

The Influence of Multimedia-Interactive Project-Based Learning Models on The Metacognitive Abilities, Critical Thinking Abilities and Fiber Optic Communication Learning Outcomes

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ABSTRACT

Critical thinking as a component in the high-level thinking process uses the basis of analyzing arguments and generating insight into each meaning and interpretation to develop cohesive and logical reasoning patterns. This research used quantitative research methods and aimed to determine the metacognitive abilities, critical thinking abilities, and learning outcomes of students before and after being treated through posttest pretest with control class and experimental class, so the research method used by researchers is quasi experimental. The research design used is Nonequivalent Control Group Design. The results of the pre-test statistical hypothesis test show that the significance value obtained in the independent sample t-test shows a significance value of 0.767 or in other words the significance value is greater than the alpha degree of 5% ($0.767 > 0.05$) so it can be said that there is no real difference in the average value of learning outcomes of XI SMK Telkom Jakarta between the experimental group and the control group.

Keywords: Project-based learning, Critical thinking, Learning outcome, Multimedia

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INTRODUCTION

An integral aspect of the national education system, vocational high school (SMK) trains students to use their newly gained knowledge and abilities in the workforce for the benefit of individuals, communities, and the country (Delcker, 2023). Several skills are necessary for students to succeed in the modern world. According to (Álvarez-Huerta et al., 2023), critical thinking skills are one of sixteen qualities outlined by the World Economic Forum as essential for students to succeed in the modern world. A person's ability to think critically is crucial in every area of life. One must possess this skill in order to understand how to think critically, make reasonable and responsible judgments, and seek out alternate solutions when faced with a problem. Reasonable and thoughtful thought with an emphasis on belief or action decision-making is what (Suarniati et al., 2019) calls critical thinking. On the other hand, critical thinkers are able to draw conclusions from their knowledge, use that

knowledge to solve issues, and find other relevant sources of information to back up their solutions (Rahmawati et al., 2021).

Critical thinking is an important and vital topic in modern education, critical thinking as a component in the high-level thinking process uses the basis of analyzing arguments and generating insight into each meaning and interpretation to develop cohesive and logical reasoning patterns. Critical thinking skills are abilities that can be taught, so that these abilities can be learned (Nuryanti et al., 2018). One way to develop critical thinking skills is through productive learning. In productive learning, students are taught to gain knowledge through collecting d. In addition, the aim of training students' critical thinking skills is to prepare students to become critical thinkers, able to solve problems, and become independent thinkers, so that they can face life, avoid indoctrination, fraud, brainwashing, and make decisions wisely. appropriate and responsible.

(Latifah, 2022) revealed that the critical thinking ability of vocational school students is currently relatively low. Likewise, (Kurniawan et al., 2021) stated that the critical thinking abilities of vocational school students are still lacking or low because students are not yet trained on indicators of critical thinking abilities, and there is still a lack of learning that is applied to empower students' abilities to think critically. The same thing was stated by (Mutohhari et al., 2021) that the low critical thinking ability of vocational school students results in the students' inability to respond and seize opportunities when they graduate from school as well as their inability to solve various problems when they are in the world of work.

A person's skills in self-reflection can encourage cognitive, metacognitive development, increased thinking power, learning behavior and student learning outcomes. A person's ability to find ways and understand learning is called metacognitive skills As stated by (Chen et al., 2023) metacognitive skills, high-level thinking patterns that must be developed in students, students who have high metacognitive skills will be successful in the learning process. This lack of student skills is usually caused by students who cannot be independent, who are still dependent on the subject teacher and students who are also unable to monitor the class during the learning process. Another factor is that students lack interest in learning which influences learning outcomes.

(Suryati et al., 2019) found that the metacognition of vocational school students currently falls into the field dependent cognitive style category which is divided into 2, namely students with metacognition at the strategic use level who are able to carry out problem solving plans, and students with metacognition at the beginning level. are use that has not been able to implement the problem solving plan. The same thing was also expressed by (Rahayu et al., 2020) that current vocational school students have good metacognitive skills, but are weak in problem solving abilities. Meanwhile, the metacognitive abilities of vocational school students are currently in the medium category, namely a) not being able to know what they know; b) unable to sequence what he will do; c) able to analyze a problem and determine initial steps and completion steps; d) evaluate the results obtained as true or false. Based on previous research, it is necessary to re-

develop the metacognitive skills of vocational school students, so that they have fully good metacognitive abilities.

By developing students' metacognitive skills, student independence will emerge. Students will also know the advantages and disadvantages of learning outcomes in the learning process in the classroom. (Jossberger et al., 2015) stated that metacognitive skills do not appear by themselves but need practice so that they become habits. So, to develop these skills in learning, teachers need to plan strategies, methods or learning models.

The learning model is a guide for educators in planning learning in the classroom, starting from preparing learning tools, media and tools, to evaluation tools that lead to efforts to achieve lesson objectives. The learning model used by teachers greatly influences the achievement of learning targets, therefore teachers need to choose the right model from among the many learning models. It is hoped that teachers use learning models based on habits but based on the material and targets to be achieved. Each student is unique in various ways, this shows that the teacher's understanding of the learning model that will be used cannot be ignored (Savelides, 2019).

Using the right learning model can increase student motivation and learning outcomes. Apart from that, choosing the right learning model that is in line with current developments will be more effective and efficient in order to improve the quality of learning itself (Sudana, 2021). Sagala stated that there are four categories that are important to pay attention to in learning models, namely information models, personal models, interaction models, and behavioral models (Mirdad, 2020). Meanwhile, according to Komalasari (2017) the types of learning models consist of Problem-based Learning, Cooperative Learning, Contextual Teaching, Inquiry Learning Model, Concept Learning, and Project-based Learning.

Interactive multimedia is one of the teaching materials that can be used in the learning process, including in model. Interactive multimedia is included in the category of audiovisual teaching materials. As non-print teaching materials, interactive multimedia has advantages over other learning media. This advantage is because interactive multimedia allows students to receive material through moving images and accompanying sound. The benefits of interactive multimedia according to (Alam et al., 2022) namely that it can influence the improvement of students' critical thinking abilities because they are faced with the reality of an image that exists in the real world. Through interactive multimedia, educators are able to streamline learning time and make students understand more about the learning material, because students get a direct picture of the material being studied.

Previous research by Han and Bhattacharya lends credence to learning model, which positions the teacher as a facilitator rather than an authority figure in project-based learning (Widiyanti et al., 2020). Students view their own problems as challenges or questions that need answering, and they effectively manage their own time to complete their projects. (Zitter et al., 2016) Zitter outlined the following learning processes in their Project-based Learning (PjBL) model: 1) Identifying essential questions, 2) Crafting a project plan, 3) Establishing a timeline, 4) Supervising, 5) Analyzing test results, and 6) Assessing the

experience. It differs from other learning models, such as Discovery Learning and Problem Based Learning, with these phases (syntax).

The first findings from the researchers' observations of the learning process for fiber optic communication revealed that the activities implemented by teachers fell short of expectations. Indeed, the debating approach was employed by educators that day, and it was quite intriguing. Teachers have been successful in capturing their pupils' interest thanks to the strategies put into place. Educators typically assign students 30 minutes to read a variety of materials on the topic of the next discussion. While some students may be reading or researching in books or online, it is common knowledge that they are also engaging in activities such as watching movies or playing on social media. After the argument, it became clear that very few students had participated in the discussion that the instructor had initiated.

The pupils' metacognitive abilities were found to be deficient in the field of fiber optics, according to researchers who performed restricted first interviews with professors. The majority of class XI students (70%) struggle to draw practical conclusions from their fiber optics lessons. Sixty percent of students struggled with report writing during practicum, while eighty percent simply used the teacher-provided worksheet. Still, the majority of students (80%) still look to their teachers for direction when articulating the association between factors. The results for students who haven't made it to the KKM yet are evidence that this leads to less-than-ideal learning outcomes overall. With KKM = 75, the following table displays the most recent test scores of the pupils.

Researchers picked Telkom Jakarta Vocational School in part because of the benefits accruing to students' education at that institution from the use of various learning models, including the Project-based Learning (PjBL) model. The problem with the way learning is done at Telkom Jakarta Vocational School is that the project-based learning (PjBL) model is used too much, without enough supplementary media, which makes students lose interest, engagement, and participation in the material. In this type of setting, pupils have less opportunity to hone their critical thinking skills. Consequently, students will graduate with a wealth of theoretical knowledge but little practical experience; this will diminish their ability to apply what they've learned by bridging the gap between theory and reality.

This finding lends credence to the idea that students might benefit from a learning model that places an emphasis on metacognitive awareness and learning outcomes. The project-based learning (PjBL) paradigm is one educational strategy that prioritizes students' metacognitive awareness and the results of their learning. Through the use of a discipline's overarching ideas and principles, students in project-based learning engage in problem-solving and get experience working independently. Students' critical thinking skills and their capacity to make meaningful connections between classroom content and real-world situations are fostered through the project-based learning paradigm (OECD, 2020).

METHOD

Researchers employed quantitative research methodologies in this study. This study will employ an experimental methodology known as a quasi-experimental design (quasi-experiment). As per (Maciejewski, 2020), a type of experimental design known as Quasi Experimental Design evolved from the more challenging and time-consuming real Experimental Design. Even though there is a control group in this design, it is not completely capable of controlling for extraneous variables that impact the execution of the experiment. But compared to the design that was in place before the experiment, this one is superior. When a control group is not readily available, researchers resort to quasi-experimental designs. For example, in administrative or managerial tasks, randomly assigning certain personnel to experiments and others not is generally not feasible. Not everyone uses the latest methods of operation. Hence, a quasi-experimental design was devised to circumvent the problems associated with research including the control group. Not equivalent control group design and time series design are the quasi-experimental designs. Researchers using Time-Series Design cannot pick their study populations at random. In order to determine the stability and clarity of the group's condition before therapy, they were administered a pretest up to four times. The group is in a state of instability, uncertainty, and inconsistent performance if the values of the pretest findings alter on four separate occasions. It is only once the group's situation has stabilised that treatment may begin. Because there is just one group in this study, a control group is not necessary. However, in the Nonequivalent Control Group Design, the experimental and control groups are not randomly selected, but otherwise, the design is quite similar to the pretest-posttest control group design. The experimental and control groups are both compared in this design, despite the fact that they are selected and allocated without randomization. Each of the two groups had to complete a pre- and post-test before receiving any kind of treatment.

Researchers employed a quasi-experimental design to compare students' pre- and post-treatment metacognitive and critical thinking skills as well as their learning results in a control and experimental group. The Nonequivalent Control Group Design is the research methodology employed. The sole difference between this design and the pretest-posttest control group design is that in this design, the experimental and control groups are not randomly selected. The experimental and control groups are both compared in this design, despite the fact that they are selected and allocated without randomization. Each of the two groups had to complete a pre- and post-test before receiving any kind of treatment. Prior to treatment, this design undergoes a pretest. This allows for a more precise knowledge of the treatment's effects by comparing them to the state of affairs before to treatment. According to (Miller et al., 2020), the following table displays the research design.

The population in this study was all class XI students. The samples in this research were students from class XI Tel 1 and class XI Tel 2. In two classes, the sampling technique was carried out using the Total Sampling technique. Total sampling is an overall sampling technique. The reason for taking total sampling is because according to (Miller et al., 2020) the population is less than 100, so the entire population will be used as the research sample.

So in this research 55 students of XI Tel 1 and 2 Vocational School Telkom Jakarta were used as samples. Therefore, this study determined the following inclusion criteria:

1. Registered as a student in class XI at Telkom Jakarta Vocational School for the 2022/2023 academic year.
2. Be present when the research is carried out.
3. Willing to be a research respondent.
4. Meanwhile, the exclusion criteria are as follows:
5. Students who refuse to be sampled.
6. Students who were not present or present when the research was conducted.

The sampling technique in this research is total sampling. The reason for taking total sampling is because according to (Muse & Baldwin, 2021) the total population is less than 100, the entire population is used as the entire research sample. So, the sample in this study consisted of 55 students, of which 26 students were class XI Tel 1 and 29 students were class XI Tel 2.

The variables used in this research include:

1. The treatment variable (X) in this research is the Project Based Learning (PjBL) learning model assisted by interactive multimedia. This variable reflects the learning method applied by the researcher as a treatment or engineering aimed at influencing the response variable.
2. The response variable (Y) in this study consists of three variables:
 - a. Metacognitive Ability (Y1): This variable measures the level of students' ability to understand and control their own learning process, including monitoring, organizing, and assessing their understanding.
 - b. Critical Thinking Ability (Y2): This variable measures students' ability to critically analyze, evaluate and solve problems, as well as develop logical and reflective thinking.
 - c. Fiber Optic Communication Learning Outcomes (Y3): This variable measures the level of student achievement in fiber optic communication material taught through the PjBL model assisted by interactive multimedia.

Questionnaires and exams were utilized to gather data for this study.

a. Suggested Questionnaire

This study employed a closed questionnaire, meaning that all of the answers are known in advance and respondents are asked to make a direct selection using a graded scale. With four options—"strongly agree," "agree," "disagree," and "strongly disagree"—this questionnaire's multidimensional scale employs a modified Likert scale. In this survey, respondents can choose from four possible responses, as outlined by (Muse & Baldwin, 2021): strongly agree (4 points), agree (3), disagree (2 points), and strongly disagree (1 point). A Likert scale questionnaire uses four-point likert scales to exclude the "neutral" option. The "undecided" category, according to (Maciejewski, 2020), is removed from the revised scale because of the central tendency impact and its dual meaning. For responders

who aren't sure where their opinion is going, this means less knowledge and less research data. For this reason, the adjusted scales are ideal.

b. Test

The capacity to assess an individual's or group's level of competence, knowledge, intelligence, talent, or skill can be achieved through the administration of standardized tests (Maciejewski, 2020). In order to compare the two classes' pre- and post-treatment learning outcomes, this test was administered to both the experimental and control groups.

RESULT

Descriptive pre-test and post-test learning outcomes on fiber optic communication material for class XI students at SMK Telkom Jakarta

In the initial stage, a pre-test of ability was held in learning fiber optic communication material for class XI SMK Telkom Jakarta. Researchers distributed test sheets about fiber optics XI learning questions. This stage was carried out to measure the ability of learning outcomes in XI fiber optics learning. The results of the pre-test statistical calculation of learning outcomes on material XI fiber optics for the two groups are shown in table 1.

Table 1 Descriptive Statistics of Learning Results for Experimental Class and Control Class Before Treatment (Pre-test)

PRE TEST		
Group	Control	Experiment
Class	XI TEL 2	XI TEL 1
Mean	66.21	64.81
Std. Dev	17.23	17.23
Minimum	30.00	30.00
Maximum	90.00	90.00
Median	70.00	70.00

Table 1 shows that the pre-test descriptive statistics of learning outcomes in fiber optics lessons for the control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 66.21 and for the experimental group XI TEL 1 of 64.81 . Furthermore, in the control group Telkom Jakarta Vocational School, the minimum value was 30.00 , the maximum was 90.00, the median was 70.00 and Std. Dev of 17.23 . In the experimental group at SMK Telkom Jakarta XI TEL 1 The minimum value is 30.00 , the maximum is 90.00, the median is 70.00 and Std. Dev of 17.23 .

The average *pre-test score* for learning outcomes in fiber optics lessons for both classes has a low mean score and does not meet the school's Minimum Completeness Criteria (KKM) score of 70. Based on the calculation of the scores from the control and experimental groups *Pre-test* results for fiber optics learning The average value obtained can be seen in Figure 1

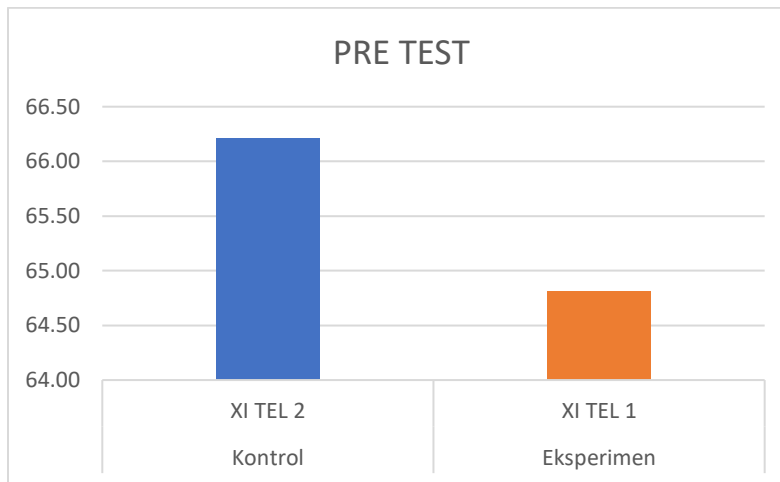


Figure 1 Pre-test scores for learning fiber optics material for class XI SMK Telkom Jakarta

Based on this graph, there is a difference between the average pre-test learning outcomes of the experimental group and the control group. In the control group, the mean class score was obtained, the mean score for SMK Telkom Jakarta class XI TEL 2 was 66.21 and XI TEL 1 was 64.81 . The average pre-test score for learning outcomes in the fiber optics lesson in both classes is still low and does not meet the school's Minimum Completeness Criteria (KKM) score of 70. Based on the calculation of the scores from the control group, the Pre-test on fiber optics learning outcomes.

In the initial stage, a *post-test* of ability was held in learning fiber optic communication material for class XI SMK Telkom Jakarta . Researchers distributed test sheets for XI optical fiber learning questions . This stage was carried out to measure the ability of the XI fiber optics learning outcomes . The results of the *pre-test statistical calculation* of learning outcomes on material XI fiber optics for the two groups are shown in table 2

Table 2 Descriptive statistics of learning outcomes in the experimental class and control class after treatment (*post-test*)

POST TEST		
Group	Control	Experiment
Class	XI TEL 2	XI TEL 1
Mean	65.34	78.85
Std. Dev	19.41	14.44
Minimum	25.00	50.00
Maximum	100.00	100.00
Median	65.00	80.00

Table 2 shows that *post-test descriptive statistics* on learning outcomes in fiber optic lessons for the control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 65.34 and for the experimental group XI TEL 1 of 78.85 . Furthermore, in the control group Telkom Jakarta Vocational School, the minimum value was 25.00 , the maximum was 100.00, the median was 65.00 and Std. Dev of 19.41 . In the experimental group Telkom Jakarta XI TEL 1 Vocational School, the minimum value was 50.00 , the maximum was 100.00, the median was 80.00 and Std. Dev of 14.44 .

The average *post-test score* for learning outcomes in fiber optics lessons for both classes has a mean score that meets the school's Minimum Completeness Criteria (KKM) score of 70. Based on the calculation of the scores from the control and experimental groups, *the post-test* results for fiber optics learning obtained an average score of average which can be seen in figure 2.

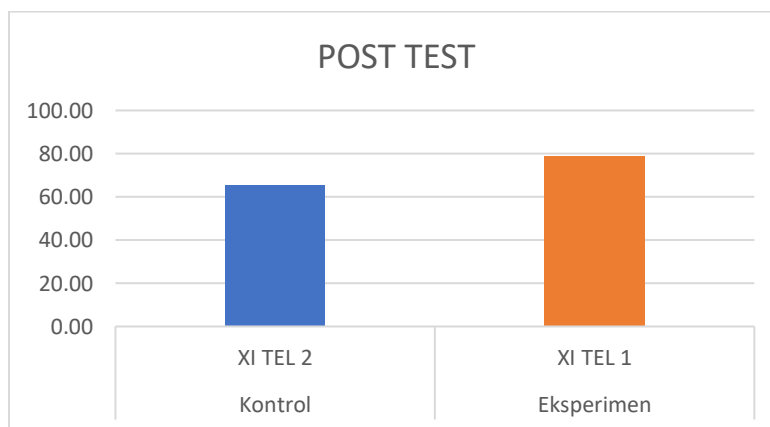


Figure 2 Learning Value of class XI fiber optic material at SMK Telkom Jakarta

Based on this graph, there is a difference between the average post-test learning outcomes of the experimental group and the control group. In the control group, the mean class score was obtained, the mean score for SMK Telkom Jakarta class XI TEL 2 was 65.34 and XI TEL 1 was 78.85. The average *post-test score* for learning outcomes in fiber optics

lessons for both classes has a mean score that meets the school's Minimum Completeness Criteria (KKM) score of 70. So it can be concluded that class The post-test showed an increase in the average , obtaining a mean class score for class XI TEL 2 of 65.34 and XI TEL 1 of 78.85 .

Descriptive results of metacognitive abilities in fiber optic communication material for class XI students at SMK Telkom Jakarta

In the initial stage, a pre-test was held for the ability to learn fiber optics material for class XI students at SMK Telkom Jakarta. Researchers distributed questionnaire sheets for project-based learning models assisted by interactive multimedia. This stage is carried out to measure the ability of learning learning outcomes. Next is a description of the mean level, std. dev, minimum, maximum and median, as follows;

Table 3 Descriptive Statistics of Metacognitive Ability

Group	Control	Experiment
Class	XI TEL 2	XI TEL 1
Mean	75.50	81.41
Std. Dev	6.39	8.39
Minimum	64.58	66.67
Maximum	89.58	95.83
Median	75.00	79.17

Table 3 shows that descriptive statistics of metacognitive abilities In the fiber optics lesson , the control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 75.50 and in the experimental group XI TEL 1 it was 81.41 . Furthermore, in the control group Telkom Jakarta Vocational School, the minimum value was 64.58 , the maximum was 89.58 , the median was 75.00 and Std. Dev of 6.39 . In the experimental group at SMK Telkom Jakarta XI TEL 1 the minimum value was 66.67 , the maximum was 95.83 , the median was 79.17 and Std. Dev of 8.39.

Average value of metacognitive ability in the fiber optics lesson both classes had mean scores that met different mean scores. The control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 75.50 , while in the experimental group XI TEL 1 it was higher at 81.41 . So it can be concluded that the average value of the XI TEL 1 experimental group is higher at 81.41 . Based on the calculation of the results from the control and experimental groups on metacognitive abilities The average value obtained can be seen in Figure 3.

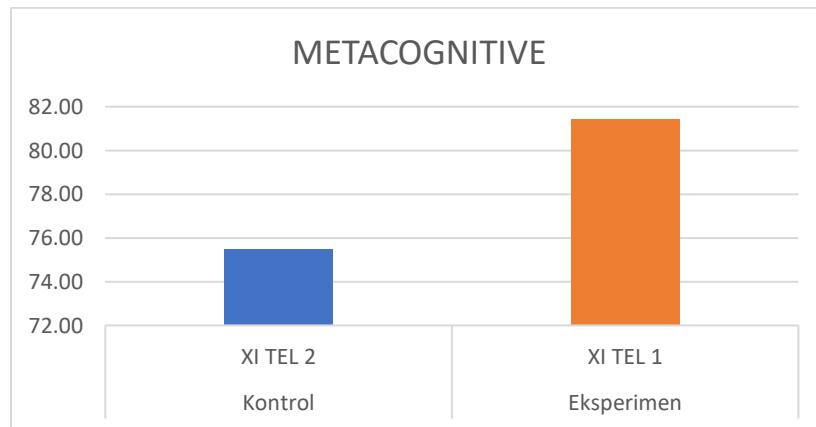


Figure 4.3 Pre-test scores for learning fiber optics material for class XI SMK Telkom Jakarta

Based on this graph, there is a difference between the average pre-test learning outcomes of the experimental group and the control group. On metacognitive abilities in the fiber optics lesson both classes had mean scores that met different mean scores. The control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 75.50 , while in the experimental group XI TEL 1 it was higher at 81.41 . So it can be concluded that the average value of the XI TEL 1 experimental group is higher at 81.81.

Descriptive results of critical thinking skills in fiber optic communication material for class XI students at SMK Telkom Jakarta

In the initial stage, a pre-test of critical thinking skills was held in learning fiber optic material for class XI students at Telkom Jakarta Vocational School. Researchers distributed questionnaire sheets for project-based learning models assisted by interactive multimedia. This stage is carried out to measure the ability of learning learning outcomes.

Table 4 Descriptive Statistics of Critical Thinking Ability

Group	Control	Experiment
Class	XI TEL 2	XI TEL 1
Mean	75.22	86.54
Std. Dev	10.87	9.87
Minimum	56.25	60.94
Maximum	95.31	100.00
Median	71.88	88.28

Table 4 shows that the descriptive statistics of critical thinking skills in fiber optics lessons for the control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 75.22 and for the experimental group XI TEL 1 of 86.54 . Furthermore, in the control

group Telkom Jakarta Vocational School, the minimum value was 56.25 , the maximum was 95.31 , the median was 71.88 and Std. Dev of 10.87 . In the experimental group Telkom Jakarta XI TEL 1 Vocational School, the minimum value was 60.94 , the maximum was 100.00, the median was 88.28 and Std. Dev of 9.87 .

Average value of critical thinking abilities in the fiber optics lesson both classes had mean scores that met different mean scores. The control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 75.22 , while in the experimental group XI TEL 1 it was higher at 86.54 . So it can be concluded that the average score of the XI TEL 1 experimental group is higher with a score of 86.54 . Based on the calculation of the results from the control and experimental groups, critical thinking skills The average value obtained can be seen in Figure 4.

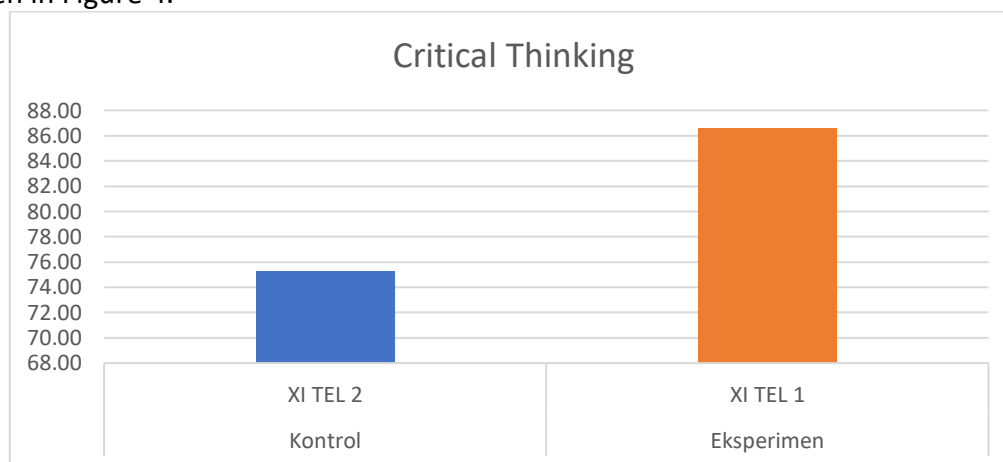


Figure 4 Learning Value of class XI fiber optics material at SMK Telkom Jakarta

Based on this graph, there is a difference between the average pre-test learning outcomes of the experimental group and the control group. In terms of critical thinking skills in fiber optics lessons , the control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 75.22 and for the experimental group XI TEL 1 it was 86.54 . So it can be concluded that the average score of the XI TEL 1 experimental group is higher with a score of 86.54 .

Normality test

The normality test aims to test whether in the research model the variables are normally distributed. The data normality test in this study used the *One-Sample Kolmogorov Smirnov test* contained in the SPSS 2 6.0 for *Windows program* . Data is said to be normally distributed if the residuals are normally distributed, that is, they have a significance level above 5% (Ghozali, 2013: 86). Normality test results can also be seen using *the one sample Kolmogorov-Smirnov test* as seen in table 5.

One-Sample Kolmogorov-Smirnov Normality Test Results

		Tests of Normality					
		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistics	df	Sig.
Pre Test	Experiment	,157	26	,099	,950	26	,237
	Control	,155	29	,074	,911	29	,018
Post Test	Experiment	.127	26	,200 *	,933	26	,091
	Control	,139	29	,161	,954	29	,234
Metacognitive Ability	Experiment	.144	26	,178	,944	26	,172
	Control	,152	29	,085	,967	29	,493
Critical Thinking Ability	Experiment	,161	26	,083	,888	26	,009
	Control	.138	29	,169	,963	29	,382

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From table 5 above, it can be seen that the overall value of the normality test results is $\text{sig} < 0.05$ or all of these values are greater than 0.05. Thus, it can be concluded that the significance value of normality in the results of the analysis shows that the value is > 0.05 , this shows that the distribution of pretest and posttest data throughout the research group is normally distributed .

Homogeneity Test

The homogeneity test is carried out to determine whether the data distribution is homogeneous or not. A homogeneous test is carried out on the dependent variable. This univariate homogeneity test uses Levene's test. In Levene's Test, researchers used IBM SPSS 26.0 Statistics for Windows. The normality test results can be seen in the following table:

**Table 6 Two Way Anova Homogeneity Test Results
Test of Homogeneity of Variances**

		Levene Statistics	df1	df2	Sig.
Pre Test	Based on Mean	,034	1	53	,855
	Based on Median	,004	1	53	,948
	Based on Median and with adjusted df	,004	1	52,993	,948
	Based on trimmed mean	.028	1	53	,868
Post Test	Based on Mean	2,032	1	53	,160
	Based on Median	2,148	1	53	,149
	Based on Median and with adjusted df	2,148	1	49,249	,149
	Based on trimmed mean	2,114	1	53	,152
Metacognitive Ability	Based on Mean	3,037	1	53	,087
	Based on Median	2,241	1	53	,140
	Based on Median and with adjusted df	2,241	1	49,774	.141
	Based on trimmed mean	3,090	1	53	,085
Critical Thinking Ability	Based on Mean	1,334	1	53	,253
	Based on Median	,932	1	53	,339
	Based on Median and with adjusted df	,932	1	53,000	,339
	Based on trimmed mean	1,325	1	53	,255

From table 6 above, it can be seen that the results of the homogeneity test show the overall *statistical probability value* of the pre-test and post-test in the homogeneity test, showing that all research variables have a probability value greater than the alpha degree of 5% ($\text{sig} > 0.05$) so it can be concluded All research variables have homogeneous data variants.

Hypothesis Test Results

After checking for homogeneity and normalcy, the next step is to test the hypothesis. Until the data is demonstrated otherwise, a hypothesis might be seen as a stopgap solution to a research problem. It is assumed that the distribution is normal and the variance is homogeneous. This verifies that the SPSS hypothesis testing parametric requirements have been met.

There are two main types of hypotheses: relationship hypotheses and difference hypotheses. This study's working hypothesis is the difference hypothesis, as stated in the title. The basis of many studies on differences is this premise, which identifies the factors that are different from one another (Suryabrata, 2002).

In the stages of testing the hypothesis, data analysis was carried out using the *independent sample t test* using the SPSS for Windows 26.0 program. To make it easier to analyze data through statistical tests as follows:

Table 7 Independent sample t-test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pre Test	Equal variances assumed	,034	,855	-.298	53	,767	-1.39920	4.69364	-10.81346	8.01505
	Equal variances not assumed			-.298	52,521	,767	-1.39920	4.68951	-10.80717	8.00876
Post Test	Equal variances assumed	2,032	,160	2,899	53	,005	13.50133	4.65760	4.15936	22.84330
	Equal variances not assumed			2,945	51,337	,005	13.50133	4.58389	4.30025	22.70240
Metacognitive Ability	Equal variances assumed	3,037	,087	2,954	53	,005	5.90651	1.99917	1.89668	9.91634
	Equal variances not assumed			2,911	46,510	,006	5.90651	2.02900	1.82356	9.98947
Critical Thinking Ability	Equal variances assumed	1,334	,253	4,027	53	,000	11.32349	2.81212	5.68308	16.96389
	Equal variances not assumed			4,048	52,988	,000	11.32349	2.79715	5.71308	16.93389

Independent Sample T Test Learning Results

Table 7 displays the results of the statistical tests. The independent sample t-test yielded a significance value of 0.767, which is greater than the alpha degree of 5% ($0.767 > 0.05$). Therefore, it can be concluded that the experimental group and the control group did not significantly differ in terms of the average value of XI SMK Telkom Jakarta learning

outcomes. What this means is that SMK Telkom Jakarta's class XI pupils' learning results are not significantly improved when traditional learning approaches are applied. The following is the procedure to follow in order to get the student's post test results.

Following this, we have post-test data from XI SMK Telkom Jakarta that compares the efficacy of PowerPoint with that of the project-based learning model with multimedia-interactive support. Scientists used IBM SPSS 26.0, a Windows statistical program, to conduct their experiments.

It can be concluded that there is a discrepancy in the average value because, according to table 7, the statistical test results reveal a significance value of 0.005 for the independent sample t-test, which is greater than the 5% alpha level ($0.005 < 0.05$). - Learning outcomes for the experimental group compared to the control group at XI SMK Telkom Jakarta on a real-world average. What this means is that students in SMK Telkom Jakarta's tenth grade greatly benefit from the project-based learning paradigm when it is implemented with the use of multimedia-interactive tools.

Independent Sample T Test Metacognitive Ability Test

The benefit of the project-based learning paradigm with multimedia-interactive support for metacognitive skills is shown in table 7. The data was processed using SPSS 26.0 for Windows, according to the researchers' estimations. The null hypothesis (H0) is rejected if the significance or probability value is less than 0.05, and the alternative hypothesis (H1) is accepted if the value is greater than or equal to 0.05. The hypothesis was accepted since the application of the project-based learning model with multimedia-interactive assistance yielded a significance value of 0.005, as shown by the output findings of the independent sample t test, which is less than 0.05. Students in the eleventh grade at Telkom Jakarta Vocational School improved their metacognitive skills in the fiber optics course as a result of their exposure to the project-based learning paradigm augmented by multimedia-interactive.

Independent Sample T Test Critical Thinking Ability

Table 7 illustrates that the project-based learning model with multimedia-interactive supports has a positive influence on students' critical thinking skills. The data was processed using SPSS 26.0 for Windows, according to the researchers' estimations. The null hypothesis (H0) is rejected if the significance or probability value is less than 0.05, and the alternative hypothesis (H1) is accepted if the value is greater than or equal to 0.05. The implementation of the multimedia-interactive project-based learning model was supported by the output results of the independent sample t test, which had a significance value of 0.000, indicating that $0.000 < 0.05$, and so, the hypothesis was accepted. Students in the eleventh grade of Telkom Jakarta Vocational School's fiber optics class showed an improvement in their critical thinking abilities after implementing a project-based learning approach with multimedia-interactive support.

DISCUSSION

The influence of the Project Based Learning (PjBL) model assisted by interactive multimedia on the fiber optic communication learning outcomes of class XI students

The project-based learning (PjBL) learning model is innovative learning that is student-centered and places the teacher as a motivator and facilitator, where students are given the opportunity to work autonomously to construct their learning (Anggraini & Wulandari, 2020). The choice of this learning model is because PjBL uses several stages in its process. The stages in the *Project-based Learning model* can make it easier for students to analyze a problem, make students more active and successful in solving complex problems, increase collaboration, and encourage students to develop thinking skills and practice communication skills, so that the learning model This is believed to be able to improve students' critical thinking skills. Using the PjBL model can activate students, because from the beginning to the end of learning students will discuss and create projects with the help of interactive multimedia.

Interactive multimedia is one of the teaching materials that can be used in the learning process, including in the PjBL model. Interactive multimedia is included in the category of audiovisual teaching materials. As non-print teaching materials, interactive multimedia has advantages over other learning media. This advantage is because interactive multimedia allows students to get material through moving images and sound accompanying it (Guo et al., 2020). The benefits of interactive multimedia according to Burns & Herring (2020), namely that it can influence the improvement of students' critical thinking abilities because they are faced with the reality of an image that exists in the real world. Through interactive multimedia, educators are able to streamline learning time and make students understand more about the learning material, because students get a direct picture of the material being studied.

The choice of the PjBL learning model is also supported by previous research stated by Han and Bhattacharya that through PjBL, students perceive their own problems as challenges or questions that must be answered, and manage their own time to be able to complete their projects so that in project learning the teacher's role is truly right as a facilitator (Warsono & Hariyanto, 2012). Learning steps in *the Project-based Learning (PjBL)* model as developed by *The George Lucas Educational Foundation* (2005) namely 1) Determining basic questions, 2) Developing a plan project, 3) Developing schedules, 4) Monitoring, 5) Testing results, 6) Evaluation of experience. These steps (syntax) are its characteristic and differentiate it from other learning models such as *the Discovery Learning model* and *the Problem Based Learning model* (Hikmah, 2020).

Project-based learning is carried out in groups of 4-5 people, so that in this group there is an opportunity for students to convey ideas, listen to other people's ideas and reflect their own ideas on other people's ideas. Apart from that, implementing the PjBL model also allows students to collaborate, work together and have empathy. According to Ngalimun (2014), the process of approaching colleagues like this will help the knowledge construction process (*meaning-making process*). This is the reason why researchers chose *the Project-based Learning (PjBL)* model assisted by interactive multimedia to be used in this research.

There has been a lot of research that examines the *Project-based Learning learning model (PjBL)*, but each study certainly has its own characteristics related to this theme. Both

from its implementation, the subjects involved, the stages passed during the implementation of *Project-based Learning* (PjBL), and the obstacles encountered. Apart from that, the focus of the problem studied is related to the influence of *the Project-based Learning* (PjBL) model assisted by interactive multimedia on metacognitive abilities and learning outcomes in fiber optic communication. There has not been much research done on class X students . As for novelty The research that will be carried out is using *the Project-based Learning* (PjBL) model with the help of interactive multimedia. In its implementation, this model will be applied to fiber optic communication learning in improving metacognitive abilities and fiber optic communication learning outcomes learners .

Based on a preliminary study by conducting interviews with fiber optic communication teachers who saw the fact that the learning methods used in schools still used lecture and blackboard methods so that learning was not student-centered. Most students use the rote method so that students have less interest in learning and if they are given problems related to the fiber optic communication material that has been given, students find it difficult to solve them.

Learning patterns that are still conventional cause boredom and nowadays are no longer suitable, because learning resources are increasingly developing along with the development of information that is increasingly easily accessed by anyone, including students. The conventional learning model that is currently applied is the cause of students having difficulty further improving their metacognitive abilities so that they cannot coordinate the learning process with daily life. The application of a more creative learning model is expected to motivate students in learning activities.

The results show that the pre-test descriptive statistics of learning outcomes in fiber optic lessons for the control group obtained a mean score for SMK Telkom Jakarta class XI TEL 2 of 66.21 and for the experimental group XI TEL 1 of 64.81 . Furthermore, in the control group Telkom Jakarta Vocational School, the minimum value was 30.00 , the maximum was 90.00, the median was 70.00 and Std. Dev of 17.23 . In the experimental group at SMK Telkom Jakarta XI TEL 1 The minimum value is 30.00 , the maximum is 90.00, the median is 70.00 and Std. Dev of 17.23 . In the control group, the mean class score was obtained, the mean score for SMK Telkom Jakarta class XI TEL 2 was 66.21 and XI TEL 1 was 64.81 . The average pre-test score for learning outcomes in the fiber optics lesson in both classes is still low and does not meet the school's Minimum Completeness Criteria (KKM) score of 70. Based on the calculation of the scores from the control group, the pre-test on fiber optics learning outcomes.

The results demonstrate that XI TEL 1 of the experimental group achieved a mean score of 78.85 on the post-test descriptive statistics on learning outcomes in fiber optic lectures, whereas the control group at SMK Telkom Jakarta achieved a mean score of 65.34. In addition, the normative data for the control group at Telkom Jakarta Vocational School was 19.41 standard deviations, a median of 65.00, and a range of 25.00 to 100.00. Results ranged from a low of 50.00 to a high of 100.00 in the experimental group at Telkom Jakarta XI TEL 1 Vocational School, with a median of 80.00 and a standard deviation of 14.44. The control group consisted of students from SMK Telkom Jakarta in grades XI TEL 2 and XI TEL

1, with average scores of 65.34 and 78.85, respectively. With a mean score of 70, both classes have achieved the school's Minimum Completeness Criteria (KKM) for learning outcomes in fiber optics lessons on the post-test. Therefore, it's safe to say that class Class XI TEL 2 achieved an average class score of 65.34 on the post-test, while class XI TEL 1 achieved an average class score of 78.85.

According to the pre-test statistical hypothesis test, the independent sample t-test yielded a significance value of 0.767, which is greater than the alpha degree of 5% ($0.767 > 0.05$). Therefore, it can be concluded that the experimental group and the control group did not significantly differ in terms of the average value of XI SMK Telkom Jakarta learning outcomes. What this means is that SMK Telkom Jakarta's class XI pupils' learning results are not significantly improved when traditional learning approaches are applied. The following is the procedure to follow in order to get the student's post test results. We can say that there is a difference in the average value because the significance value obtained in the independent sample t-test is 0.005, which is greater than the alpha degree of 5% ($0.005 < 0.05$). This is revealed by the results of the post test statistical hypothesis test. Learning outcomes for the experimental group compared to the control group at XI SMK Telkom Jakarta on a real-world average. What this means is that students in SMK Telkom Jakarta's tenth grade greatly benefit from the implementation of project-based learning models that incorporate multimedia-interactive components.

By developing students' critical thinking skills, student independence will emerge. Students will also know the advantages and disadvantages of learning outcomes in the learning process in the classroom

Research conducted by Mulia Rasyidi and Asrorul Azizi (2018) with the title Scientific Learning Process Oriented Problem Based Learning Process in Basic Electronics Material at Uswatun Hasanah Cempaka Putih Islamic High School for the 2018/2019 Academic Year. The research aims to develop a plan for implementing the learning process on basic electronics material at Uswatun Hasanah Islamic High School. In RPPs based on a scientific approach through the PBL learning process model, it has succeeded in motivating and instilling internal attitudes in students. The stages of a scientific approach can improve students' abilities in observing, asking, reasoning, trying and communicating their findings, thus having a positive impact on their *soft skill abilities*.

Research conducted by Fauziah (2013) entitled Basic Electronics Scientific Learning Oriented to Problem Based Learning. The research aims to develop a plan for implementing basic electronics learning in Vocational High Schools. Based on the results of the questionnaire assessment, the majority of students gave good responses. From the comments on the questionnaire sheet, it is known that with a scientific approach through the PBL learning model, students can express their opinions well, students can find out all the answers to problems from independent learning and exchange of knowledge during group discussions, students can interact well between fellow students as well as teachers and students as a whole actively carry out learning steps that are entirely student-centered.

Research conducted by Suparman (2014) with the title Increasing Learning Independence and Learning Interest of Students in Analog Electronics Subjects with

Learning PBL. The research aims to increase student learning independence with a PBL learning approach in the Analog Electronics course and increase student interest in learning. Learning with a PBL approach can increase student learning independence in Analog Electronics courses; and learning with a PBL approach can increase students' interest in learning in Analog Electronics courses.

Based on the presentation of previous research, it was found that the similarity that previous research has with the research conducted is that they both use a *project-based learning model* assisted by multimedia-interactive which has a significant effect on improving the learning outcomes of class XI students at SMK Telkom Jakarta. Meanwhile, the difference lies in the variables used. In this research, the novelty of using a multimedia-interactive *project-based learning model* can improve the learning outcomes of class XI students at SMK Telkom Jakarta.

CONCLUSION

Based on the results obtained from data obtained during research in class XI SMK Telkom Jakarta. It can be concluded that as follows:

1. The results of the test carried out using the *independent sample t-test* show a significance value of 0.005 or in other words the significance value is smaller or equal to the alpha degree of 5% ($0.005 < 0.05$), so it can be said that there is a difference in the average value of learning outcomes. XI Vocational School Telkom Jakarta between the experimental group and the control group. In other words, the application of *the project-based learning learning model* assisted by multimedia-interactive has a significant effect on improving the learning outcomes of class XI students at SMK Telkom Jakarta.
2. The test results carried out using the *independent sample t-test* show a significance value of 0.005, meaning that $0.005 \leq 0.05$, hypothesis accepted. So it is concluded that there is an influence of learning using *the project-based learning model* assisted by multimedia-interactive on increasing metacognitive abilities in fiber optics subjects in class XI students at Telkom Jakarta Vocational School.
3. The test results carried out using the *independent sample t-test* show a significance value of 0.000, meaning that $0.000 \leq 0.05$, hypothesis rejected. So it is concluded that there is an influence of learning using *the project-based learning model* assisted by multimedia-interactive on increasing critical thinking skills in the fiber optics subject of class XI students at Telkom Jakarta Vocational School.

The results of this classroom action research have the implication that the *Project - Based Learning* model can improve metacognitive abilities , critical thinking abilities and fiber optic communication learning outcomes for class X I students . It is known that the implications are as follows:

1. *The Project-Based Learning* learning model influences learning outcomes as seen from the number of students' grades that achieve the desired target grades.

2. *Project-Based Learning* learning model needs clear preparation so that the objectives of this learning model are achieved, because it needs to prepare students individually for different tasks and responsibilities in each group. Even though this learning model requires good preparation and understanding in its implementation, once students understand how the *Project-Based Learning learning model works*, the goal to be achieved is that students not only understand the basics of fiber optics, but also analyze the fiber optic communication material being discussed.
3. *Project-Based Learning* learning model is only suitable for material that prioritizes case studies and problems related to students' critical thinking.

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