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PROJECT BASED LEARNING FRAMEWORK WITH STEAM METHODOLOGY ASSESSED BASED ON SELF-EFFICACY: DOES IT AFFECT CREATIVE THINKING SKILLS AND LEARNING ACHIEVEMENT IN STUDYING FUNDAMENTAL COMPUTERS?

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Abstract

Students must grasp creative thinking as a crucial 21st-century talent to enhance learning achievement. Empirical research indicates that pupils' creative thinking skills and learning achievements require enhancement and attention. This study examines the impact of a project-based learning framework with STEAM methodology and self-efficacy levels on creative thinking abilities and learning achievement in primary computer education, focusing on computer architecture. A quasi-experimental pre-test-post-test non-equivalent control group design was utilised to develop the research design. One hundred students were enrolled, of which 50 were divided into the experimental and control groups. Research data was collected using questionnaires and test devices. Student self-efficacy was assessed using a 44-item questionnaire, creative thinking skills were evaluated with a 10-question essay test, and student learning achievement was measured using a multiple-choice test. Data analysis entails the application of descriptive and inferential statistics, specifically using MANCOVA. Research indicates that implementing the project-based learning framework with STEAM methodology is effective in enhancing students' creative thinking abilities and academic performance. Research shows that self-efficacy affects creative thinking skills and learning achievement differently. A p-value of less than 0.05 denotes this. The project-based learning framework with STEAM methodology has been proven to help enhance creative thinking abilities and academic achievement through simultaneous and partial testing. This strategy is indicated for enhancing creative thinking skills and improving learning achievement.

Keywords – Project-based learning, STEAM methodology, Self-efficacy, Creative thinking skills, Student achievements.

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1. Introduction

Learning is an essential activity in supporting the quality of educational development. The development of education and learning has entered a new phase since the pandemic, and changes in the learning process have been made significantly through the use of technology (Bertrand & Namukasa, 2020; Nurhasnah, Festiyed & Yerimadesi, 2023; Putri, Prasetyo, Purwastuti, Prodjosantoso & Putranta, 2023). Learning innovations must be developed to address the challenges of the post-pandemic era. These innovations play a critical role in building students' 21st-century skills (Setyarto, Murtiyasa & Sumardi, 2020; Suryaningsih, 2023; Zhao & Li, 2022). The challenge for educators in the 21st Century is that learning is no longer based solely on material completion but has changed to skill development, knowledge management, and character formation (Bertrand & Namukasa, 2020). Furthermore, the learning process in the 21st Century provides more opportunities for students to build their knowledge concepts through activities around them (Rati, Arnyana, Dantes & Dantes, 2023; Suryaningsih, 2023).

21st-century learning is in line with constructivist theory, which is widely used from elementary school to higher education by providing opportunities for students to explore more knowledge through real-life phenomena (Liston, Morrin, Furlong & Griffin, 2022; Sholahuddin, Anjuni, Leny & Faikhamta, 2020; Yildiz & Guler-Yildiz, 2021). Previous research from Santyasa, Santyadiputra and Juniantari (2019) and Syahril, Nabawi and Safitri (2021) revealed that teachers have widely used innovative learning models such as PBL and PjBL to encourage the achievement of 21st-century skills. Using these learning models directly impacts the learning process, assessment, and evaluation of subsequent learning (Almulla, 2020; Ananda, Rahmawati & Khairi, 2023).

The Computer Architecture course is one part of the INSTIKI Informatics Engineering study program curriculum. This course aims to educate students on analyzing components in computer architecture (Nayak, Hiremath, Umadevi & Garagad, 2021; Sidek, Yatim, Ariffin & Nurzid, 2020; Suhaimi, Rosli, Ariffin, Muniandy & Wahab, 2019). This course is designed to understand how hardware and software in a computer system can work together. Students who study this course are expected to be able to analyze and design computer architecture that is optimally suited to work needs. Therefore, students must be equipped with creative thinking skills to develop and create computer device specifications following the structure and organization of the computer.

Developing creative thinking skills is essential for all educational endeavours in the 21st century (Aurava & Meriläinen, 2022). Creative thinking skills can be generated continuously by allowing students to practice thinking and express their ideas directly according to their interests and learning needs (Montero, 2019; Puozzo & Audrin, 2021). Creative thinking skills aim to produce new and unique ideas. In other words, creative thinking skills are a flexible combination of rational and divergent thinking following feelings but still in awareness (Lu, Lo & Syu, 2021). Developing students' creative thinking skills can give birth to new ideas that were previously unthinkable, find different ways of solving problems, and have many perspectives in completing a learning activity (Rusilowati, Ulya & Sumpono, 2020; Kalashi, Bakhshalipour, Azizi & Sareshkeh, 2020; Suryaningsih, Nisa, Muslim & Aldiansyah, 2023). Creative thinking skills help students develop designs and innovations when learning computer architecture (Encheva, Tammaro, Yancheva, Zlatkova, Conti & Maasilta, 2024; Putri et al., 2023; Habibi, Mundilarto, Jumadi, Gummah, Ahzan & Prasetya, 2020; Suhaimi et al., 2019). Thus, optimal creative thinking skills are expected to encourage student's enthusiasm and motivation to learn, positively impacting learning achievement.

Learning achievement results from learning activities, which means the extent to which students can master the learning material they have carried out (Cheng, 2023; Feraco, 2023; Ifinedo & Burt, 2024). This means that student learning achievement can be measured if an assessment of the student's learning outcomes has been conducted. Learning achievement is an achievement that students have been able to achieve consciously and plan in their learning activities (Darmuki, 2023; Jiang, 2023). Through learning achievement, a student can measure his progress in learning activities. Learning achievement and the learning process are units that complement each other, where, in essence, learning achievement is the final result of a learning process (Zainuddin, 2022). Learning achievement is said to reach the entire domain, including cognitive, affective, and psychomotor domains (Pratiwi & Santyasa, 2021). The cognitive domain relates to the level of knowledge needed to understand, analyze, and create (Tenhovirta, Korhonen, Seitamaa-Hakkarainen & Hakkarainen, 2022). The affective domain refers to students' attitudes, behaviour, and norms during learning activities (Guo, Saab, Post & Admiraal, 2020). The psychomotor domain relates to the skills or abilities demonstrated during the learning process (Tisna, Parwati, Warpala, Sudatha, Sudarmika & Suartama, 2022). From this point of view, learning abilities and success in school come from the process of learning. So, increasing creative thinking skills in the learning process should be accompanied by changes in learning achievement for the better (Santyasa et al., 2019).

However, the reality that happened was far from what had been planned. The problem analysis found that students carrying out learning activities were still dominated by completing material through traditional learning (Diana, Surjono & Mahmudi, 2023). Results of previous research by Hew, Jia, Gonda and Bai (2020) show that as many as 75% of higher education students still use direct learning methods. Previous research results from Parwati and Suharta, (2020) and Santyasa et al. (2019) revealed that traditional learning methods provide less challenge to students who study formally in higher education units. Learning activities in higher education should facilitate learning activities so that more students make discoveries, solve problems, and think at a higher level (Ali, 2021; Ma, 2023).

Based on past research findings, learning processes may not achieve ideal two-way interaction in higher education. This is because many students who learn using traditional methods tend to be given assignments and practice questions more often accompanied by teachers, where these learning activities are less able to train creative thinking skills (Atmojo, Ardiansyah & Saputri, 2022; Sigit, Ristanto & Mufida, 2022). This fact proves that traditional learning models have weaknesses when used in daily learning activities, especially in providing space to practice developing thinking skills. The harmful impact of the traditional learning process is that many students avoid learning activities and skip class. This situation certainly affects learning outcomes that are less than optimal and impacts students' abilities far from standard work qualifications (Heilala, Shibani & de Freitas, 2023). Based on the 1994 AECT definition, educational technology covers five domains, and this research focuses on the utilization domain. It is designed to develop novel learning models that may be applied to developing creative thinking abilities and learning achievement.

The learning model known as project based learning can potentially cultivate students' creative and active thinking skills (Ananda et al., 2023, Chistyakov, Zhdanov, Avdeeva, Dyadichenko, Kunitsyna & Yagudina, 2023, Pawar, Patil & Kulkarni, 2023). The project based learning model provides more opportunities for students to manage learning based on project activities (Atmojo et al., 2022). The project activities are problem-based learning activities that are the first step in collecting and integrating new knowledge based on experience gained during the learning process (Lu, Wu & Huang, 2022; Mayar, Putra, Monia, Kosassy, Fadli & Arinalhaq, 2023; Randazzo, Priefer & Khamis-Dakwar, 2021). A learning process that links real life can lead students to practice problem-solving skills, make decisions, carry out investigations, and learn independently or in groups. Past research findings on project based learning methods indicate that the methodology is centred around students (Domenici, 2022), where students are invited to develop their existing abilities by creating learning projects so that it is hoped that through actual project activities carried out, they can develop students' reasoning and creative thinking abilities (Hasanah, Parno, Hidayat, Supriana, Yuliati, Latifah et al., 2023; Rahayu, Sutikno & Indriyanti, 2023; Rahmania, 2021).

Previous studies have examined the project-based learning model's effects, consequences, and efficacy. On average, these studies have found that the project based learning model offers more opportunities for students to develop their creative thinking skills than traditional learning methodology (Heilala et al., 2023; Kwan & Wong, 2021). Prior studies have shown that the project based learning model can enhance students' analytical, creative, problem-solving, investigative, and teamwork abilities. (Atmojo et al., 2022; Ortiz-Laso, Diego-Mantecón, Lavicza & Blanco, 2023). According to other studies, e-learning in conjunction with the project based learning methodology is the best way to maximize limited classroom time (Sigit et al., 2022). Further research also states that the project-based learning model is very suitable and effective for students studying in formal education. The meta-analysis research found that the project based learning methodology significantly differed from traditional learning and was used from elementary to high school (Torres, Lagarón & Bargalló, 2024).

The project-based learning methodology is highly effective in developing 21st-century abilities in elementary and middle school students. Thus, conducting an in-depth analysis of the project-based learning model in higher education units is necessary. However, what differentiates this research from previous research is that the project-based learning model is integrated with the STEAM methodology. In this research, the syntax of the project based learning model combined with the STEAM methodology was not merged to become a new stage; according to Sigit et al. (2022) and Siregar, Rahmawati and Suyono (2023) findings, a new syntax is formed: Reflection, Research, Discovery, Application, and Communication. Instead, it maintains the six syntax of learning steps from the project based learning model, which is reinforced with each syntax using STEAM components (Lu et al., 2021).

Factors that influence creative thinking skills and learning achievement are classified into two factors, namely internal and external factors. External factors come from outside the student, including the learning model (Santyasa et al., 2019), while internal factors within students include self-efficacy (Yada, Leskinen, Savolainen & Schwab, 2022). Apart from paying attention to the learning model, it is essential to consider each student's self-efficacy level, which is thought to influence creative thinking skills and learning achievement (Ekatushabe, 2021; Masdarini, Candiasa, Agustini & Sudatha, 2024). Previous research reports that the level of student self-confidence affects learning activities. The higher the self-efficacy, the less likely the student will give up and give up on the learning process (Luo, So, Wan & Li, 2021). Other research reports that low levels of self-confidence in students influence hesitant decision-making and lack of confidence in the answers given (Fatimah, Murwani, Farida & Hitipeuw, 2023). A high level of self-confidence is more prominent in conveying new ideas and the mentality to dare to express opinions in front of the class (Dinh, 2022; Wang & Frye, 2019). Due to the results of previous research regarding students' level of self-confidence influencing the learning process, it is imperative to include the level of self-confidence in the research variables.

This study intends to examine the impact of the project-based learning model incorporating the STEAM methodology on self-efficacy in creative thinking skills and academic performance by analyzing the relationship between the project based learning model and the STEAM methodology. The research carried out is different from previous research. This study examines the structure of project-based learning enhanced by the STEAM methodology and its impact on creative thinking abilities and academic performance. Project based learning frameworks and the STEAM methodology The model that focuses on this research is based on previous research data and can train high-level thinking skills.

Therefore, this research aims to improve creative thinking skills because it will affect students' higher-level thinking abilities when creative thinking skills progress. If a new learning model is applied to students in the learning environment, their experience and knowledge of the material they are studying will increase. Thus, according to the outlined description, the project-based learning model and the STEAM methodology are student-centred learning models that encourage students to actively produce new ideas, flexible answers, and problem-solving solutions beyond expectations but can still be rationalized. The present research offers insights into enhancing creative thinking skills and improving learning outcomes by implementing a project based instructional framework with the STEAM methodology. The problems that have been addressed in this study can be categorized as follows:

1. How much effect does the project-based learning framework incorporating STEAM methodology have on creative thinking skills and academic performance?
2. How can varying levels of student self-efficacy impact creative thinking abilities and academic performance?
3. How do students' creative thinking skills progress according to each indicator?
4. How does academic performance improve according to Bloom's taxonomy levels?

2. Methodology

The research that was conducted, as stated by (Rogers & Revesz, 2019), employed a quasi-experimental design featuring a control group comprising a pre-test and a post-test. Control and experimental groups were constructed to categorize the various stages of the research implementation process. Students in the experimental group were taught utilizing a project-based instructional framework using the STEAM methodology. The control group of children was exposed to a project-based learning methodology that did not use a STEAM methodology. The pre-test and post-test were carried out in each control and experimental group to evaluate whether there were differences between the groups before and after treatment regarding creative thinking skills and learning achievement.

The data collected in this study are (1) the students' first creative thinking skills when studying, utilising the project based learning framework using the STEAM methodology (Y1-1); (2) final creative thinking skills for students who learn utilizing the project based learning framework with the STEAM a perspective (Y1-2); (3) the early creative thinking skills of kids that learn utilizing the project based learning framework without the use of the STEAM methodology (Y1-3); (4) the final creative thinking abilities of children who are taught utilising the project based learning procedure without the STEAM methodology (Y1-4); (5) students' initial learning achievement using the project based learning framework with the STEAM methodology (Y2-1); (6) Students' final learning outcomes when using the project based learning framework with the STEAM methodology (Y2-2); (7) initial learning achievement of project based learning students without STEAM (Y2-3); (8) final learning achievement of project based learning students without STEAM (Y2-4).

The research trial was conducted at the INSTIKI Informatics Engineering Study Program involving 320 first-semester students from 10 classes A1 to A10. The next stage is determining the number of research samples. A group random sampling technique was used in this research. This technique was used because respondents had been grouped into classes by the academic department, making it impossible for researchers to take respondents as samples randomly.

An experimental class consisted of 50 respondents from classes A1, A3, and A7, while the control class consisted of 50 people from classes A4, A8, and A10. The use of group random sampling techniques means that researchers cannot know the initial conditions of each individual in the class because they do not test equality in each class. The Multivariate Analysis of Covariance, a data analysis technique, was used based on the natural conditions at the research location. Using covariate variables, factors that interfere with or have the potential to influence the dependent variable during the research process can be reduced statistically.

Questionnaires and test instruments were designed to collect data in this research process. At the assessment and evaluation stage of the learning process, a questionnaire instrument is used to measure the self-efficacy scores of students from each class. The self-efficacy questionnaire was developed from Bandura's self-efficacy dimensions (Bandura, Freeman & Lightsey, 1999) and modified the questionnaire from previous research related to self-efficacy (Fatimah et al., 2023; Lee, Davis & Li, 2023) —the modified questionnaire comprised 44 statement items divided into positive and negative statements. In Table 1, self-efficacy indicators are displayed. The instrument developed was then tested for validity and reliability. The CVR (Content Validity Ratio) formula is used to test the content validity of the self-efficacy instrument. Based on the provisions of the CVR formula, each statement item is 1.00, and the overall total CVR score for the self-efficacy instrument is 44.00, which means the instrument is declared valid. Testing the reliability of the self-efficacy instrument using Cronbach-Alpha obtained a score of 0.982, which means the instrument level has high reliability.

Essay tests are used to evaluate creative thinking skills, and multiple-choice tests are used to assess student learning achievement. The creative thinking skills test instrument is adapted from Paul Torrance's dimensions of thinking skills (Torrance, 1972; Sendag, Yakin & Gedik, 2023). Furthermore, the instrument was modified based on the research conducted. The essay test is designed with ten questions to evaluate creative thinking skills. The ten essay assessments are calibrated according to Bloom's Taxonomy levels C4 to C6, which measure degrees of creative thinking. Indicators of creative thinking abilities as measured by the instrument are shown in Table 2.

Meanwhile, the multiple-choice test is designed with 15 questions for learning achievement, which has a level of C2-C6. Indicators on the multiple-choice test can be seen in Table 3. The validity test results on the two test instruments obtained an overall CVR score on the creative thinking skills test of 10.00 and the learning achievement test of 15.00. Following the provisions of the CVR formula, both instruments are declared valid. After being tested using CRV, proceed to the CVI (Content Validity Index) formula to test each statement item. The CVI results obtained a score of 1.00 on the creative thinking skills and learning achievement test, so it can be declared to have excellent validity. Reliability analysis of the two instruments for creative thinking skills and learning achievement using Cronbach-Alpha obtained a score of 0.876 for the essay test and 0.868 for the multiple-choice test, which means it is in a perfect category.

Dimensions	Indicator	Item		Total
		Positive	Negative	
Magnitude	Confidence in the task given as a challenge in learning	1&2	3&4	4
	Confidence in your ability to overcome barriers is directly related to the difficulty level of the tasks.	5&6	7&8	4
	Confidence in the ability to take the actions necessary to achieve a result	9&10	11&12	4
	Have a positive view of the tasks carried out	13&14	15&16	4
Strength	Believe strongly in your ability to accomplish objectives.	17&18	19&20	4
	Have a fighting spirit and do not give up easily when experiencing obstacles in completing tasks	21&22	23&24	4
	Have the spirit to work hard and try to achieve the maximum	25&26	27&28	4
	Commit to completing academic assignments well	29&30	31&32	4
Generality	Generality: Able to respond to diverse situations and conditions with a positive attitude	33&34	35&36	4
	Displaying an attitude that shows self-confidence throughout the learning process	37&38	39&40	4
	Using life experience as a step to achieve success	41&42	43&44	4

Table 1. Self-efficacy indicators for fundamental computer material

Aspects measured	Markers of Creative Thinking Skills	Level Cognitive	Quantity
Fluency	Analyzing computer structural components and BUS interconnections on the computer	C4	2
	Evaluate the advantages and disadvantages of the existing line types in the BUS interconnection.	C5	1
Elaboration	Designing a block diagram of the computer's bus, data, and address lines.	C6	1
	Providing arguments on the role of BUS interconnection in the data transfer process	C5	1
Flexibility	Relate the concept of BUS interconnection to activities in daily life	C4	1
	Comparing the Multiplexer Bus type with the Dedicated Bus	C4	2
Originality	Constructing the concept of memory and storage on a computer using an analogy in real life	C6	1
	Develop a concept using real-life analogies regarding transferring data from CPU, Memory, I/O, and BUS Line.	C6	1

Table 2. Indicators of creative thinking skills for fundamental computer material

Markers of Fundamental Computers Learning Achievement	Level Cognitive	Total
Explain the main components of a computer and the BUS interconnection lines.	C2	2
Determine the main components that make up the computer architecture and interconnection paths.	C3	2
Determines the type of bus interconnection on the computer structure	C3	2
Conceptualise bus interconnection lines (data, control, and address)	C3	2
Compare bus interconnection categories (data, address, and control)	C4	2
Analyzing data transfer on the bus interconnection line	C4	1
Comparing the data communications used in the interconnection line	C5	2
Construct the operating principle on the bus interconnection line	C6	2

Table 3. Learning achievement indicators for fundamental computers material

The data obtained from the research were analyzed descriptively, and inferential statistics were used using SPSS software. Descriptive statistical analysis is displayed through the average, standard deviation, highest, and lowest values. The inferential statistical technique used is MANCOVA, which tests the research hypothesis proposed in this study. Assumption tests include normality tests using Kolmogorov-Smirnov, homogeneity of variance tests using Levene, homogeneous multivariate tests using Box's M, and multicollinearity tests are carried out before proceeding to hypothesis testing using MANCOVA.

3. Results

Learning activities are carried out using a project-based learning framework with STEAM methodology for ten meetings that are adjusted to the academic schedule. Figure 1 shows the class conditions during the learning process. The learning activities improve creative thinking skills by training students to create ideas, answers, and opinions related to bus system material in computer architecture. An overview of the descriptive study can be seen in Table 4.

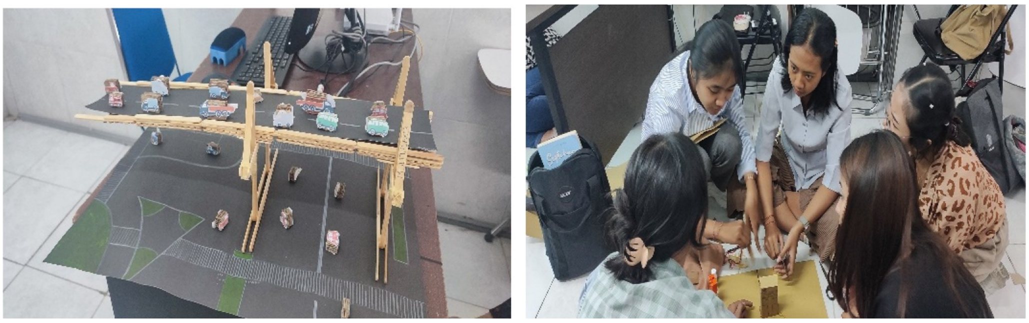

Figure 1. Active learning using a project based educational framework combined with the STEAM method

Model	Variable	Mean	Standard deviation	Minimum Score	Maximum Score	Range
A-1 (Project based learning model with STEAM methodology)	Creative thinking skills	73.20	73.20	47.50	92.50	45.00
	Learning achievement	63.59	17.09	33.30	100.00	66.70
A-2 (Project based learning model without STEAM methodology)	Creative thinking skills	58.00	11.53	40.00	80.00	4.00
	Learning achievement	48.93	17.79	20.00	80.00	60.00

Table 4. Creative thinking and student learning achievement descriptive analysis summary

The data in Table 4 shows a difference in the average creative thinking skills of students in the experimental group, with an average difference in creative thinking skills of 15.20. These results reveal that the creative thinking skills of the experimental group are higher than those of the control group. Meanwhile, the average difference also occurred in student learning achievement in the control and experimental groups, with a difference of 14.66. These results show that the learning achievement of the experimental group is superior to that of the control group. Thus, the learning process that uses a project-based learning framework with STEAM methodology effectively creates disparities in creative thinking skills and learning achievement. Research findings show that the project-based learning framework with STEAM methodology has a more significant impact on creative thinking skills than student learning achievement.

Self-efficacy	Group	Variable	Mean	Standard deviation
B-1 (Students with High Self Efficacy)	A-1	Creative thinking skills	79.40	7.36
		Learning achievement	72.80	17.30
	A-2	Creative thinking skills	65.40	9.88
		Learning achievement	57.60	15.26
B-2 (Students with Low Self-Efficacy)	A-1	Creative thinking skills	67.00	9.81
		Learning achievement	54.39	10.99
	A-2	Creative thinking skills	58.80	12.05
		Learning achievement	40.26	16.02

Table 5. An overview of the findings from a descriptive study on the relationship between self-efficacy and creative thinking abilities and student achievement

Table 5 displays a disparity in the mean creative thinking abilities among high and low self-efficacy student groups. The mean difference in creative thinking abilities between high self-efficacy students in the experimental and control groups is 14.0, indicating that high self-efficacy students in the experimental group exhibit higher creative thinking skills than those in the control group. There are also differences in how well kids with high self-efficacy do in school between the experimental and control groups. The disparity in mean academic performance is 15.2. Based on this information, it can be concluded that students in the experimental group with high self-efficacy exhibit superior learning outcomes compared to their counterparts in the control group.

On the other hand, there is a difference in the average creative thinking skills of students with low self-efficacy between the experimental and control classes, and the average difference is 8.2. Furthermore, there is a difference in the learning achievement of students with low self-efficacy in the experimental and control classes, with an average difference of 14.13. Thus, apart from the learning model, the student's internal factor, self-efficacy, successfully influences creative thinking skills and student learning achievement. Based on this research's findings, the self-efficacy level in students who use the project-based learning framework with STEAM methodology has a more significant impact on learning achievement than creative thinking skills.

The data shown in Table 6 explains that the results of the data normality test using the Kolmogorov-Smirnov formula with a p-value > 0.05, which means that the data used in this study are normally distributed. Testing homogeneity of variants using Levene's Test Based on Mean for creative thinking skills gets a p-value = 0.385 > 0.05, while Levene's Test Based on learning achievement gets a p-value = 0.292 > 0.05. These results show that the research data comes from homogeneous data sources. The multivariate homogeneity test using the Box's M formula obtained an *F* value (0.460) and p-value = 0.711 > 0.05.

Variable	Learning model	Kolmogorov-Smirnova		
		Statistic	df	Sig.
Creative thinking skills	Model for Project based Learning that Utilizes STEAM	0.84	50	0.20
	Models Project Based Learning that Does not Utilize STEAM	0.43	50	0.13
Learning achievement	Model for Project based Learning that Utilizes STEAM	0.43	50	0.12
	Models Project Based Learning that Does not Utilize STEAM	0.41	50	0.15

Table 6. Summary results of data normality tests

The precondition tests showed a VIF score of 2.56 and a tolerance value of 0.99, indicating no multicollinearity among the dependent variables. All prerequisite hypothesis tests have been carried out, and the results can be continued to the hypothesis testing stage using MANCOVA analysis. Table 7 and Table 8 summarize the findings obtained from evaluating the hypothesis for validity.

The results for Wilks' Lambda, Pillai's Trace, Roy's Largest Root, and Hotelling's Trace are displayed in Table 7. The coefficient for these values is *F*(33.126), and the p-value is 0.000, which is less than the significance level of 0.05. Among the groups of students who study using an integrated project-based learning model with and without a STEAM methodology, these findings demonstrate simultaneous variations in creative thinking skills and learning achievement. These disparities are observed between the two groups.

Effect	F coefficient	Sig.
Intercept	33.126b	0.000
	33.126b	0.000
	33.126b	0.000
	33.126b	0.000
Learning Treatment	34.597b	0.000
	34.597b	0.000
	34.597b	0.000
	34.597b	0.000
Self-efficacy	34.861b	0.000
	34.861b	0.000
	34.861b	0.000
	34.861b	0.000

Table 7. Summary results of simultaneous hypothesis tests using MANCOVA data analysis techniques

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Learning Treatment	Creative thinking skills	669.124	1	669.124	53.065	0.000
	Learning achievement	5266.231	1	5266.231	23.125	0.000
Self-efficacy	Creative thinking skills	590.499	1	590.499	46.830	0.000
	Learning achievement	6928.923	1	6928.923	30.426	0.000
Pre-test creative thinking skills	Creative thinking skills	0.121	1	0.121	0.010	0.922
	Learning achievement	163.127	1	163.127	0.716	0.400
Pre-test learning achievement	Creative thinking skills	0.500	1	0.500	0.040	0.843
	Learning achievement	1.308	1	1.308	0.006	0.940
Error	Creative thinking skills	1172.689	93	12.610		
	Learning achievement	21179.221	93	227.734		
Total	Creative thinking skills	71840.000	100			
	Learning achievement	351820.520	100			
Corrected Total	Creative thinking skills	2881.240	99			
	Learning achievement	35211.738	99			

Table 8. Summary results of partial hypothesis testing using Tests of Between-Subjects Effects

Table 8 shows substantial variations in creative thinking capabilities and partial learning achievement based on the data analysis results. The F score was obtained in the learning treatment line (53.065), and p-value = 0.000 < 0.05. The results demonstrate that the project-based learning framework incorporating the STEAM methodology influences students' creative thinking skills. Additionally, in the learning treatment group, *F* value of 23.125 and a p-value of 0.000, which is less than 0.05, were found. This investigation demonstrates that combining the methodology of a project-based learning framework with STEAM methodology significantly affects learning achievement.

Table 8 displays a notable disparity in creative thinking abilities and academic performance based on students' self-efficacy levels. In the self-efficacy line, the *F* value (46.830) and p-value = 0.000 < 0.05 are obtained. The results show that students' levels of self-efficacy in the control and experimental groups differ, which affects their ability to think creatively. Apart from that, there are differences between students with high and low self-efficacy in each class regarding student learning achievement, as shown by the *F* value (30.426) and p-values = 0.000 < 0.05. In light of this, it may be deduced that variations in the levels of self-efficacy among students have an effect on the level of learning achievement.

Table 8 also shows the pre-test scores for creative thinking skills and pre-test learning achievement as covariate variables. The covariate variable data analysis results show a p-value score of 0.922 for the pre-test for creative thinking skills and a p-value score of 0.940 for the learning achievement pre-test. The p-value results of the covariate variables are all above the 0.05 significance level. This shows that the differences in creative thinking skills and learning achievement are indeed due to the treatment provided in learning, not because of the students' different initial abilities.

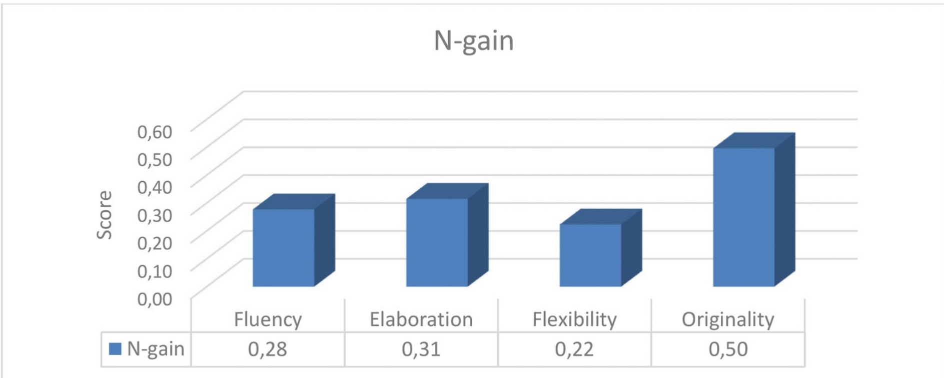

Figure 2. Comparison of n-gain for each indicator of creative thinking skills

Comparison of the average increase in value (n-gain) in the creative thinking skills indicator in the experimental group shows variations between the medium and low categories, as seen in Figure 2. The highest average n-gain value occurs in the Originality indicator at 0.50, while the Flexibility and Fluency indicators range between 0.22 and 0.28, which places it in the low category. Overall, the use of the project-based learning framework model with STEAM methodology has an impact on the development of students' originality skills. The research results show that during learning, students are more courageous in providing responses and opinions directly from what they find during the project-based learning process with STEAM. Meanwhile, the flexibility, fluency, and elaboration indicators are still relatively low, which results in a lack of difference between the pre-test and post-test results. In the future, evaluation and improvements need to be carried out.

The comparison of the average n-gain on student learning achievement in the experimental group is in the medium category. Learning achievements are grouped into two categories, namely levels C1 – C3 in the Low Order Thinking Skills (LOTS) category and levels C4 – C6 in the High Order Thinking Skills (HOTS) category. The calculation results show a difference in learning achievement between LOTS of 0.39 and HOTS of 0.41. This shows that applying the project-based learning framework model with STEAM methodology has an impact on increasing student learning achievement in the LOTS and HOTS categories. However, in the results of this research, the increase in student learning achievement in the HOTS category is higher than in LOTS.

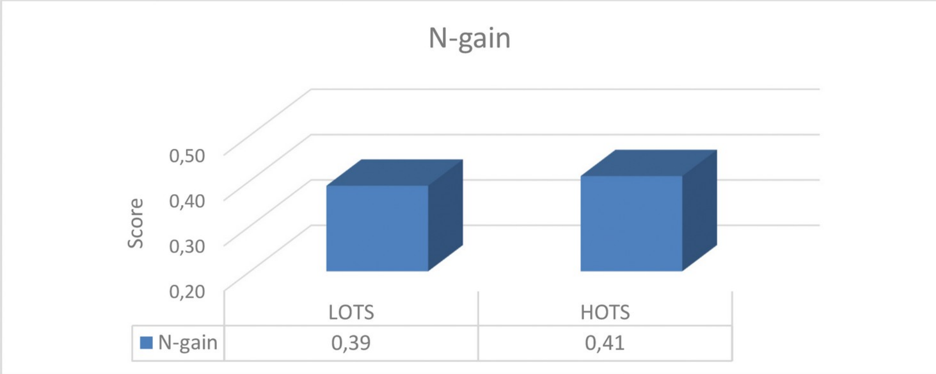

Figure 3. Comparison of n-gain learning achievement grouped based on Bloom's Taxonomy

4. Discussion

4.1. The Impact of Instructional Paradigms on Creative Thinking Skills and Learning Achievement

Research shows that students using project-based learning combined with the STEAM methodology can enhance their creative thinking skills and academic performance. The research findings offer empirical proof that the project-based educational framework incorporating the STEAM methodology substantially affects student engagement in the learning process. The learning activities created became more attractive, with more dominant interaction from students in learning using project-based learning with a STEAM methodology. Students are motivated to actively explore computer architecture-related learning materials in a classroom that employs the STEAM project-based learning methodology. Students like the challenges in learning presented through project activities.

This study's conclusions are consistent with those of earlier studies by Chung, Huang, Cheng and Lou (2022); Ozkan and Topsakal (2021); and Tenhovirta et al. (2022), which shows that there is a positive influence of implementing the project based learning framework with STEAM methodology on creative thinking skills and learning achievement. Real-world-based project learning in the form of phenomena around students can stimulate high curiosity in students, and activities involving more discussion with groups can facilitate students to form their understanding through discussion activities and projects (Ekayana, 2022).

Implementing a project-based learning strategy along with STEAM allows pupils to enhance their creative thinking abilities. These skills help solve problems through project activities so that students better understand the concepts of the material being studied. Project based learning, strengthened by the STEAM methodology, motivates students to actively try to find connections between scientific disciplines in their projects. The results of this study are also supported by research by Lu et al. (2021) and Sigit et al. (2022), which revealed that the project based learning framework with STEAM methodology provides new experiences for students to explore learning material through project activities that are integrated with STEAM components. The empirical study shows that the project-based instruction framework with the STEAM methodology aligns with constructivist theory by shifting the learning focus to students. This model allows students to explore their knowledge through hands-on activities in their environment and collaborate in groups to solve problems.

The project activities in this lesson relate students' curiosity and creative thinking skills to computer architecture subject matter. The results of this research are strengthened by previous research by Guo et al. (2020), which found that students who studied using a project based learning framework with STEAM methodology could store knowledge in long-term memory. At the problem-solving stage through project activities, students work together in a cooperative atmosphere in group discussions and class discussions to find new ideas that can be used to solve problems. Student activities at this stage show learning by doing and learning together.

Furthermore, a theoretical study is used to justify that the project-based learning procedures using the STEAM methodology provide superior results in achieving creative thinking skills and learning achievement compared to other learning models. First, looking at the characteristics included in the project-based learning procedures using the STEAM methodology, among others, (1) trigger questions are used as initial triggers for learning; (2) the problems given and solved through project activities challenge students to gain experience in new learning domains; (3) learning is collaborative, communicative and cooperative; (4) strengthening each learning step with STEAM components. This study follows the opinion of Arends (2012); Laboy-Rush (2007), who said that in the project based learning model stage with the STEAM methodology, students must be able to investigate the problems found and then solve these problems, apart from this learning model encourages students to contextualize projects to existing knowledge and experience and to communicate what they learn as a result.

Second, judging from the syntax of the project-based learning procedures using the STEAM methodology, it can improve students' creative thinking skills and learning achievements. The steps for learning the project-based learning procedures using the STEAM methodology consist of 6 steps using the project-based learning model's syntax. The STEAM (science, technology, engineering, arts, and math) methodology is used to strengthen each syntax in the project based model learning adapted from research by Lu et al. (2021). namely stage (1) determines basic questions reinforced with the Science and Technology (ST) component, in this step, students are trained to develop creative thinking skills to understand and analyze the questions given. Stage (2) designs project designs strengthened by Technology and Engineering (TE) components. In this step, students learn to design project forms used to solve problems. These two components help students find the right technology and effective engineering methods to optimize the project activities' product form. Stage (3) Prepare a project activity schedule strengthened by Arts and Mathematics (AM). At this stage, the project activity plan must be appropriately calculated, and the project activity timeline considers the work time and the deadline for the work to be completed.

Next, in Stage (4), monitoring the progress of the project is strengthened by the Engineering and Arts (EA) component. At this stage, students are trained to provide progress reports on project activities that have been carried out. Lecturers and students are required to communicate with each other to ensure that the project goes according to the agreed plan. The Engineering and Arts components at this stage help students to be able to report on project progress. Stage (5) assessment of the resulting product is strengthened by all STEAM components (Science, Technology, Engineering, Arts, and Math). At this stage, each group presents to all the other groups in front of the class. At this stage, each student must convey the results of their project activities, challenges in working on the project, and experiences while working on the project. Stage (6) evaluation which is strengthened by all STEAM components (Science, Technology, Engineering, Arts, and Math). Students are trained to express their feelings and experiences through a written report at this stage. The role of each STEAM component is explained to help link and strengthen the process of project activities that have been carried out. In addition, during this phase, an assessment of the completed project activities and outcomes is made. The learning achievement objective for each stage of the project-based learning model utilizing the STEAM methodology is the development of creative thinking skills necessary for problem-solving through project activities. The increase in students' creative thinking skills is proven in this research to be directly proportional to their learning achievement. Based on the description that has been outlined, the STEAM methodology for the project-based learning model seems to provide solid strengthening of creative thinking skills in computer architecture material.

4.2. The Impact of Different Levels of Student Self-Efficacy on Creative Thinking Skills and Learning Achievement

The descriptive analysis and inferential statistics results indicate disparities in creative thinking skills and learning achievement among student groups with high and low self-efficacy. Thus, it can be generalized that creative thinking skills and student learning achievement in groups of students with high self-efficacy are superior to those with low self-efficacy.

The findings of this study align with prior studies carried out by Fatimah et al. (2023), Luo et al. (2021), Puozzo and Audrin (2021), Suhaimi et al. (2019), Yada et al. (2022), which shows a relationship between self-efficacy and creative thinking skills and learning achievement. Several empirical studies reveal a linear relationship between self-efficacy and creative thinking skills and learning achievement, so the more students have high self-efficacy, the more likely they will get high grades or learning achievements. The results of this research are also supported by Zou and Ratana-Olarn, (2023) and Huang, Richter, Kleickmann and Richter (2023), which state that self-efficacy is a good predictor variable of student behaviour in the future. Students with high self-efficacy will try harder and commit to all actions to achieve goals. This can be observed through self-efficacy scores and classroom observations during the learning process to ensure whether the self-efficacy score matches the students' personalities in the class. On the other hand, students with low self-efficacy tend to have low commitment and lack the courage to try, so they wait for other friends to do it first.

A theoretical study is used to justify that the achievement of creative thinking skills and learning achievement of students with high self-efficacy is superior to that of students with low self-efficacy. Based on each student's self-efficacy, (Bandura et al., 1999) stated that the role of self-efficacy in each individual is a function of self-efficacy, namely, (1) behavioural choices, (2) efforts made, endurance in overcoming challenges (3) patterns of thinking and reactions, (4) predictions subsequent behaviour, (5) determining subsequent performance.

They are judging from the dimensions of self-efficacy, namely the dimensions of magnitude, strength, and generality. The magnitude dimension refers to the difficulty level of an academic task that students believe they can complete. This level of self-confidence influences the choice of activities during project-based learning activities, the passiveness and activeness of students in groups, the amount of effort and creativity made, and the students' resilience in dealing with and completing the project assignments they are undertaking. When the learning process can be observed, students with high self-efficacy have confidence that they can work on and satisfy the demands of challenging project activities (Ekayana, Parwati, Agustini & Ratnaya, 2024). Students with solid self-efficacy contribute more suggestions to their group when deciding on the project's design. Lancer provides explanations when there are questions from his group friends and does not give up easily if the previous idea is less relevant to the agreement of other friends. In contrast to students with low self-efficacy, it can be observed during the learning process that students with low self-efficacy tend to wait for other friends to convey ideas related to the project they will be working on, lack the confidence to give opinions, and stay away when appointed. Students with low self-efficacy tend to stay away from challenging tasks.

The second dimension of self-efficacy is the strength dimension related to the strength of judgments about students' abilities. This dimension refers to the degree of student stability in their beliefs. Students with high self-efficacy during project-based learning frameworks with STEAM methodology show resilience and tenacity when faced with demanding tasks or problems. They have a high commitment to completing the project tasks being carried out. If they experience difficulties working on a project, they will look for solutions to solve them and always focus on future solutions to face the following challenges.

Meanwhile, students with low self-efficacy tend to give up quickly during the learning process, lack the motivation to give their best to the learning process, and, when working on project activities, do not provide maximum abilities. The third dimension is generality, which is related to students' confidence in carrying out tasks in various activities. Activities during a project-based learning framework with STEAM methodology require students' confidence to carry out the task or activity. Students with solid self-efficacy may easily position themselves and effectively gather feedback from different sources to finish project activities. On the other hand, students with low self-efficacy tend to be less able to master other scientific fields to complete their work.

Based on the explanation above, we can generalize that the difference in the level of self-efficacy of students in the experimental group and the control group influences creative thinking skills and learning achievement. Students with high self-efficacy tend to understand the learning model better (Masdarini et al., 2024). Confidence in oneself to be able to do something means that one will be able to achieve that goal. Every student strives to take optimal actions to attain their desired goals. On the other hand, self-efficacy is essential for students to increase their self-confidence in facing challenges in the world of work (Yulastri, Ganefri, Ferdian & Elfizon, 2023). Self-efficacy is a mediator that can impact improving creative thinking skills and learning achievement. The higher the student's self-efficacy, the higher the implications of STEAM project-based learning on student learning motivation.

Utilizing the project-based learning framework with the STEAM methodology can enhance students' cognitive abilities, particularly by fostering creative thinking skills, as demonstrated in this study. The project based instructional framework with the STEAM methodology encourages and motivates students to be active in project-based learning activities. All five senses are used in the project learning environment. Project based learning based on real-world phenomena and involving student involvement in project activities with a STEAM methodology can strengthen understanding (Dale, 1969). Based on this description, students' creative thinking skills will increase as the learning activities provided are related to phenomena and challenges that occur in the real world so that they have an impact on increasing learning achievement in the future. The project based instructional framework with the STEAM methodology needs to be implemented to achieve this goal.

Achievement in learning is the result of the learning process that has been carried out from beginning to end (Hidayah, 2021; Qodri, 2017). So, increasing learning achievement in a learning process can be said to be successful, accompanied by student changes (Muljana, 2023). In this research, changes in creative thinking skills are examined. Based on this description, implementing an appropriate learning model will have implications for increasing learning achievement. The findings of this research show that applying the project based instructional framework with the STEAM methodology helps students develop creative thinking skills in the learning process, positively impacting learning achievement. Apart from that, the differences in students' self-efficacy influence learning achievement. In the future, to improve student learning achievement, apart from implementing the project based instructional framework with the STEAM methodology, it is imperative to consider the level of student self-efficacy.

4.3. Differences in Students' Creative Thinking Skills Per Indicator

Based on the results of research on indicators of creative thinking skills, the average n-gain for each indicator of creative thinking skills is at medium and low levels. The indicator of creative thinking skills (originality) gets the highest average n-gain value. Originality skills relate to students' skills to convey new ideas during the project-based learning process with STEAM methodology. Originality skills can be observed through student activities in finding and sharing new ideas, project ideas, and opinions to solve problems related to computer architecture material.

These findings show that the project-based learning framework model with STEAM methodology allows students to think about and discover new ideas through the STEAM approach, which they investigate from various learning sources. This investigation's findings align with previous research by Siregar et al. (2023) and Subiki, Elika and Anggraeni (2023) that the project-based learning model combined with the STEAM approach and contextual problems in the students' environment provides a rich learning experience with real things to help students discover the relationship between phenomena in the everyday environment and the learning material.

The elaboration and flexibility indicators get the lowest n-gain values compared to other indicators. Several factors can cause this. First, the elaboration indicator, which refers to the ability to develop in-depth ideas, is often challenging to create in a project setting because of limited time and focus on completing specific tasks. Students may be limited in exploring ideas thoroughly due to time demands or project priorities that are more about the result than the idea elaboration process itself. Second, limited resources, a predefined project structure, or pressure to complete the project quickly can limit students' flexibility in exploring alternative solutions.

4.4. Student Learning Achievement Based on Bloom's Taxonomy Level

Based on the results of the analysis of learning achievement, it is believed that the project-based learning framework model with STEAM methodology can improve learning achievement in a more optimal direction. The combination of learning models and approaches, as well as challenging problems, fosters self-confidence to provide the best ability in the learning process (Cheng, Wang, Chen, Niu, Hong & Zhu, 2022; Torres et al., 2024). Self-efficacy in students contributes to the learning process implemented so that they can improve creative thinking skills, which has an impact on improving learning achievement as well (Wang & Frye, 2019).

While implementing the learning model, students can be observed trying harder to solve problems related to computer architecture learning material. Project learning activities with STEAM encourage students to dare to express ideas, provide input, and ask questions about things they do not understand. These efforts are consistently made during the learning process, which gradually trains creative thinking skills. This strength has implications for increasing learning achievement to a higher level. Even though there are minor differences in mathematical concepts, these differences have led to students' learning achievements reaching the HOTS category.

Research findings reveal that the project based instructional framework with the STEAM methodology successfully improves creative thinking skills and learning achievement. This success cannot be separated from the model used in the implemented learning process. In this research, the project based instructional framework with the STEAM methodology encourages an active learning environment and dominant student participation in the learning process. The project-based learning framework with STEAM methodology helps students' mindset toward maturity by practising facing difficulties more often and using creative thinking skills to solve them. The project based instructional framework with the STEAM methodology helps realize more meaningful learning due to the learning steps taken.

Meaningful learning helps students find their dreams and encourages them to develop social and emotional feelings that can be useful in the future (Araña-Suárez, Hernández-Castellano, Morales-Santana & Hernández-Pérez, 2023; Utomo, Rahmawati & Mardiah, 2020). Furthermore, the project based instructional framework with the STEAM methodology has a more dominant influence on creative thinking skills. In contrast, differences in self-efficacy have more of an impact on learning achievement. This is because the project based instructional framework with the STEAM methodology strengthens students' enthusiasm for adapting learning to the environment and conditions that suit them. Students feel more comfortable and enjoyable in the learning process with a learning model that provides more learning space and dynamism, and intense interaction between students and learning resources will occur.

The project-based learning framework with STEAM methodology helps students integrate inter-, trans, and multidisciplinary content and develop collaborative actions, argumentation skills, reflective thinking, creativity, and time management in a project (Chemerys, Ponomarenko, Kardashov & Briantsev, 2022). The project-based learning framework with STEAM methodology allows students to produce work/prototypes/products with high creative value. Every element in the work produced through the project-based learning model is scrutinized and linked to the STEAM components. The resulting work is more interesting because the STEAM methodology reinforces what must be considered when designing a product, including having a good blueprint design, a structured product pattern, better-prepared product manufacturing materials, and more calculated dimensions.

These findings have broad implications and can be applied across various levels of education, from elementary school to university. However, its implementation needs to be tailored to the conditions of the learners and their respective learning environments. For instance, at the elementary school level, this approach can be modified with simpler and more engaging projects, while at higher levels, projects can be designed to be more complex to challenge students' analytical and creative abilities. Factors such as age, prior knowledge, and available facilities also need to be considered to ensure the method functions optimally.

5. Conclusion

The project-based learning framework with STEAM methodology helps improve creative thinking skills and student learning achievement. On the other hand, differences in the self-efficacy level in students also increase creative thinking skills and learning achievement. The difference in average scores between students studying in the experimental and control groups and the average difference between students with high and low self-efficacy confirm these findings. Furthermore, research findings confirm that the project-based learning framework with STEAM methodology provides incredible benefits for creative thinking skills. These findings can be observed from developing indicators of creative thinking skills, namely fluency, elaboration, flexibility, and originality. Meanwhile, the difference between high and low levels of student self-efficacy has a more dominant impact on learning achievement. The effectiveness of the project-based learning framework with STEAM methodology and the consideration of student self-efficacy can be helpful solutions in the future learning process, especially in improving creative thinking skills and learning achievement.

The findings of this study can be generalized to various educational settings or disciplines. For instance, a similar approach could be adapted for teaching science, arts, or even humanities, as long as it is tailored to the needs and characteristics of the students. Furthermore, this framework can be modified to address potential limitations, such as differences in students' initial skill levels, resource availability, or the challenges posed by diverse learning environments.

Although the results of this study provide a positive contribution to creative thinking skills and student learning achievement as reviewed from self-efficacy, this study has several limitations in its implementation, namely related to the generalization of the results and the context of the application of the project-based learning framework using the STEAM methodology, as well as the influence of self-efficacy on creative thinking skills and students' academic achievement. First, this study is limited to a specific population and learning conditions, so its findings may not be fully applicable to other contexts, such as different levels of education or learning environments that do not optimally support the STEAM method. Second, this study has not explored the influence of other factors that can affect creative thinking skills and students' academic performance, such as the role of teachers, learning resources, or support from the school and family environment. Future research can focus on a more in-depth investigation of the long-term effects of self-efficacy and how it can be developed to help students achieve their full potential in learning. In addition, although this study highlights the important role of student self-efficacy, further research is needed to examine the interaction between self-efficacy and other psychological factors, such as motivation and academic anxiety, which may also play a role in influencing students' academic performance.

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