 students from the experimental group who used STEM learning, project-based. A multiple choice test consisting of twenty questions and two essay questions, with a maximum score of 100, was used to assess learning outcomes. In this study, the experimental class used project-based STEM learning. The researcher gave a pre-test to the students before starting to learn the basic material about airplanes. The purpose of pretesting students was to assess their initial cognitive knowledge. The experimental class pretest scores were then calculated

to determine whether they met the CCM evaluation criteria. The purpose of pretesting students was to assess their initial cognitive knowledge Student learning outcomes are presented in Table 1 below.

**Table 1.** Control class learning outcomes

	Control Class		Experiment Class	
	Pretest	Posttest	Pretest	Posttest
Valid N	25	25	25	25
Min	35.0	50.0	35.0	65.0
Max	62.5	82.5	62.5	90.0
Mean ( $\bar{x}$ )	48.8	66.9	47.6	80.9
Sd	9.0462		7.4120	6.6489
		10.1108		

The purpose of pretesting students was to assess their initial cognitive knowledge. The experimental class pretest scores were then calculated to determine whether they met the CCM evaluation criteria (minimum completeness criteria).

The results of data analysis showed that the average pretest score of 25 students in the experimental class was 47.6 with the lowest score of 35.0 and a highest score of 62.5. None of the students in the experimental class reached the MMC (minimum completeness criteria), as the percentage of completeness was zero. The poor learning outcomes of the students were due to the fact that they were not taught the basics of aviation and therefore performed poorly on the assignment.

After processing the experimental class using STEM project-based learning, students took the final exam. The posttest scores were then assessed using descriptive analysis on SPSS 25. The results of the data analysis showed that for the experimental class, the average posttest score was 80.9 and the minimum score was 65 and the maximum score was 90% completeness. 68% of 25 students.

Then look for the N-Gain value of the experimental and control classes to find out how well students learn. N-Gain represents the difference between pre-test and post-test scores. The mean N-Gain value of the experimental class is 1.87 which is seen in the output which shows that the learning outcomes of the experimental class are quite high. This shows that STEM-based project-based learning is effective in improving student learning outcomes on simple aviation components.

In this study, the control class used traditional teaching resources and the lecture method, where the teacher has an important role in the process of teaching and learning activities. Before starting the training, students were tested to assess their initial knowledge. The next step was descriptive analysis after calculating the pretest scores. Descriptive analysis of twenty-five students showed results with an average pretest score of 48.8, with a lowest score of 35.0 and a highest score of 62.5. The results of the student pretest, showed that none of the participants reached the MCC (minimum completeness criteria), which means the percentage of completeness in the control class is 0%. The poor learning outcomes of the students were due to the fact that they were not taught the basics of aviation and therefore performed poorly on the assignment.

In addition, learning activities in the control class using traditional teaching methods were also examined. After the treatment of the control class, students completed a posttest to assess their learning outcomes. From the descriptive analysis of the post-test results, the mean score of the control class was 66.9 points, the minimum score was 50 points, and the maximum score was 82.5 points, resulting in a completion rate of 8% out of 25 students.

Then look for the N-Gain value of the experimental and control classes to find out how well students learn. N-Gain is the difference between pretest and posttest scores. SPSS 25 was used to analyze the data before and after the test. The control class N-gain exit value was obtained at

0.30. In the control class there was an increase in learning outcomes. Students in the experimental class showed a higher level of interpretation with a value of 1.87, while students in the control class showed a moderate level of interpretation.

The results of the data analysis presented show that students improved in both classes; however, the experimental class using STEM projects had better results. This shows that the use of STEM-based project-based learning is better than traditional learning in improving student learning outcomes.

### Differences in Learning Outcomes of Experimental and Control Class Students

First, the normality test is used to evaluate have the resulting data is properly divided. According to the normality test standard, data is considered normally distributed if  $\text{sig} > 0.05$ , and if  $\text{sig} < 0.05$  then it is not normally distributed. The following are the normality criteria for this study.

The results of the pre and post test normality test of the experimental and control classes are presented in the table above. In the experimental class, the significance of the pretest was 0.425, higher than 0.05, and the significance of the posttest was 0.160, higher than 0.05, can be seen in table 2.

**Table 2.** Normality test results homogeneity

class		Normality	homogeneity
		Sig.	Sig.
Learning outcomes	experimental pretest	.425	.150
	Experimental posttest	.160	.178
	control pretest	.129	.178
	Experimental posttest	.052	.154

The normality test for the control class produce in a pre-test significance value of 0.129 ( $>0.05$ ) and a significance value for the pest test of 0.052. From these data can be decided the data that can be distributed normally, both before and after testing. Homogeneity test is used to determine the homogeneity of the data obtained before and after testing. The standard used in the homogeneity test is as follows: sig value above 0.05 is considered homogeneous, and sig value below 0.05 is considered heterogeneous. The results showed that the pre-test and post-test data of both experimental and control classes were homogeneous.

Second, the main purpose of the independent sample T-test is to determine whether there is a difference in means between two unpaired samples. Table 3 below shows the results of the data analysis:

**Table 3.** Independent sample t-test results

	Pre-test		Post-test	
	X	Si (2-tqilet)	X	Si (2-tqilet)
Experimental class	47,6	0,610	80,9	0,000
Control class	48,8		66,9	

The table above shows that the average post-test scores between the experimental and control classes are significantly different. The Si (2-kilet) value of  $0.000 < 0.05$  confirms this. Testing can be used to determine differences in student learning outcomes before and after learning. The initial test is normality and homogeneity test using Shapiro Walking Test. It is said that it the value greater than 0.05 ( $>0.05$ ), the results show that the data is normally distributed and homogeneous. The results of the Independent Sample t-test test show that the pre-test value does not show a significant difference as indicated by a significance value (2-tailed) of 0.610 which is greater than 0.05. Meanwhile, the posttest results showed differences in student learning outcomes in the STEM

(Science, Technology, Engineering, and Mathematics) experimental project-based learning class and the traditional control class. independent test results. The sig value of the sample t test (2-tailed) is less than 0.05.

The implementation of STEM-based project based learning has a good impact for students. In addition to cognitive aspects, PjBL-STEM learning also has a good impact on improving the psychomotor aspects of students. Student show more activity and creativity compared to traditional learning. Project based learning with science, technology, engineering, and mathematics methods (PjBL-STEM) is one form of teaching and learning model that is integrated with curriculum design and based on STEM approaches to learning (Lou et al., 2017; Chen & Lin, 2019).

Project-based learning in STEM consists of five phases: reflection, exploration, discovery, application, and communication. Simple aircraft material is briefly addressed at the *reflection* stage by conveying aspects of *technology* where learners are introduced to the application of technology to an object or work product that explains the concept of simple aircraft and the use of technological media to assist the learning process and aspects of *science*, namely a brief explanation of the concept of simple aircraft. Then the *research* stage is carried out which contains aspects of science, namely students discussing scientific procedures to investigate the application of simple aircraft concepts in everyday life. After the *research* stage is continued with the *discovery* stage, this stage emphasizes the *engineering* aspect where students begin to discuss a product design that will be made and identify the tools and materials needed based on the LKPD that was distributed at the previous meeting. Entering the *application* stage, which is a stage that applies aspects of science where students begin to make tools based on the product design that has been designed, and conduct experiments with these tools. The last stage carried out is the communication stage, a stage that contains aspects of *mathematics* and STEM itself, namely aspects where students present projects or products that have been made and the results of experiments on products and explain the concept of simple aircraft applied to products and relate to mathematical models such as equations that exist in simple aircraft material. Although learning is carried out with a limited face-to-face system, STEM-based project-based learning can still be optimized effectively as evidenced by the learning outcomes of students both cognitive aspects that increase higher than classes that apply conventional learning. According to research by Afriana et al. (2016), STEM-based project-based learning can improve students' science literacy, make the subject matter interesting and motivating, develop creative thinking, and improve problem-solving skills, thus leading to improved learning outcomes. Assessment of psychomotor aspects is part of project-based learning in STEM (Riastuti & Febrianti, 2021). Creativity is one of several aspects of the psychomotor dimension that are assessed. In this study, the assessment of creativity in the experimental class using STEM-based project learning was demonstrated using a project assessment rubric. The fifth group got the highest score of 90, followed by the first and second groups with scores of 90, 83.3, and the fourth and third groups scored 75, 75, and 66.6, respectively. Based on the assessment rubric, so it can be decided that the improvement in psychomotor learning outcomes is quite high. According to research conducted by Laila Wulandari in 2019, the STEM approach can improve students' creativity and psychomotor abilities in creative thinking.

The lecture system was the typical teaching method in the control class. In traditional education, the teachers an important role in the teaching and learning process. In addition, traditional learning is teacher-centered, which means that the teacher is the main source of knowledge for students. Traditional learning models make students inactive and less creative in the learning process (Kurniawan et al., 2015).

STEM-based project-based learning can provide new experiences to students. This can improve students desire to learn in simple airplane materials and other learning materials. Ismayani (2016) argues that STEM-based project-based learning can help students think creatively. In STEM-based PjBL teaching, students are provided with significant learning to understand and

explore an idea. They participate in project activities and participate in the process. Students develop analytical, critical and creative thinking through this (Capraro et al., 2013).

STEM-PjBL learning makes students learn and work on projects like scientist, aligned with the theory of environment-based learning, STEM-PjBL places students in a real world context and helps them to develop scientist like abilities that use reasoning to solve problems in a task (Samsudin et al., 2020; Baran et al., 2021; Triana et al., 2020). Student learning outcomes are certainly influenced by the difference between project-based learning in STEM (PjBL - STEM) and conventional learning.

## CONCLUSION

Based on the data has been analyzed, the learning outcomes of students at SMP Negeri 5 Pontianak have increased with the level of completeness ranging from 0% to 68%. Traditional teaching was able to increase student achievement from zero to eight percent. This indicates that students experienced better learning outcomes in classes with project-based STEM learning than in classes with or without traditional/conventional learning; Learning outcomes in each of the two classes were significantly different. Seen on the rubric of the evaluation of student outcome products, the use of STEM-based project-based learning can improve learning outcomes in the psychomotor dimension.

Based on the data analysis, both experimental and control classes demonstrated improvements in student learning outcomes on the topic of simple airplane material. In the experimental class, which implemented STEM-based project-based learning, the average pretest score was 47.6, with a posttest average of 80.9. In contrast, the control class, which followed traditional teaching methods, had an average pretest score of 48.8 and a posttest average of 66.9. The N-Gain value, which measures the effectiveness of the learning method, was significantly higher in the experimental class (1.87) compared to the control class (0.30), indicating that the STEM-based approach was more effective in enhancing student learning outcomes. Additionally, the normality and homogeneity tests confirmed that the data from both classes were normally distributed and homogeneous. The independent sample t-test showed a significant difference in posttest scores between the experimental and control classes, with the experimental class showing greater improvement. Furthermore, the STEM-based project-based learning method also positively impacted students' psychomotor aspects, particularly in terms of creativity, as evidenced by the project assessment rubric. This suggests that STEM-PjBL not only improves cognitive learning outcomes but also fosters creativity and active participation among students, making it a more effective approach compared to traditional learning methods.

Several limitations may have affected the results of the study. First, the sample size was relatively small, consisting of only two classes from SMP Negeri 5 Pontianak, which may not fully represent the broader student population. Additionally, the study's duration was limited to three weeks, which might not have been sufficient to capture long-term effects of the STEM project-based learning approach. Other factors such as variations in teacher effectiveness, differences in student engagement, and external influences on learning could not be fully controlled, potentially impacting the outcomes. The lack of a longitudinal component also means that the sustainability of the learning improvements over time remains unexamined.

Future research should consider expanding the sample size to include multiple schools or grade levels to enhance the generalizability of the findings. Increasing the duration of the study could provide insights into the long-term effects of STEM project-based learning on student outcomes. Additionally, incorporating qualitative methods, such as interviews or observations, could offer a deeper understanding of how different teaching methods influence student engagement and motivation. Investigating the impact of various factors, such as teacher training

and classroom environment, on the effectiveness of STEM-based learning could also provide valuable insights. Finally, a longitudinal study could assess the lasting effects of STEM project-based learning on student performance and skills development over an extended period.

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