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Multiple Scaffolding STEAM Project-Based Learning Model In Science Learning

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Abstract: Higher order thinking skills (HOTs) are skills needed to face the 21st century. This research aims to (1) analyze simultaneously the differences in learning outcomes, critical thinking skills, and achievement motivation of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (2) analyze the differences in learning outcomes of students who learning using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (3) analyzing differences in critical thinking skills of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (4) analyzing differences in achievement motivation students who learn to use the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning. This research is a quantitative research with nonequivalent pretest-posttest control group design. The sampling technique used was cluster random sampling with the sample size consisting of 159 students in classes VII A, VII B, VII D, and VII F at SMP Negeri 5 Denpasar. The research instruments used were learning achievement tests, critical thinking skills tests and achievement motivation questionnaires. Data analysis used Multivariate Analysis of Covariance (MANCOVA). Hypothesis testing is carried out using a significance level of 5%, hypothesis testing is carried out after assumption testing (normality test, variance homogeneity test, variance covariance homogeneity test, linearity test, multicollinearity test, regression line slope homogeneity test). Based on the data analysis, the research results show that (1) there are simultaneous differences in learning outcomes, critical thinking skills, and achievement motivation of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (2) there are differences in the learning outcomes of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (3) there are differences in the critical thinking skills of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (4) differences in the achievement motivation of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning.

Keywords: Achievement Motivation; Critical Thinking Skills; Multiple Scaffolding; PjBL-STEAM; Project based learning.

Introduction

The 21st century has entered the era of Industrial Revolution 4.0, and all human activities are dominated by high-tech products, which has brought major changes to human life. This situation leads to more complex and uncertain life, problems and challenges, and new jobs that require a high level of competence. The positive impact that occurs from this development is the increasingly complex interrelationships between countries and individuals around the world. This linkage has positive impacts, such as an increased exchange of ideas, technology, and resources (Kraujalienė, 2019). On the other hand, this development

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also has negative impacts, such as increased global competition and economic injustice (Ciriello *et al*., 2018).

To be able to face problems and challenges and at the same time take opportunities to win the competition, a person must have critical thinking skills. Critical thinking skills are the ability to evaluate information objectively and rationally, identify arguments, and make rational and appropriate decisions based on available evidence *(Sellars et al*., 2018). CBC is important for students to be able to hone cognitive skills, analyze, evaluate information, and develop logical reasoning related to the problems they face (Rahayu & Alyani, 2020). CBC involves the ability to systematically collect, analyze, and organize information, as well as the ability to identify assumptions and biases underlying arguments (Espey, 2018). Through CBC, students will become more active, creative, and able to grasp the theories, events, facts, and concepts related to the subject, which will positively contribute to the student's learning outcomes (Dywan & Airlanda, 2020).

Learning outcomes are abilities that students acquire after getting a learning experience from the teacher by carrying out certain assessments that explain the criteria that have been achieved (Agusti & Aslam, 2022; Gulo, 2022). Educators must strive for effective learning for students in order to provide meaningful experiences and can instill critical thinking skills in students (Marudut et al., 2020). In addition to KBK, motivation is also needed, one of the motivations needed is achievement motivation. According to (McClelland, 1987) achievement motivation is a determinant capable of influencing individual behavior, encouraging individuals to achieve excellence. Achievement-oriented individuals usually set realistic goals and often have good planning. By having achievement motivation a person tends to always try to achieve what he wants even though he experiences some obstacles and difficulties in achieving it (D. Amalia *et al*., 2018).

Based on Research conducted by (Bektas, 2017) states that the achievement motivation of students is still relatively low. It is characterized by a lack of student initiative in the classroom, resulting in students being receptive, often misunderstood, and unable to transfer knowledge to everyday life (Arvyati *et al*., 2016; Bektas, 2017). Likewise, with the KBK, the reality on the ground shows that the KBK of students in Indonesia is still relatively low. This statement was also conveyed by (Hermayani *et al*., 2015; Nurazizah *et al*., 2017; Susilowati *et al*., 2017) who stated that the CBC is still a problem for the world of education in Indonesia as indicated by the results of measuring scores that are still low.

The results of the study show that Indonesian students are consistently ranked at the bottom, namely ranking 44 out of 49 countries in the 2015 TIMSS (Novaliyosi, 2019). The PISA results also show that the quality of education and the thinking skills of Indonesian students are still relatively low. In line with the results of the TIMSS and PISA surveys. Some research results also show that students' critical thinking skills are classified as low according to research conducted by (Nurfadilah & Siswanto, 2020) which states that teacher-centered learning makes students unable to master the material more deeply as a result, students critical thinking skills are not properly developed.

The low KBK of students is caused by several factors including, (1) learning activities in class that have been carried out by teachers are none other than conveying information (lecturing method), by activating teachers more, while students passively listen and copy (Adnyani *et al*., 2018 & Yuyu, 2017), (2) in the learning process that takes place students are less encouraged to be able to develop their thinking skills so that students are only capable theoretically but are lacking in terms of application so that students' critical thinking skills freeze even become difficult to developed (Niky Amanah, 2017), (3) the lack of variety of learning models used by teachers in teaching, more students are required to sharpen their memory without being directed how to think and use their reasoning power in implementing existing concepts (Nurmayani, 2018). The inability of students to think critically is also caused by a low understanding of concepts. Students tend to memorize and solve problems without understanding concepts (Koes, Kusairi, & Muhardjito, 2015).

To improve the KBK of students, a new innovation is needed that is in accordance with the problems faced by students. An alternative solution that can overcome these problems is by applying a learning model that is able to grow KBK students. One learning model that is in accordance with scientific characteristics and higher-order thinking is the Project Based Learning (PjBL) model. Training students' critical thinking skills can be done by implementing project-based learning (PjBL) (Azizah & Widjajanti, 2019; Insyasiska et al., 2015; Khairani Astri et al., 2022; Rachmawati et al., 2018). The project-based learning model is an innovative student-centered learning (student center) and places the teacher as a motivator and facilitator, and students are given the opportunity to work autonomously to construct their learning (Prasetyo et al., 2021). Based on previous research, it is known that the PjBL model is able to improve the KBK of students, but in order to be more effective it can collaborate the learning model with the learning approach. The right approach to improve KBK is the Science, Technology, Engineering, Art, and Mathematics (STEAM) approach (Ramli et al., 2020; Santoso & Mosik, 2019; Tsai et al., 2018). STEAM is learning using a conceptual approach between science, technology, engineering, art and mathematics into a

holistic whole so that students are required to be able to apply STEAM concepts related to problems that exist in everyday life (Mardhiyatirrahmah et al., 2020; Stansell et al., 2016; Yuliati & Saputra, 2020).

The five STEAM components are able to create an active and cohesive learning system (Ngabekti et al., 2019; Sumarni et al., 2019) mentally train students to stimulate critical thinking skills so they are able to analyze, make decisions, evaluate, investigate and solve problems properly (N. F. Amalia & Pujiastuti, 2016; Khoiriyah et al., 2018). Learning through the STEAM-integrated PjBL model to improve critical thinking has been widely used. Research conducted by (Fitriyah & Ramadani, 2021) states that PjBL-based STEAM learning has a significant influence on generating ideas, creative solutions and students' critical thinking. Learning using the PjBL-STEAM model provides meaningful experiences to students through making projects, students are given the freedom to plan learning activities, design and implement projects, and produce products (Priantari et al., 2020). However, the PjBL-STEAM model has not been widely implemented with the addition of scaffolding. Scaffolding is the provision of a number of assistance in the learning process which can take the form of instructions, warnings, encouragement, describing problems into solving steps, and providing examples so as to enable students to grow independently (Nasrulloh & Umardiyah, 2020). Scaffolding strategies are provided to guide students through key questions to test the ideas, arguments, and reasoning students generate in order to develop projects. Therefore, scaffolding does not only produce results in the form of cognitive development, but also accommodates the emergence of the skills needed to solve problems independently in the future (Suryono and Hariyanto, 2011). Based on the above descriptions, we conducted a study to understand the impact of the multiple scaffold-assisted PjBL-STEAM model on learning outcomes, critical thinking skills, and student achievement motivation. This research is a quantitative research with a nonequivalent pretests-posttest control group design which aims to (1) analyze simultaneously differences in learning outcomes, critical thinking skills, and achievement motivation of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (2) analyze the differences in learning outcomes of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (3) analyze the differences in critical thinking skills of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning, (4) analyzing the differences in achievement motivation of students who learn using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model in science learning.

Method

The method used in this study was quasi-experimental with a non-equivalent pretest-posttest control group design.

Table 1. Research Design Nonequivalent Pretest Posttest Control Group Design (Sugiono, 2017)

Group	Pre-test	Treatment	Post-test
Experiment		X_1	O_2
Control	O_3	X_2	O_4

Information:
X1: The learning process uses the PjBL-STEAM model assisted by scaffolding
X2: The learning process uses the PjBL model
O1, O3: Pre-test results
O2, O4: Post-test results
R: Random

Population and sample

The population of this study were class VII students of SMP Negeri 5 Denpasar even semester of the 2022/2023 school year, with a total of 318 class VII students distributed into eight classes, namely: class VII A, VII B, VII C, VII D, VII E, VII F, VII G, and VII H. The samples selected in this study were four classes using the cluster random sampling technique, namely two experimental classes will be applied to the scaffolding-assisted PjBL-STEM model and two control classes will be applied to the PjBL model with a total sample of 159 learners.

Instrument

The instruments used in this study amounted to three instruments according to the number of dependent variables studied, namely learning achievement tests, critical thinking skills tests, and achievement motivation scales. Assessment of learning outcomes is made in the form of tests and is constructed with reference to indicators of learning outcomes that follow the taxonomic bloom indicators on cognitive aspects. Assessment of critical thinking skills is made in the form of tests and constructed with reference to indicators of critical thinking skills Facione (1990), namely interpretation, analysis, evaluation, inference, explanation, achievement motivation instruments are also developed according to (McClelland, 1987) in the form of a questionnaire. Tests of learning outcomes and tests of critical thinking skills in this study were tested for validity, reliability, discriminating power, and problem difficulty, then for achievement motivation questionnaires were tested for validity. The research

instrument was not only tested but also validated by experts.

Data Analysis Technique

Data were analyzed using antecedent tests and hypothesis tests. The prerequisite test was carried out using the normality test, variance homogeneity test, covariance variance homogeneity test, linearity test, multicollinearity test, slope homogeneity test of the regression line. Hypotheses were then tested using a multivariate analysis of covariance (MANCOVA) test to understand the impact of the scaffold-assisted PjBL-STEAM model on learning outcomes, critical thinking skills, and student achievement motivation.

Result and Discussions

The data described in this study are learning outcomes, and the results of critical thinking skills as a result of the treatment of applying the scaffolding-assisted PjBL-STEAM learning model to student achievement motivation. The variables of learning outcomes in science lessons were measured by learning achievement questions for students in the experimental group and the control group in the form of minimum scores, maximum scores, average, standard deviation, and variance. The posttest qualifications of the learning outcomes of the experimental group and the control group can be seen in the bar chart in Figure 1.

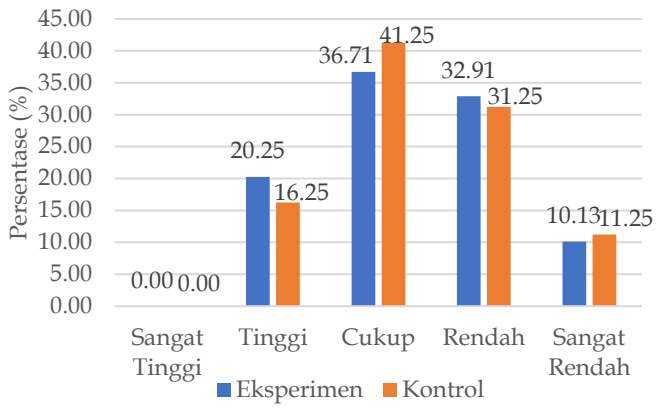

Figure 1. Bar Diagram of Qualification of Posttest Scores of Student Learning Outcomes at 100 Scale Conversion

Based on the conversion results of the 100 scale post-test, the experimental group students learning outcomes had better learning outcomes than the control class, this was because in the experimental class, students had more science learning outcomes with very high qualifications than the control class students. Qualification of the results of the posttest critical thinking skills of students in the experimental group and the control group can be seen in the bar chart in Figure 2.

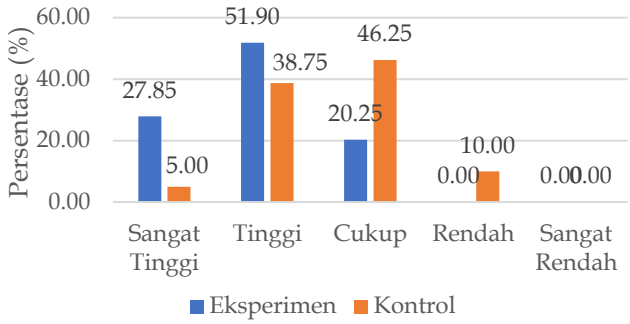

Figure 2. Bar diagram of KBK Posttest Qualification Scores of 100 Scale Conversion Students

Based on the results of the 100 Scale conversion, the results of the post-test critical thinking skills of experimental group students had better critical thinking skills qualifications than the control class because in the experimental class students who had critical thinking skills with very good qualifications were more than control class students. The results of the achievement motivation categories of students in the experimental group and the control group can be seen in the bar chart in Figure 3.

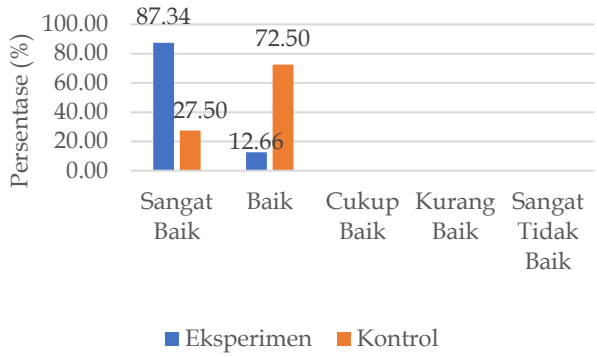

Figure 3. Bar Diagram of the Final Achievement Motivation Category

The results of the achievement motivation of students in the experimental group had a better achievement motivation category than the control class because in the experimental class students who had achievement motivation with very good qualifications were more than students in the control class.

Prerequisite Test

The data normality test was performed using the Kolmogorov-Smirnov test. The normality test was carried out on the variable data on learning outcomes, critical thinking skills and achievement motivation in each treatment class.

Based on Table 2, for each variable for the normality test statistic, if the value is more than α (0.05), then H0 is accepted. Thus, it can be concluded that the sample comes from normally distributed data. The homogeneity of variance test is intended to determine the similarity of variance between groups in each dependent variable.

Table 2. Summary of Data Normality Test Results

Data	Category	Sig.
Pre-test Learning Outcomes	PjBL-STEAM	0.200*
	PjBL	0.200*
Post-test Learning Outcomes	PjBL-STEAM	0.059
	PjBL	0.052
Critical Thinking Skills Pre-test	PjBL-STEAM	0.200*
	PjBL	0.200*
Critical Thinking Skills Post-test	PjBL-STEAM	0.200*
	PjBL	0.200*
Achievement Motivation Pre-test	PjBL-STEAM	0.200*
	PjBL	0.200*
Achievement Motivation Post-test	PjBL-STEAM	0.200*
	PjBL	0.057

Table 3. Levene Test Results for Equality of Variances

	Levene Statistic	df 1	df 2	Sig.
Pre-test Learning Outco	0.072	1	156.982	0.789
Post-test Learning Outcomes	0.022	1	155.888	0.883
Critical Thinking Skills Pre-test	0.027	1	156.964	0.870
Critical Thinking Skills Post-test	0.022	1	156.959	0.882
Achievement Motivation Pre-test	0.533	1	156.988	0.466
Achievement Motivatio Post-test	0.284	1	128.047	0.800

Based on Table 3, the sig (p) value obtained is greater than the α value (0.05) for all variables so H0 is accepted. In other words, it can be concluded that the population variance is homogeneous or identical. Test the homogeneity of the variance-covariance matrix using the Box's Test

Table 4. Homogeneity Test Results of the Covariance Variance Matrix

Item	Value
Box's M	1.895
F	23.900
df 1	6
df 2	178511.362
Sig.	0.281

Based on the results table, the sig. (p) obtained is 0.281 greater than α (0.05) so H0 is accepted. Thus, the variance-covariance matrix is homogeneous. The linearity test was carried out to determine the influence of the covariate variables on the dependent variable. The results of the linearity test are presented in Table 5.

Table 5. Linearity Test Results between Pretest and Posttest Learning Outcomes, Critical Thinking Skills, and Achievement Motivation

Variable	Between Groups	Sig.
Post-test Learning Outcomes * Pre-test Leaning Outcomes	Linearity	0.000
	Deviation from Linearity	0.435
Critical Thinking Skills Post-test * Critical Thinking Skills Pre-test	Linearity	0.000
	Deviation from Linearity	0,596
Achievement Motivation Post-test * Achievement Motivation Pre-test	Linearity	0.000
	Deviation from Linearity	0.742

Table 5 shows that the sig. (p) obtained in the aspect of deviation from linearity in the learning outcome variable, namely 0.435. The critical thinking skill variable shows that the sig (p) value obtained in the deviation from linearity aspect is 0.596. The achievement motivation variable shows that the sig (p) value obtained in the aspect of deviation from linearity is 0.742, the acquisition of sig. (p) on each variable is greater than the value of α (0.05). Thus, H0 is accepted. It can be concluded that the regression model for the influence of covariate variables on learning outcomes, critical thinking skills, and achievement motivation is linear. Molinearity test is a regression test between the dependent variables.

Table 6. Multicollinearity Test Results Data on Learning Outcomes, Critical Thinking Skills, and Achievement Motivation

		Post-test Learning Outcome	Critical Thinking Skills Post-test	Achievement Motivation Post-test
Pre-test Learning Outcome	Pearson Correlation	0,365**	0,454**	0,539**
	Sig. (2-tailed)	0,000	0,000	0,000
	N	159	159	159
Critical Thinking Skills Pre-test	Pearson Correlation	0,462**	0,437**	0,533**
	Sig. (2-tailed)	0,000	0,000	0,000
	N	159	159	159
Achievement Motivation Pre-test	Pearson Correlation	0,510**	0,431**	0,471**
	Sig. (2-tailed)	0,000	0,000	0,000
	N	159	159	159

Table 5 shows the sig. (p) obtained from) on each variable is less than the value of α (0.05, then H0 is accepted. This means that there is a linear relationship between learning outcomes, critical thinking skills, and achievement motivation. The homogeneity test of the slope of the regression line is intended to determine the slope or slope of the regression line of the covariate variables and whether the dependent variable for the experimental and control groups in each dependent variable is homogeneous or not. The results of the slope homogeneity test of the regression line are shown in Table 7.

Table 7. Slope Homogeneity Test of the Regression Line

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Pre HB	1254.264	10	125.426	1.379	0.196
	Pre BK	749.343	10	74.934	0.868	0.565
	Pre MB	326.362	27	12.087	1.422	0.109

Based on the data in Table 7 it shows that the sig. (p) from the interaction between groups and pretest for the dependent variable learning outcomes, critical thinking skills and achievement motivation respectively 0.196, 0.565, and 0.109. These three sig (p) values are more than 0.05. This means that H0 is accepted. Thus, there is a slope of the regression line both for learning outcomes, critical thinking skills, and achievement motivation are homogeneous.

Hypothesis Test

After all the prerequisite tests have been carried out and met the requirements, the next step is hypothesis testing. Hypothesis testing was carried out on all hypotheses proposed in this study. The null hypothesis (H0) is accepted if the significance value is above 0.05 and the alternative hypothesis (Ha) is accepted if the significance value is below 0.05. Regarding the submission of the third hypothesis, this was carried out based on the guidelines for the MANCOVA analysis results presented in Table 8.

Table 8. The Effect of Scaffolding Assisted PjBL-STEAM Model on Learning Outcomes, Critical Thinking Skills and Achievement Motivation

Effect		Value	F	Hypothesis df	Error df	Sig.
Model	Pillai's Trace	0.588	72.262[b]	3.000	152.000	0.000
	Wilks' Lambda	0.412	72.262[b]	3.000	152.000	0.000
	Hotelling's Trace	1.426	72.262[b]	3.000	152.000	0.000
	Roy's Largest Root	1.426	72.262[b]	3.000	152.000	0.000

The data in Table 8 shows that the sig. (p) obtained for the four Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root on the group aspect less than the value of α (0.05). This means, H0 is rejected or Ha is accepted. Thus, it can be concluded that there are significant differences in learning outcomes, critical thinking skills, and achievement motivation between groups of students taught using the PjBL-STEAM model assisted by multiple scaffolding and groups of students taught using the PjBL model.

Table 9. Results of Analysis of the Effect of the PjBL-STEAM Model assisted by multiple scaffolding on Learning Outcomes compared to the PjBL model

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Learning Outcomes	3772,350	1	3772,350	44,317	0,000

Based on the data in Table 9, the significant value obtained is less than 0.05, so H0 is rejected and Ha is accepted. Thus, it can be concluded that there is a significant difference in learning outcomes between groups of students who are taught with the PjBL-STEAM model assisted by scaffolding and the group of students who are taught with the PjBL model.

Table 10. Results of Analysis of the Effect of the PjBL-STEAM Model assisted by multiple scaffolding on Critical Thinking Skills compared to the PjBL model

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Critical Thinking Skills	5276,804	1	5276,804	61,024	0,000

Based on the data in Table 10, the significant value obtained is less than 0.05, so H0 is rejected and Ha is accepted. Thus, it can be concluded that there is a significant difference in critical thinking skills between groups of students who are taught with the PjBL-STEAM model assisted by scaffolding and the group of students who are taught with the PjBL model.

Table 11. Results of Analysis of the Effect of the Multiple Scaffolding Assisted PjBL-STEAM Model on Achievement Motivation Compared to the PjBL Model

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Achievement Motivation	1533.136	1	1533.136	136.339	0.000

Based on the data in Table 10, the significant value obtained is less than 0.05, so that H0 is rejected and Ha is accepted. Thus, it can be concluded that there is a significant difference in achievement motivation between groups of students who are taught with the PjBL-STEAM model assisted by scaffolding and the group of students who are taught with the PjBL model.

The use of the PjBL-STEAM model is able to train students' critical thinking skills because students are asked to find their own solutions to each problem. This obtained is in accordance with research conducted by (Cahyani & Sulastri, 2021) which states that the application of the project-based learning model learning with the STEAM approach has an effect on students' critical thinking skills and there is a significant increase in critical thinking skills. In addition, the STEAM integrated project-based learning model is a learning model that requires students to participate actively both individually and in groups, because through collaboration in groups it will involve students in the process of problem-solving investigations so that they are able to construct the core of the lesson from the findings. findings in tasks or projects carried out and integrating them into various scientific disciplines such as science, technology, engineering, art, and mathematics (Astuti et al., 2019; Kanza et al., 2020).

The results of the data analysis showed that the learning outcomes and achievement motivation of students who used the PjBL-STEAM model assisted by multiple scaffolding were better than the learning outcomes of students who used the PjBL model. This is consistent with the characteristics of the PjBL model emphasizing students learn actively and in groups and share information with each other so as to help open other students' insights in thinking by integrating STEAM so that students get meaningful and memorable learning experiences because students are directly involved in the learning process (Haerani & Rahman, 2022; Mamahit *et al*., 2020). Makmum (2018) states that student motivation is seen from carrying out learning activities: duration of learning, frequency of activities, persistence, and ability of students to overcome various obstacles. This is able to measure the achievement of student achievement seen from the motivation that has been formed during the learning process.

Achievement motivation arises because it is influenced by the existence of hope, desire and effort in students as a driving force in learning activities. Motivation plays a very important role in the learning process, with the motivation of students to be diligent in learning so that the quality of learning outcomes can be realized properly. In this study, the PjBL model was used with a STEAM-oriented approach with the help of multiple scaffolding. The assistance referred to in this multiple scaffolding strategy is in the form of providing instructions, encouragement, describing problems into solving steps, providing examples so that students grow independently.

Conclusion

Based on the research that has been done, it can be concluded that simultaneously there are differences in learning outcomes, critical thinking skills and achievement motivation of students using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model There are differences in learning outcomes of students using the PjBL-STEAM model assisted multiple scaffolding and PjBL models. There are differences in the critical thinking skills of students who use the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model. There are differences in the achievement motivation of students using the PjBL-STEAM model assisted by multiple scaffolding and the PjBL model.

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Author Contributions

Ida Mareta, Wayan Redhana, Wayan Suastra conceptualized research ideas, methodological designs, data analysis, management, and coordination responsibilities. Ida Mareta conducted research and process investigations, literature

reviews, Wayan Redhana and Wayan Suastra provided critical feedback on the manuscript. All authors read and approved the final version of the manuscript.

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