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The Effectiveness of PjBL Learning on Interest and Mathematical Creative Thinking in Determining the Number of Construction Workers for 11th Grade Students in the Construction Department

Mozard Aryan Hukunala[1], Rizky Fatmalasari L[2], Agung K. Henaulu[3], Tri Siwi Nasrulyati[4]
[1]Department of Mathematic Education, Universitas Darussalam Ambon, Ambon, Indonesia
[2]Department of Physics Education, Universitas Darussalam Ambon, Ambon, Indonesia
[3]Department of Industrial Engineering, Universitas Darussalam Ambon, Ambon, Indonesia
[4]Department of Mechanical Engineering, Universitas Darussalam Ambon, Ambon, Indonesia
[1]mozard_hukunala@yahoo.com, [2]rizkyfatmalasari@gmail.com, [3]agung@unidar.ac.id, [4]trisiwi@unidar.ac.id

ABSTRACT

This study examined the effectiveness of the Project-Based Learning (PjBL) model in improving students' learning interest and mathematical creative thinking skills in spatial geometry at SMK Negeri 4 Ambon. It also investigated the implementation of project-based learning in the Building Engineering Program through a project to determine the number of construction workers based on the Indonesian Standard Work Unit Price Analysis (AHSP-SNI). This quasi-experimental study involved 69 eleventh-grade students. Data were collected through observations, learning interest questionnaires, creative thinking tests, project portfolios, assessment rubrics, and project presentations, and analyzed using descriptive statistics. The number of construction workers was calculated using the AHSP-SNI formula: (8 working hours × building area) ÷ desired project completion time. The results showed that students' average learning interest reached 97.10%, while mathematical creative thinking reached 87.00%. Students' ability to identify building components was categorized as good, whereas their ability to determine the required number of construction workers was good for a one-month duration and very good for two- and three-month durations. The findings indicate that PjBL effectively improves learning interest, creative thinking, and the application of mathematics in vocational construction education.

Keywords: Project-Based Learning (PjBL), learning interest, mathematical creative thinking, spatial geometry.

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Corresponding Author:
Mozard Aryan Hukunala,
Department of Mathematic Education,
Universitas Darussalam Ambon,
Jalan Waehakila Puncak Wara Ambon, 97128, Indonesia.
mozard_hukunala@yahoo.com

1. INTRODUCTION

Mathematics is a fundamental subject that plays a vital role in various areas of life, including vocational work, particularly in building construction. However, many students in vocational high schools (SMK) still view mathematics as an abstract and difficult subject that is irrelevant to their practical needs (Rahim et al., 2023). This results in low interest in learning and a lack of creative thinking skills in solving real-world problems related to their fields of expertise (Oktaviastuti et al., 2021a); (Qurohman & Sungkar, 2018a).

The process of learning mathematics in vocational high schools (SMK) has characteristics that are different from learning mathematics in general high schools (SMU). The difference lies in the implementation of the teaching material, which must be integrated with productive subjects (Qurohman & Sungkar, 2018b) One math topic that is useful for students is solid geometry. This material provides an understanding of the elements of solid figures, the practice of measuring length, width, and angles, calculating the area and volume of structures, as well as applying it to determine the number of construction workers based on a specified time (Oktaviastuti et al., 2021b)(Murad et al., 2024).

SMK Negeri 4 Ambon, especially in the building department, mathematics should serve as an important foundation for students to support vocational skills. One of the basic competencies taught is calculating the number of construction workers needed to complete a construction project ("Implementasi Model Pembelajaran Berbasis Proyek Dalam Penanaman Konsep Matematika Pada Siswa Sekolah Menengah," n.d.). This calculation not only requires an understanding of mathematical concepts but also creative thinking skills, such as generating various alternative solutions, using different strategies, and detailing answers thoroughly. In construction practice, a worker or technician

is often faced with situations that cannot always be resolved through routine methods. For example, when determining the number of construction workers required, it is not enough to simply use a basic formula; students also need to consider real factors such as labor productivity, project deadlines, types of work, and the efficiency of task distribution.

Unfortunately, spatial geometry learning in grade 11 of the building department at SMK Negeri 4 Ambon is still quite conventional, where teachers only provide examples of problems and students only imitate the steps to solve them. This condition is in line with the findings of (Rifai et al., 2025) who stated that mathematics learning in vocational schools is still teacher-centered and dominated by structured practice problems so that students' opportunities to build conceptual understanding and explore problem-solving strategies are still limited. This pattern makes students accustomed to single, passive answers and rarely connects spatial geometry concepts with real-world problems, resulting in underdeveloped creative thinking skills, even though these skills are very much needed in the construction workforce (Sabaruddin et al., 2018).

One alternative to addressing the challenges of mathematics learning in vocational schools is the implementation of the Project-Based Learning (PjBL) model. This model emphasizes active student involvement in completing authentic and contextual projects, encouraging students to build knowledge through hands-on learning experiences. In the Building Engineering Expertise Program, PjBL provides students with the opportunity to connect spatial geometry concepts with real-world problems in the construction sector. Research on the application of PjBL to spatial geometry materials has been conducted by (Sundari et al., 2024) which shows that PjBL can improve creative thinking skills through entrepreneurship-based projects. However, this research was conducted on university students and did not integrate mathematics learning with the context of vocational education, specifically the Building Engineering Expertise Program in vocational schools, or the application of the Work Unit Price Analysis (AHSP-SNI) standard in determining construction labor requirements. Therefore, this study offers a novelty in the form of the application of PjBL to spatial geometry learning integrated with authentic AHSP-SNI-based projects, so that students not only understand spatial geometry concepts but are also able to apply mathematical concepts to determine the number of construction workers according to project needs. The application of this model is expected to increase interest in learning mathematics while developing students' creative thinking skills (Laili et al., 2025); (Giro et al., 2024)

Based on the above explanation, this study aims to determine the effectiveness of the Project Based Learning (PjBL) model on interest and creative thinking ability in determining the number of construction workers among 11th-grade students in the Building Department at SMK Negeri 4 Ambon.

2. RESEARCH METHOD

A. Research Type and Design

This study uses a quantitative approach with a quasi-experimental type (quasi-experimental research) using a Pretest-Posttest Control Group Design (Sugiyono, 2022). This design was chosen to determine the effectiveness of the implementation of the Project-Based Learning (PjBL) model on students' learning interest and mathematical creative thinking abilities compared to conventional learning. The study was conducted in class XI of the Building Engineering Expertise Program of SMK Negeri 4 Ambon in May 2025. The research sample consisted of 69 students consisting of 34 students in class XI.A as the experimental class and 35 students in class XI.B as the control class. The independent variable of the study is the Project-Based Learning (PjBL) model, while the dependent variables include students' learning interest and mathematical creative thinking abilities.

B. Research Stages

1. Preparation Stage

At this stage, the following activities were carried out:

a. Conducting a literature study on Project-Based Learning (PjBL), learning interest, mathematical creative thinking skills, spatial geometry, and Work Unit Price Analysis (AHSP-SNI).
b. Conducting initial observations and interviews with mathematics teachers to identify learning problems.
c. Determining the experimental and control classes.
d. Developing learning materials, including:
   • Teaching Modules;

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- Project-based Student Worksheets;
- Pretest and posttest instruments;
- Learning interest questionnaire;
- Project assessment rubric;
- Student activity observation sheets.

e. Validating the instruments by experts.
f. Conducting a pilot test of the instruments to determine validity and reliability.

2. Implementation Stage

The implementation stage is carried out over several meetings.

a. Experimental Class (Project-Based Learning)

Learning activities follow the PjBL syntax according to the Ministry of Education and Culture, namely:

1. Determine the fundamental question (Start with the Essential Question).
   The teacher presents a real-life problem in the form of planning a simple house construction, asking students to determine labor requirements based on the building area.
2. Students are divided into groups and develop steps to complete the project.
3. Develop an activity schedule. Each group develops a project schedule.
4. Monitor project implementation.
   The teacher guides the discussion process, calculates spatial geometry, identifies building components, and calculates the number of workers using AHSP-SNI.
5. Test the project results. Each group presents their project results.
6. Evaluate the learning experience.
   The teacher and students reflect on the learning process and outcomes.

b. Control Class

In the control class, learning was conducted using conventional methods such as lectures, questions and answers, example problems, and individual practice without project activities.

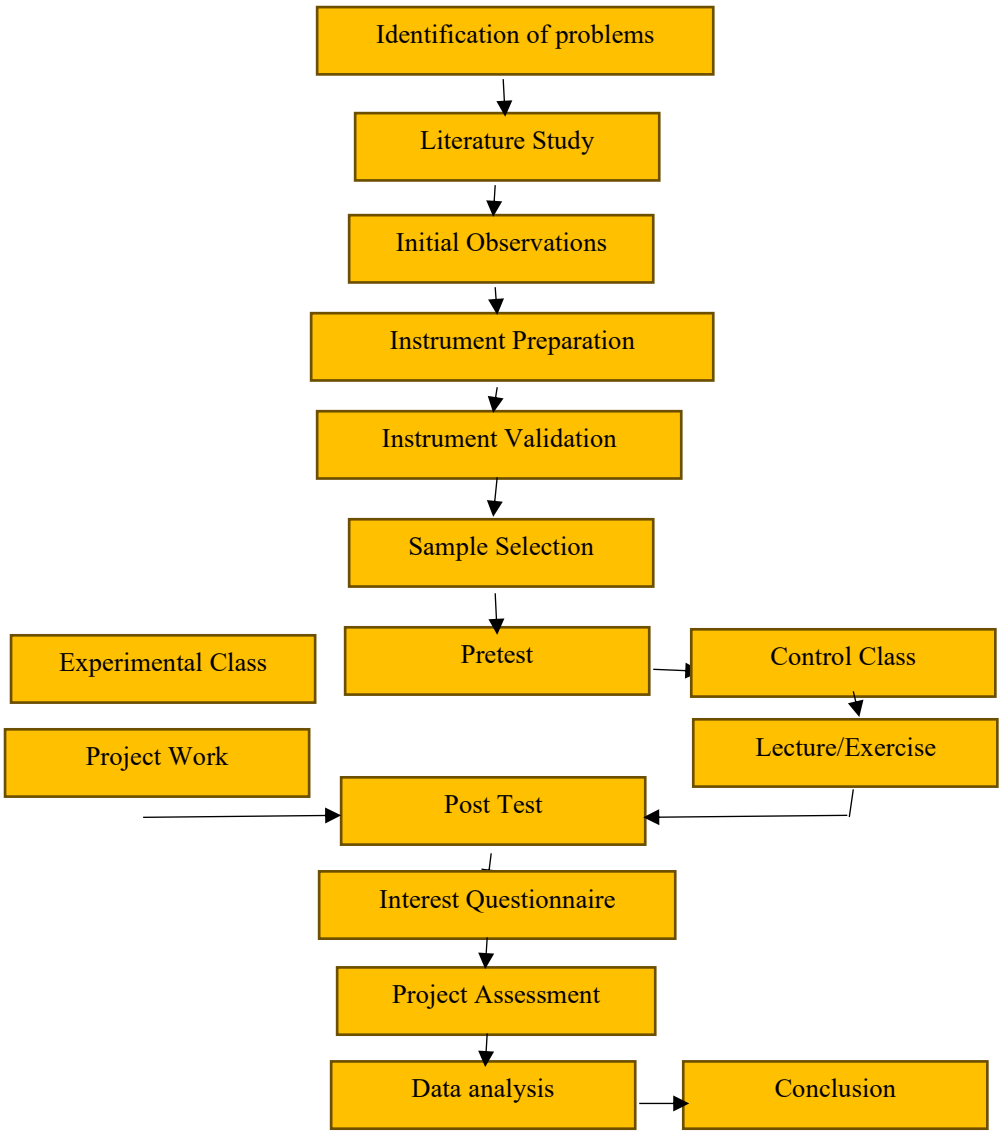
3. Evaluation Stage

Evaluation was conducted after the entire learning process was completed. The evaluation included:

- administering a post-test on mathematical creative thinking skills;
- completing a learning interest questionnaire;
- assessing project outcomes using a rubric;
- observing student activities;
- documenting learning outcomes.

All data was then analyzed to determine the effectiveness of the Project-Based Learning implementation. The following is the research flow carried out by the researcher:

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(Sugiyono, 2022)

C. Data Collection Techniques

Data collection techniques include:

1. Observation. Conducted to determine teacher and student activities during learning.
2. Questionnaires. Used to measure student learning interest.
3. Tests. Open-ended essay questions to measure mathematical creative thinking skills.
4. Project Assessment.

Used to assess students' ability to determine building components and the number of construction workers based on AHSP-SNI

D. Data Analysis Techniques

Data analysis was conducted through the following stages:

1. Descriptive analysis of learning interest, creative thinking skills, and project outcomes.
2. Instrument validity and reliability testing.
3. Data normality testing and homogeneity of variance testing
   (Henaulu & Ardian, 2020; Wulansari et al., 2025).
4. Hypothesis testing using an Independent Sample t-test to compare learning outcomes in the experimental and control classes.
5. Project outcome analysis using the calculation of the number of workers based on AHSP-SNI with the formula:

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Number of Workers = (8 Working Hours × Building Area) ÷ Implementation Time
6. Drawing conclusions based on the statistical analysis results

3. RESULTS AND DISCUSSION

A. Research Result

Initial Data Analysis

This study was conducted in the eleventh grade at SMK Negeri 4 Ambon by implementing the PjBL Learning Model. In order to obtain initial data regarding students' learning interest in the eleventh grade at SMK Negeri 4 Ambon, a learning interest questionnaire was distributed with the following indicators: (1) Enjoyment in learning mathematics, (2) Student involvement in learning mathematics, (3) Interest in the material presented, and (4) Students' attention to the material being taught. The results were analyzed and summarized for two sample classes, XIA and XIB, and can be described as follows

Table 1. Recapitulation of Interest in Learning Mathematics Based on All Indicators

Number	Interval	Category	Class A	Class B	Percentage
1	$X > 68$	Very Interested	1	3	5,8
2	$56 < x \leq 68$	Interested	3	3	8,7
3	$44 < x \leq 56$	Quite Interested	20	17	53,6
4	$32 < x \leq 44$	Less Interested	4	7	15,9
5	$x \leq 32$	Not Interested	6	5	15,9
6					
	Amount		34	35	100

Table 1 shows that the average interest in learning mathematics in class XI of SMK Negeri 4 Ambon is 53.6 in the category of Quite Interested in learning mathematics, this shows that most students have interest but it is not strong yet, To prove the difference in the average interest in learning class XIA and class XIB, a t test was carried out with $\alpha = 5\%$, the test results showed that $t = 0.3364 < t_{tab} = 2.1318$ meaning that H0 is accepted and Ha is rejected so it can be concluded that class XIA and class XIB have a relatively balanced distribution even though class XIB has slightly more students in the very interested category than class XIA, but class XIB has more students in the less interested category. To analyze the data on creative thinking in mathematics of class XI students majoring in Building at SMK Negeri 4 Ambon, initial observation data was used on the learning process carried out by the teacher, based on the results of the observation, students' creative thinking was found as follows:

Table 2. Summary of Students' Creative Thinking Based on Indicators

Creative Thinking Ability Level	Class XI.A	Class XI.B	Percentage
Creative	9	7	23,29
Lack of creativity	19	23	60,87
Not Creative	6	5	15,94
Amount	34	35	100

From table 2 above, it shows that the average creative thinking of students at SMK Negeri 4 Ambon is 23.29 consisting of the average creative thinking of class XIA (experimental) students of 26.47 with a class percentage of 26.5%. and class XIB (control) of 0.2 with a class percentage of 20%. F-test two sample for variance was conducted to test the homogeneity of the two classes above. The results of the analysis show that $F_{hit} = 1.4477797 < F_{tab} = 1.7720665$ meaning that both are homogeneous

Final Stage Data Analysis

The analysis of learning interest data using the same indicators after the PBjL learning process on spatial geometry material can be described as follows:

Table 3. Summary of Mathematics Learning Interest Based on All Indicators

Number	Interval	Category	Class A	Class B	Percentage
1	$X > 68$	Very Interested	12	17	42,03

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$56 < x \leq 68$	Interested	20	14	49,28
$44 < x \leq 56$	Quite Interested	1	3	5,80
$32 < x \leq 44$	Less Interested	1	1	2,89
$x \leq 32$	Not Interested	0	0	0
Amount		34	35	100

Table 3 above shows that the average interest in learning mathematics of class XI students of SMK Negeri 4 Ambon is 97.10, consisting of an average of class XIA students (experimental class) of 0.97 with a percentage of 97.06%, and an average interest in learning mathematics of class XIB (control class) of 0.94 or 94.29%, while to find out students' creative thinking can be assessed from the results of the product in the form of portfolio assessments and presentations of student work results. Based on the results of data analysis in the form of portfolios and percentages of student work results can be described as follows.

Table 4. Summary of Students' Creative Thinking Based on Indicators

Creative Thinking Ability Level	Class A	Class B	Percentage
Creative	31	29	82,86
Lack of creativity	2	4	12,86
Not Creative	1	2	4,29
Amount	34	35	

Table 4 above shows that the average creative thinking of class XI students at SMK Negeri 4 Ambon is 0.87 or 87% consisting of the average creative thinking for class XIA (experimental class) of 91.18% and class XIB (control class) of 82.86%. The following will explain the comparison of learning interest and creative thinking data at the initial and final stages as shown in the graph below

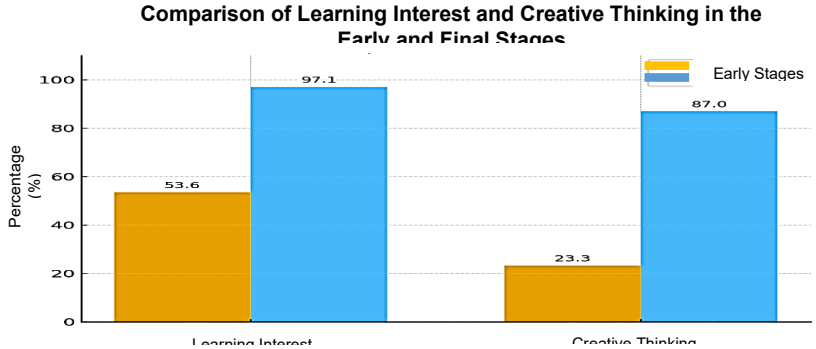


Fig 1. Comparison of Learning Interest and Creative Thinking in the Early and Final Stages

Based on the figure 1 above, both learning interest and creative thinking experienced a very significant increase from the initial to the final stage. This increase indicates that the learning approach or method used was effective in improving students' creative thinking skills.

a. Data from the Results of Analysis of the Implementation of Learning Spatial Structures in the Productive Sector

Analysis Data Determines Building Components

In order to obtain data related to the implementation of the mathematics learning process (space construction) in productive majors (building majors), the researcher provided a project in the form of a worksheet (LKS) to be worked on both independently and in groups, then analyzed the results of the students' work. Based on the results of the analysis of student work (Andyny, 2022), the overall picture can be described as follows:

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Table 5 Questionnaire Results Summary

No	Sub Indicators	Average	Criteria
1	Determining building components	78,3	Good
2	Designing Building Component Costs	80,2	Good
3	Prepare a building work schedule	83,5	Good
4	Finalizing Building Component Costs	81,7	Good
5	Compile reports and presentations of estimated building component costs	85,4	Good
6	Evaluate the process and results of each building component cost	80,1	Good

Table 5 shows that each indicator in the building components can be determined or completed well by both class XIA and class XIB students.

i. Data Analysis Results Determine the Number of Construction Workers

To obtain data on the ideal number of construction workers in a construction project during the desired time, the researcher conducted tests on class XIA and class XIB students, the results of the students' work were analyzed and presented in the following table;

Table 6. Test Results Summary Determining the Number of Construction Workers for a Building Area of 9 meters x 12 meters

No	Month	Number of Workers	Class XI.A	Class XI.B	Criteria
1	I	33	80,7	75	Good
2	II	17	90	87.7	Very Good
3	III	11	95,8	89.5	Very Good
	Amount		34	35	

Table 6 shows that students of class XIA and class XIB in solving problems of spatial structures into the productive field in this case determining the number of construction workers, for the number of workers in completing a building in the first month of class XIA as many as 80.7% and class XIB as many as 75% of students can determine the number of construction workers in completing the project well. Meanwhile, in the second and third months both class XIA students (90% and 95.83%) and class XIB students (87.7% and 89.5%) can determine the number of construction workers very well.

B. Discussion

The learning process carried out by the researcher in two classes using different learning models, this is intended to determine the effectiveness of the PjBL learning model (Christian, 2021). The PjBL learning carried out by the researcher refers to the rules including creating basic questions that provide motivation for students, designing project plans in the form of LKS, compiling a project activity schedule including deadlines for each project stage, monitoring or monitoring the progress of project work, testing project results through group presentation results, evaluating project activities (according to the RPP). The PjBL learning carried out by the researcher is intended to provide a learning experience in spatial construction by confronting students of SMK Negeri 4 Ambon with building construction (productive fields) and determining the number of construction workers in real life for students who are solved in groups (Muljani & Bunawar, 2022). The project based learning model is an innovative learning model, which emphasizes contextual learning through complex activities. Through project-based learning, students are required to be able to choose topics and presentation/product projects, produce final products, and solve problems related to the real world, as well as involving various disciplines (Farihatun & Rusdarti, 2019).

Mathematics learning (spatial construction) for students majoring in construction or productive fields using the project-based PjBL learning model encourages and increases interest and creative thinking in identifying and solving mathematical problems in productive fields. Creative thinking skills expressed in identifying and solving problems are the hope for mathematics teachers in vocational

schools. This thinking ability will lead students to be able to compete in the academic field and in real life in society (Analia & Bharata, 2022). The learning of spatial construction, carried out by researchers using the PjBL learning model, is in principle divided into three stages, namely the pre-research stage, the research stage, and the post-research stage. In the pre-research stage, researchers conducted initial discussions with mathematics subject teachers and building construction teachers, this was done by researchers to collect initial information related to students' knowledge of mathematics and building construction that they had studied(Galuh & Riana, 2022)(Firdaus, 2023). At this stage, researchers also distributed questionnaires on learning interests and creative thinking to students in grades XIA and XIB and determined class XIA as the Experimental class and class XIB as the Control class(Musa'ad et al., 2024). For the second stage, the researcher carried out the learning process accompanied by the subject teacher as an observer. Meanwhile, in the third stage, the researcher distributed learning interest questionnaires and creative thinking questionnaires to the students (Slameto, 2015)..

Based on the results of the analysis of the distribution of questionnaires on interest in learning mathematics to class XI students before being given treatment, it shows that the average interest in learning is 53.6% with a fairly interested category, likewise the ability to think creatively is still low, only reaching 23.3%. towards the mathematics learning process carried out by mathematics teachers. The mathematics learning process only focuses on the application of mathematical theory (space shapes) not at the level of application in the productive fields they are engaged in. so that students' thinking abilities are only at the level of mathematical understanding(Musa'ad et al., 2024)(Slameto, 2015). To prove the difference in the average interest in learning between class XIA and class XIB, a t-test was carried out with $\alpha = 5\%$, the test results showed that $t < t\ tab = t0.3364 < t2.1318$ meaning that accepting H0 and rejecting Ha so it can be concluded that there is a difference in the average interest in learning between class XIA students and class XIB students(Slameto, 2015).

The results of this initial analysis serve as a reflection for researchers to plan a meaningful learning process oriented towards the productive field (construction department). The reflection results were discussed with subject teachers and colleagues (lecturers) to determine the model to be used in subsequent learning processes. Based on the discussion, the model to be used for subsequent learning was determined, namely learning using the PjBL learning model(Farihatun & Rusdarti, 2019).

The Project Based Learning learning process at SMK Negeri 4 Ambon is a student-centered learning approach using projects as a learning medium. Mathematics learning using Project Based Learning both in class XIA (experimental class) and class XIB (control class) with the same material, namely geometric shapes, the difference is that in class XIA (experimental class) students are given in-depth material on geometric shapes and are given projects in the form of calculating the area of a building, the required building components and the required (number) of workers for one month, two months, and three months. In the experimental class, the researcher explains the geometric shapes material accompanied by several examples of geometric shapes in the productive field, then divides them into small groups and is given a project in the form of a worksheet to work on(Sundari et al., 2024). The project (LKS) provided contains a building area as shown in the following image:

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Fig 2. Rectangular building measuring 9 x 12 meters

In the Figure 2 above, it appears that the size of the house is rectangular with a size of 9 meters x 12 meters and a building height of 3.5 meters with 4 bedrooms, 2 bathrooms, living room, family room, kitchen, work room, car garage, terrace, garden space. Students are asked to calculate the number of house construction workers and building components needed with a specified time of 1 month, 2 months and 3 months while in class XIB, only focuses on understanding the material of spatial construction. To encourage students in the learning process, the researcher begins with a rhyme "Like a book my heart is open, understanding mathematics that opens the way, that's how we should be proud, fight and move forward to build a future home, then students are formed into small groups and given trigger questions to open students' thinking insights. Students are given projects according to productive fields, analyzing, working in teams, solving problems together, solving problems and presenting the results of their work.

Learning spatial structures by applying the Project Based Learning model shows students' active interest in learning the material being taught. From the results of distributing learning interest questionnaires after the spatial learning process was carried out by applying the Project Based Learning model, the average learning interest of class XI students of SMK Negeri 4 Ambon was 97.10%, consisting of an average of class XIA students (experimental class) of 0.97 with a percentage of 97.06%, and an average interest in learning mathematics for class XIB (control class) of 0.94 or 94.29%, students' thinking ability in analyzing and solving problems given both in the form of mathematical problems and productive field projects showed that the average student in creative thinking to analyze and solve spatial problems and projects was 0.87 or 87% consisting of an average of creative thinking for class XIA (experimental class) of 91.18% and class XIB (control class) of 82.86%.. while to determine building components, building component costs for both class XIA students (experimental class) and class XIB (control class) were in the good category, as well as determining the number of construction workers for both class XIA and Class XIB for 1 month is in the Good category, while for 2 months and 3 months both class XIA and class XIB are in the Very Good category. These results indicate that the PjBL learning process carried out by the researcher in class XIA (the experimental class) is more effective when compared to class XIB (the control class).

4. CONCLUSION

Based on the research results and discussion above, it can be concluded that the effectiveness of PjBL learning in class XI of the building department of SMK Negeri 4 Ambon is more effective when compared with other conventional learning. This is shown

1. The average learning interest of 11th-grade students was 97.10%, consisting of an average of 0.97 for 11th-grade students (the experimental class) or 97.06%, and an average of 0.94 for 11th-grade students (the control class).

2. Students' creative thinking skills in analyzing and solving problems, both in the form of math problems and productive field projects, showed that the average creative thinking ability for analyzing and solving spatial problems and projects was 0.87, or 87%. This was comprised of an average of 91.18% for 11th-grade students (the experimental class) and 82.86% for 11th-grade students (the control class).
3. The ability to determine building components and building component costs for 11th-grade students (the experimental class) and 11th-grade students (the control class) was categorized as good.
4. The ability to determine the number of construction workers for both class XIA and class XIB is categorized as Good for the one-month period, while for the two-month and three-month periods, both classes fall into the Very Good category

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