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Effect of models project based learning and metacognitive skills in improving undergraduate students' creative thinking abilities

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Abstract: This study examines the effect of Project-Based Learning (PjBL) and metacognitive skills on undergraduate students' creative thinking ability (CTA). The method used is a factorial experimental design with a pre-test post-test control group model. The sample consisted of 120 students at Weetebula Catholic University. The research instruments were a questionnaire to measure metacognitive skills and a test to measure CTA. Data analysis was carried out using ANOVA and MANOVA to test the influence of variables. The results showed: (1) the experimental group had a higher average CTA (80.30) than the control group (64.30); (2) the PjBL model had a significant effect on students' CTA ($p < 0.05$); (3) metacognitive skills also had a significant effect on CTA ($p < 0.05$); and (4) there is a simultaneous influence of the PjBL model and metacognitive skills on CTA ($p < 0.05$). These findings recommend the application of the PjBL model combined with strengthening metacognitive skills as an effective strategy to improve the CTA of undergraduate students. Practically, the results of this study can serve as a reference for lecturers and educational institutions to develop more innovative learning methods and support the development of students' CTA in the context of higher learning.

Keywords: *Creative thinking abilities, Metacognitive skills, Project based learning.*

1. Introduction

Universities must develop graduates with the knowledge and skills to adapt to the dynamics of the ever-changing world of work due to technological advances and rapid changes in society. In the era of globalization and the industrial revolution 4.0, higher education faces many challenges in teaching undergraduate students [1, 2] to face an increasingly complex and dynamic work environment [3-5]. Critical thinking, creativity, collaboration, communication, and digital literacy have become important skills needed in various industries [6-8]. Apart from this, conventional learning approaches, such as content-based exams, one-way lectures, and rote memorization [7, 9] are often not enough to improve these skills [10, 11]. Conventional approaches, such as lectures, memorization, and content exams, can help disseminate basic information [12, 13] but they do not prepare students to face real-world challenges that require creativity, cooperation, and critical thinking [14, 15] which is needed by today's students.

Students' lack of CTA is still a significant problem in Indonesia. According to the PISA 2022 results, only around 5% of Indonesian students show good CTA, far below the OECD average of 78% at the primary school level and far behind Singapore and other neighboring countries where more than 50% of students have high levels of CTA. This condition shows that most Indonesian students have difficulty generating, assessing, and developing unique ideas and solving problems creatively and in diverse ways. The initial test of undergraduate students' CTA at one of the universities in Sumba - East Nusa Tenggara (NTT) showed that as many as 53% of undergraduate students had low CTA. Undergraduate students also still have difficulty generating original ideas. Apart from that, the low

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ability to think creatively is proven by the test *Torrance Test of Creative Thinking* (TTCT) conducted on STEM students in Southeast Asia in 2023, which found that creativity scores were 30% lower than European students. Another finding from analyzing essay assignments in humanities classes [16] found that 80% of undergraduate students only repeat ideas from the literature without new synthesis. Another difficulty experienced by students is related to divergent thinking (seeing many solutions). The findings that have been described indicate that undergraduate students still have difficulties in thinking creatively. This problem needs to be addressed so that students can have CTA to equip them to adapt and enter the world of work later.

The low CTA of undergraduate students is caused by the fact that the learning carried out is still centered on lecturers [17, 18] students are still given minimal opportunities for independent exploration and reflection [19, 20]. In addition, in learning activities, it was found that there was a lack of strategies that combined practical aspects (hands-on) and McS awareness (self-regulation*)*. Several research results have found that the PjBL model can inspire undergraduate students to use their knowledge contextually., collaborate, and produce innovative products. The PjBL model effectively increases engagement and creativity [21-24]. Strategy in learning is essential [25, 26] because learning strategies are systematic plans designed to facilitate the learning process effectively and efficiently [26, 27]. Empirical studies find that McS learning strategies help undergraduate students optimize creative thinking processes [28, 29]. Metacognition encourages deep reflection and adaptation of learning strategies [30-32]. McS knowledge and skills are important in effectively organizing and managing learning independently [33, 34]. When undergraduate students can accurately evaluate their understanding and apply relevant skills and knowledge in completing assignments while monitoring their learning progress, they can be categorized as learners with practical self-regulation abilities.

Combining the PjBL model and McS strategies is the right choice for training undergraduate students' CTA. The integration of the two approaches can complement each other; in this case, PjBL provides an applicable context while McS strengthens awareness of the creative process [32, 35]. Much research has been conducted on the PjBL and McS models, but not many studies have tested the interaction of the two models factorially in the context of CTA. Therefore, studies are needed regarding combining the PjBL model and McS strategies in improving undergraduate students' CTA. The urgency of this study is to conceptually fill the vacuum in the literature on PjBL and McS interactions. by offering concrete solutions to the low level of undergraduate student creativity so that it can increase the competitiveness of graduates in the era of disruption. The outcomes of this research can enhance creative pedagogical techniques, generate graduates who are ready for employment, and establish an innovation-based educational environment. This research investigates the influence of the PjBL model and McS on enchance undergraduate students' CTA. The questions in this research are: (1) Is the PjBL model influenced by undergraduate students' CTA?. (2) Is there an influence of McS on undergraduate students' CTA?. (3) Can the PjBL model and McS simultaneously influence undergraduate students' CTA?.

2. Method

2.1. Research Design

This study is included in the quasi-experimental study types of research and features an approach using factorial experimental design using pre-test and post-test controlled drafts of the model. In this study, the design is a semi-experimental design [36]:

$$\begin{matrix} O_1 & X_1 & O_2 \\ O_3 & X_2 & O_4 \end{matrix}$$

Information:

O_1 dan O_3 = Both groups were given a pre-test to determine their initial abilities

O_2	=	CTA using the PjBL model during seven meetings
O_4	=	CTA using conventional models during seven meetings
X_1	=	Classes that utilize PjBL models
X_2	=	Classes that utilize conventional model

The factorial design in this study is presented in Table 1 [36] .

Table 1.
Factorial Design 2 x 2.

Metacognitif (B)	**Learning Model**	
	PjBL (A_1)	**Convensional (A_2)**
High (B_1)	A_1 B_1	A_2 B_1
Low (B_2)	A_1 B_2	A_2 B_2

There were two groups in this research design: an experimental group using the PjBL model (x_1) and a control group using the conventional model (x_2). The groups were not randomly assigned; instead, they were selected based on similarity in initial ability based on the average score of the pre-test assessment. The McS test was conducted on each group to determine the low level of McS. Finally, a post-test was conducted on the undergraduate students to determine whether their CTA had increased.

2.2. Research Subjects

The subjects in this research were second-semester undergraduate students of FKIP Weetebula Catholic University—Sumba—NTT—Indonesia, totaling four classes. The class determined to be the research subject is the class that programs school management courses. The sampling technique used is purposive sampling with a sample size of 120 undergraduate students, each class 30 undergraduate students.

2.3. Research Instruments and Procedures

The instrument used in this research is the Torrance Test for Creative Thinking (TTCT) for creative thinking known as the TTCT undergraduate students. The aspects assessed in the TTCT are fluency, flexibility, originality, and elaboration. In this research, students will be given a questionnaire to obtain data related to student metacognition in the form of planning, monitoring, and evaluation. This questionnaire was given at the beginning of learning activities as an independent variable in this research related to undergraduate students' McS. The procedure in this study is shown in Figure 1.

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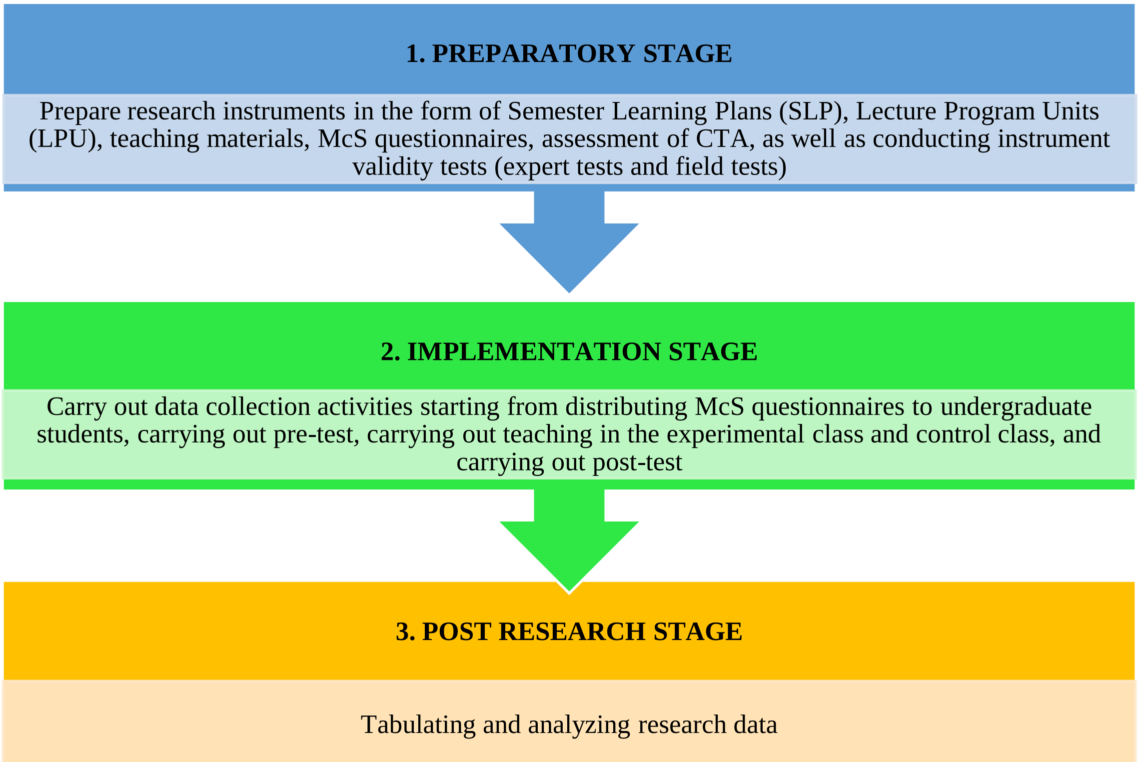

Figure 1.
Research Procedure.

2.4. Data analysis

The instrument used in this research has been tested for validity and reliability. For the McS questionnaire results, Kolmogorov-Smirnov analysis was used with the condition that the asymptotic sig. (2 tailed) value must be more than 0.05. For the student CTA test, descriptive and inferential statistical analysis were used. Descriptive statistical analysis calculated the mean value, standard deviation, maximum value, and minimum value. For inferential statistical analysis, one-way ANOVA and MANOVA tests were used; previously, the normality test was conducted with Kolmogorov-Smirnov, and the homogeneity test was conducted with Levene. This study used the SPSS 26 program.

Table 2.
Average of PjBL and McS on Students' CTA.

	Mean	**Std. Deviation**	**N**
McS			
Low	64.75	11.744	53
High	78.27	12.176	67
Total	72.30	13.708	120
CTA			
Experiment Class	80.30	10.535	60
Control Class	64.30	11.741	60
Total	72.30	13.708	120

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3. Results and Discussion

3.1. Results

The use of PjBL and McS learning models can influence undergraduate students' CTA increases. This is shown by the value obtained from the descriptive statistical analysis about the influence of the PjBL learning model and McS on students' CTA, as presented in Table 2.

The data presented in Table 2 show the average value and the standard deviation of student learning outcomes in the experimental and control classes. The average CTA value in students in the experimental class was 80.30, significantly higher than in the control class of 64.30. To ensure the validity of the analysis results, normality and homogeneity tests were conducted as prerequisites before hypothesis testing. The results of both tests are presented separately in Tables 3 and 4.

Table 3.
Normality Test Results.

	Kolmogorov-Smirnov[a]			Normal Distribution (∝ = 0.05)
	Statistic	df	Sig.	
McS				
Low	0.117	53	0.167	Yes (Sig. > 0.05)
High	0.098	67	0.185	Yes (Sig. > 0.05)
CTA				
Experiment Class	0.077	60	0.200*	Yes (Sig. > 0.05)
Control Class	0.111	60	0.648	Yes (Sig. > 0.05)

Note: *This is a lower bound of the true significance.
a. Lilliefors Significance Correction.

Table 4.
Homogeneity Test Results.

	Levene Statistic	df_1	df_2	Sig.	Homogeneus (∝ = 0.05)
McS					
Based on Mean	0.05	1	118	0.943	Yes (Sig. > 0.05)
Based on Media	0.008	1	118	0.931	
Based on Median and with adjusted df	0.008	1	115.108	0.931	
Based on trimmed mean	0.05	1	118	0.941	
CTA					
Based on Mean	1.566	1	118	0.213	Yes (Sig. > 0.05)
Based on Media	1.641	1	118	0.203	
Based on Median and with adjusted df	1.641	1	117.988	0.203	
Based on trimmed mean	1.591	1	118	0.210	

Based on the analysis results in Tables 3 and 4, the research data meet the assumptions of normality and homogeneity. Thus, hypothesis testing can be continued using the ANOVA test to evaluate the effect of the PjBL model on the CTA of undergraduate students and the effect of metacognition on the CTA of undergraduate students. The results of the ANOVA test are presented in detail in Tables 5 and 6.

Table 5.
Results of ANOVA Test of PjBL Model on CTA.

		Sum of Squares	df	Mean Square	F	Sig.
CTA	Between Groups	7680.000	1	7680.000	61.728	0.000
	Within Groups	14681.200	118	124.417		
	Total	22361.200	119			

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Table 6.
Results of McS ANOVA Test on CTA

		Sum of Squares	df	Mean Square	F	Sig.
CTA	Between Groups	5404.225	1	5404.225	37.607	0.000
	Within Groups	16956.975	118	143.703		
	Total	22361.200	119			

The data in Table 5 shows that the PjBL model influences undergraduate students' CTA. This is shown by obtaining the sig value. = 0.000 sig. = 0.05. Meanwhile, the data in Table 6 shows that McS influence undergraduate students' CTA with a value of sig. = 0.000 < sig. = 0.05. The findings obtained confirm that the PjBL model influences undergraduate students' CTA, and McS also influence them. The results of the MANOVA test were used to determine the effect of the PjBL model and McS on students' CTA. The data are presented in Table 7.

Table 7.
MANOVA Test Results.

Effect		F	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	280.237[b]	0.000	0.782
	Wilks'Lambda	280.237[b]	0.000	0.782
	Hotelling's Trace	280.237[b]	0.000	0.782
	Roy's Largest Root	280.237[b]	0.000	0.782
McS	Pillai's Trace	37.941[b]	0.000	0.395
	Wilks'Lambda	37.941[b]	0.000	0.395
	Hotelling's Trace	37.941[b]	0.000	0.395
	Roy's Largest Root	37.941[b]	0.000	0.395
Model	Pillai's Trace	50.648[b]	0.000	0.466
	Wilks'Lambda	50.648[b]	0.000	0.466
	Hotelling's Trace	50.648[b]	0.000	0.466
	Roy's Largest Root	50.648[b]	0.000	0.466

Note: a. Design: Intercept + McS + Model.
b. Exact statistic.

Based on Table 7, information on the Sig value is obtain = 0.000 < Sig. = 0.05; in this case, the overall results of the MANOVA test show significant differences in CTA, both in general and between groups with different levels of metacognition. McS variables have a significant contribution in explaining this difference.

Table 8.
Parameter Estimates Test Results.

Dependent Variable	Parameter	B	Std. Error	T	Sig.	Partial Eta Squared
CTA	Intercept	44.773	2.854	15.688	0.000	0.678
	McS	12.735	1.693	7.524	0.000	0.326
	[Model = 1]	15.363	1.681	9.139	0.000	0.417
	[Model = 2]	0[a]				

Note: a. This parameter is set to zero because it is redundant.

Based on the data in Table 8, the Sig value is obtained. = 0.000 < Sig. = 0.05, it can be concluded that overall, the results of the analysis show that 1) metacognition has a significant positive influence on CTA; 2) other factors in the PjBL model can improve CTA, even though metacognition is high, and 3) the PjBL model is a stronger predictor than McS in explaining variance in CTA. These results show a simultaneous influence of the PjBL model and McS on CTA.

3.2. Discussion

Applying the PjBL model and McS influences undergraduate students' CTA. The data in Table 7 and Table 8 prove that students' CTA have increased with applying the PjBL model and McS. It was found that the PjBL model and McS simultaneously influenced undergraduate students' CTA. There are three (3) primary studies conducted in this research, namely: (1) the influence of the PjBL model on undergraduate students' CTA, (2) the influence of McS on undergraduate students' CTA, and (3) the influence of the PjBL model and McS on undergraduate students' CTA. A complete explanation of the 3 primary studies carried out in this research is described below.

3.2.1. The influence of the PjBL model on undergraduate students' CTA

This study found a significant difference in the average CTA between students who took part in learning with the PjBL model and students who used the conventional learning model. The data in Table 2 show that the average CTA value in the experimental class that implemented the PjBL model was 80.30, while in the control class that used the conventional model, it was 64.30. This striking average difference indicates that the PjBL model can improve students' CTA. This finding is reinforced by the results of the ANOVA analysis, which shows a significance value (Sig.) of 0.000, which is smaller than the significance level of 0.05 (Table 5), so it can be concluded that the PjBL model has a significant effect on increasing the CTA of undergraduate students. These results are consistent with previous studies Amri and Muhajir [37]; Fiteriani, et al. [38] and Zulyusri, et al. [39] that have also found that applying the PjBL model improved CTA. In addition, the study conducted by and strengthens the conclusion that the PjBL model significantly impacts the development of CTA in undergraduate students [40, 41].

The PjBL model influences undergraduate students' CTA because it effectively stimulates CTA through the implementation of a series of structured and systematic project phases. This model allows students to participate actively in the learning process, thereby significantly improving their critical analysis, evaluation, and reflection skills [42, 43] and is focused on solving actual problems so that the PjBL model effectively grows undergraduate students' capacity to think creatively. The first phase starts with an open contextual challenge, encouraging students to think creatively and broadly to produce different answers. Problems related to undergraduate students' daily lives foster curiosity and intrinsic motivation, two essential qualities for the creative process [44, 45]. Additionally, during the design phase of a project, undergraduate students can combine information from several sources and knowledge from other fields to create unique and creative solutions. Undergraduate students' special interests and preferences can be expressed through the freedom to develop projects, which can increase creativity and engagement. A key component of a learning group is a collaborative process in which team members' social interactions and discussions enable various ideas, foster greater mental flexibility, and generate new and more inventive ideas.

In the implementation stage, undergraduate students must implement their creative ideas into concrete solutions. The ability to elaborate, develop, and deepen initial ideas into complete and meaningful work is needed during this process. Apart from that, the resulting solution is also tested for its effectiveness. The final stage, presentation and evaluation, allows undergraduate students to evaluate the project process and results and receive constructive feedback. This reflection is critical to increase undergraduate students' McS awareness about the CTA strategies used and identify potential for further development. Therefore, the PjBL mechanism, which synergistically involves free exploration, intensive collaboration, real problem solving, and continuous reflection, encourages and develops undergraduate students' CTA.

3.2.2. The influence of McS on undergraduate students' CTA

Before conducting the experimental research using the PjBL model, a test of students' McS was conducted on undergraduate students to group the level of McS into high and low categories. The data from students' self-assessment of McS are presented in Table 2, which shows that the group with high McS has an average score of 78.27, while the group with low McS obtained an average score of 64.75. Furthermore, an ANOVA test was conducted to analyze the effect of McS on undergraduate CTA. Based on the statistical test results listed in Table 6, a significance value of 0.000 was obtained, which is smaller than the significance level of 0.05, so it can be concluded that McS has a significant effect on the CTA of undergraduate students.

This study's findings align with previous studies by Teng and Yue [46] and Caratozzolo, et al. [47] who concluded that the higher a person's McS, the greater their potential for CTA. Metacognition, as explained by Lavrysh, et al. [48] is an ability that allows us to actively regulate and control our thinking processes. This ability is essential for achieving success in learning and self-development, as also emphasized by Lavrysh, et al. [48]. McS are crucial in increasing student creativity [49, 50]. This ability helps overcome obstacles, encourages open thinking, and generates innovative ideas [50, 51]. Creativity is closely related to cognitive strategies and metacognition, where organizing knowledge and self-direction require good McS [32]. These skills, which are realized in planning, monitoring, and evaluation, support CTA processes [47].

This research found that McS in learning influence students' CTA. McS are crucial for increasing undergraduate students' CTA capacity because they help undergraduate students organize and reflect on their thinking processes while learning [49-51]. The administration of a McS questionnaire at the start of learning in this study allows undergraduate students to identify appropriate learning strategies, track their understanding, and assess and refine their thinking processes, all of which contribute to a more effective and efficient learning process. Research shows that undergraduate students with a high level of metacognition are more likely to think creatively [50, 52, 53] especially when facing higher-order thinking challenges (HOTS). They can develop new concepts, think creatively, and oversee strategic problem-solving.

In contrast, students who lack McS show little originality [54]. In addition, McS enable undergraduate students to overcome learning challenges and develop into independent, critical, and reflective learners [51, 55]. This encourages creative growth by increasing motivation, self-confidence, and a sense of personal accountability for learning. However, the effectiveness of McS learning approaches in increasing creativity can be influenced by the undergraduate student's stage of cognitive development [56] and does not always produce significant improvements compared to other learning methods. The coefficient of determination in several studies shows that McS explain some variability in CTA, so other factors also play a role. Therefore, developing McS must be integrated with comprehensive learning strategies to optimize students' CTA.

3.2.3. The influence of the PjBL model and McS on undergraduate students' CTA

This study shows that the interaction between the PjBL model and McS significantly improves the CTA of undergraduate students. Based on the results of the MANOVA test listed in Table 7, a significance value of 0.000 was obtained, which is smaller than the significance limit of 0.05, so it can be concluded that there is a significant difference in the CTA of students with different levels of metacognition during learning using the PjBL model. In addition, the simultaneous analysis presented in Table 8 indicates that the PjBL and McS models significantly improve undergraduate students' CTA. The significance value of the parameter estimation test results of 0.000 (<0.05) strengthens this conclusion. Thus, this finding confirms that applying the PjBL model combined with the development of McS contributes significantly to improving the CTA of undergraduate students. Put forward by Lavrysh, et al. [48] who emphasized the importance of balance between thoughts and actions in seeking knowledge. According to him, CTA is about intelligence, physical activity, and the five senses. This research supports this idea by showing that students can become more creative because they have good thinking skills and are involved in active project learning. These findings align with Rivas, et al. [51] which shows that non-cognitive factors, such as experience and environment, are also very important in developing creativity. Apart from that, Huang [57] say McS strategies are higher-level strategies, including thinking before the learning process, planning to learn, monitoring understanding or production while it is taking place, and finally, self-evaluation after completing learning activities. Thus, research by Azizah and Nasrudin [58] found that students with good McS have knowledge and control over their thinking and learning activities in completing projects, and their CTA increase.

McS are understanding and controlling each individual's thinking processes [51, 59]. This skill is essential in CTA because it enables undergraduate students to plan, monitor, and evaluate their thinking processes effectively, supporting appropriate decision-making and systematic problem-solving. The planning process is carried out before starting the project; in this case, undergraduate students with good McS will prepare the steps, including how they will produce creative ideas. Then, the planning process continues with monitoring; in this process, students will monitor the ideas that emerge and whether these ideas are relevant and worth developing. The following process is to evaluate the results of their work and identify aspects that can be improved in terms of creativity. In pedagogy, PjBL and McS are two learning approaches that complement each other and are proven effective in enhancing undergraduate students' CTA. PjBL is a learning approach that places undergraduate students at the center of learning by allowing them to complete real projects relevant to their lives [60, 61]. In the process, undergraduate students gain knowledge and develop various skills, including CTA [62].

When PjBL and McS are combined, a strong synergy exists in improving undergraduate students' CTA. PjBL provides a real context for applying CTA. McS offer tools for students to manage their creative processes. The synergy between PjBl and McS results in an increased ability to generate new ideas, flexible and adaptive thinking abilities, complex problem-solving skills, and increased self-confidence in exploring new ideas. PjBL and McS are essential in developing undergraduate students' CTA. Both complement and strengthen each other. By combining these two elements, educators can create a learning environment that encourages undergraduate students to become creative, innovative learners and ready to face future challenges.

Success in this research is influenced by several supporting factors, such as collaboration and communication, student motivation and involvement, facilities and the role of lecturers, clear and relevant project design, technological support, and ongoing monitoring and evaluation. So that PjBL and McS development can be carried out successfully and have the most significant influence on students' CTA, interrelated factors in its implementation must be managed as well as possible. In addition to the supporting factors identified in this study, several obstacles arise during implementing the PjBL model and developing McS towards the CTA of undergraduate students. These obstacles include time constraints in implementing the PjBL model, student adaptation to new learning methods, limited supporting facilities and infrastructure, less than optimal project management, and variations in student involvement in project implementation. Comprehensive planning, adequate facilities and infrastructure, and continuous guidance and motivation are needed to anticipate these challenges and ensure the smooth implementation of the PjBL model and the development of McS. This approach is expected to increase undergraduate students' capacity to develop CTA effectively.

The results of this study provide a significant contribution to the enrichment of empirical data related to the influence of the PjBL model and McS on the CTA of undergraduate students. In addition, this study presents guidelines for implementing PjBL that can be adapted and replicated by educational institutions at the national and international levels. Furthermore, this study also provides relevant strategic recommendations to improve the quality of graduates who can face global challenges in the 21st century, by emphasizing the relationship between PjBL, metacognition development, and strengthening high-level thinking skills.

4. Conclusion

Based on the results of the research and discussion, it can be concluded that: a) the experimental group had an average CTA of 80.30, which was higher than the control group of 64.30; b) there is an influence of the PjBL model on undergraduate students' CTA (sig. = 0.000 < sig. = 0.05); c) there is an influence of McS on undergraduate students' CTA (sig. = 0.000 < sig. = 0.05); d) there is a simultaneous influence of the PjBL model and McS on undergraduate students' CTA obtained from the MANOVA test value sig. = 0.000 < sig. = 0.05 and test parameter estimates sig value. = 0.000 < sig. = 0.05. These findings confirm that integrating McS in project-based learning can significantly impact learning achievement.

Research limitations: this research only includes Weetebula Catholic University FKIP undergraduate students, so the results may not be fully generalizable to other contexts. The limited duration of the study does not yet make it possible to evaluate the long-term impact of PjBL on critical and CTA This research has not examined moderator variables such as learning motivation or access to learning resources.

Recommendations for further research: future studies could involve student populations from other universities to evaluate the consistency of the results of this study, longitudinal research is needed to measure the long-term impact of PjBL on higher-order thinking abilities, and further research is needed regarding this topic on other research variables as well as technological support, and access to resources moderates the success of PjBL. These conclusions not only provide important insights for practitioners and policymakers in the field of education but also pave the way for future research that can strengthen empirical evidence about the benefits of PjBL in various educational contexts.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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