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Comparison of the Effectiveness of PBL and PjBL Learning Models in Terms of Self-Regulated Learning and Mathematical Reasoning

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Abstract:
This study aimed to describe the effectiveness of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) models and to compare the effectiveness of PBL and PjBL learning models in terms of students' self-regulated learning and mathematical reasoning. The study used a quantitative approach using a quasi-experimental research design, specifically a nonequivalent comparison group design. The research was conducted at a public junior high school in Metro City, Lampung, during the even semester of the 2023/2024 academic year. The research sample consisted of class VII 1, which used the PBL learning model, and class VII 3, which used the PjBL learning model. Data collection instruments included a self-regulated learning questionnaire and a mathematical reasoning test. For inferential analysis, multivariate normality assumption tests and homogeneity of covariance matrices tests were performed, followed by one-sample mean vector tests and one-sample t-tests, and then MANCOVA tests. The results of the study indicated that both PBL and PjBL learning models were effective, and the PBL model was found to be as effective as the PjBL model in terms of students' self-regulated learning and mathematical reasoning.

Keywords: Problem-Based Learning, Project-Based Learning, Self-Regulated Learning, Mathematical Reasoning.

1. Introduction

Mathematics is a subject deeply intertwined with human life and plays a crucial role in human civilization. However, mathematics education in Indonesia that supports students' thinking abilities remains limited (Tanujaya et al., 2017). It is also emphasized that mathematical understanding is not significant unless accompanied by mathematical reasoning (Ball & Bass, 2003). Reasoning is a fundamental ability inherent in every mathematical activity (NCTM, 2000). Therefore, students' mathematical reasoning should be cultivated from an early stage in school, especially in higher grades, to prepare them for global competition. Considering the importance of students' mathematical reasoning skills for their future, enhancing these skills needs attention.

One study indicated that mathematics could be mastered with at least minimal mathematical reasoning abilities, with results showing that the average mathematical ability of junior high school students in Indonesia is at a low level (Rosnawati, 2013). Another study reported that students with low mathematical reasoning abilities are unable to master the four indicators, which consist of hypothesis proposing, mathematical manipulation, conclusion drawing, and verifying statements (Raharjo et al., 2020). To achieve optimal learning outcomes in mathematical reasoning, students need to follow teacher instructions and also manage their learning strategies, self-organization, attitudes, behaviors, and decision-making independently (Mulyana & Sumarmo, 2015). Self-directed learning in this context is not just about studying mathematical concepts individually; it involves setting learning targets independently, managing learning strategies, and taking responsibility for achieving these targets, a concept known as self-regulated learning (Zimmerman, 1990). Another study mentioned that self-regulated learning includes three components: metacognition, motivation, and behavior (Mohammadi et al., 2023).

Research conducted by teachers in Garut indicated a strong association between students' mathematical reasoning abilities and their independence in learning through problem-based learning. Students with high learning independence tend to learn better under their supervision than under program supervision, effectively monitoring, evaluating, and managing their learning, saving time in completing tasks, and efficiently managing their study time (Mulyana & Sumarmo, 2015). Another study showed that only a small portion of students engage in mathematics learning of their own volition, with low self-regulated learning evident during the planning stage in determining the strategies for learning and preparing themselves for study (Kurnia & Warmi, 2020).

The observed outcomes occur because mathematics is perceived as a daunting subject for students, leading them to find it difficult and often unenjoyable. Hence, it is not without reason that students show less interest or motivation and demonstrate less independence in learning mathematics. This presents a challenge for teachers, who must be creative and innovative to create quality and engaging learning experiences that enhance students' self-regulated learning in mathematics (Hapsari & Fatimah, 2021). Additionally, the curriculum also advocates for the simultaneous and proportional development of students' cognitive outcomes—in this case, mathematical reasoning—and affective components—namely, self-regulated learning.

To address this issue, it is essential to apply appropriate learning models during instructional activities. Learning models designed by teachers should be evaluated for their strengths and weaknesses to ensure optimal learning experiences. Therefore, when designing learning models, teachers must also consider the diverse characteristics of students (Khoerunnisa & Aqwal, 2020). Besides being optimal, learning must also be effective. A learning model is considered effective if it successfully achieves the learning objectives as intended by the teacher. An effective learning model encompasses four main aspects: (1) quality of learning, (2) adequate learning level, (3) rewards, and (4) time. Here, the quality of learning refers to the activities designed and actions taken by both teachers and students, including the curriculum and media used in the learning process (Setyosari, 2017).

Learning models that can foster students' development of self-regulated learning and mathematical reasoning include the application of PBL and PjBL in the learning process. PBL, often referred to as problem-based learning, presents students with real-world problems or scenarios and tasks them to find solutions through active learning and collaboration (Ali et al., 2023). This model promotes independent learning in solving unstructured or non-routine questions (Hidajat, 2023). PBL encourages students to engage in independent learning, critical thinking, collaboration, and problem-solving skills (Song & Shen, 2023). The integration of PBL and self-regulated learning supported by multimedia has proven to be more effective in enhancing the learning process compared to the traditional PBL model (Fitriani et al., 2019). In addition to being effective in terms of self-regulated learning, previous research also indicates that the PBL model is superior to expository models in enhancing students' mathematical reasoning abilities, as it fosters logical thinking and analysis (Wiyanti dan Leonard, n.d.).

Meanwhile, the PjBL model is typically referred to as project-based learning (Tan & Chapman, 2016). Projects undertaken require deep analysis to be completed (Gratchev, 2020). PjBL is a learning approach where students acquire knowledge and skills by working on a project over an extended period. This project is centered on real-world problems or challenges, with students actively engaged in the learning process through direct activities, collaboration, and the creation of a final product (Marnewick, 2023). One study suggests that the PjBL model can be an effective learning model in classrooms to develop students' self-regulated learning (Susilowaty, 2020). Previous research also indicates that the PjBL model improves students' mathematical reasoning more than conventional learning models, and it is hoped that PjBL can be an alternative for teachers to enhance students' mathematical reasoning (Sauri, 2017).

Research on students' self-regulated learning that clarifies the relationship between self-regulated learning and both PBL and PjBL illustrates that learning environments with practical applications can foster students' responsibility for learning. To succeed in PjBL-based learning, students must take responsibility by setting clear goals, and further, self-regulated learning can be cultivated at every phase of PBL (English & Kitsantas, 2013). Other research on students' mathematical reasoning reveals that there is an influence of both PBL and PjBL models on students' mathematical reasoning (Hasibuan et al., 2022). Research on both PBL and PjBL models has also been conducted simultaneously, with comparative results showing a significant difference in students' mathematical learning outcomes between groups using the PBL model and those using the PjBL model on the topics of prisms and pyramids, with the PjBL model proving to be more effective than the PBL model (Ratri & Nurfalah, 2023). Similar research was also conducted with different results, indicating that the PBL model was more effective compared to the PjBL model in terms of problem-solving ability in statistics (Purba, 2023).

Learning will proceed well if supported by the appropriate learning model, thus resulting in an educational experience that aligns with the objectives of mathematics education on algebraic forms. This topic of algebraic forms was chosen not only because it allows for reasoning activities in problem-solving and project completion but also because it becomes more meaningful when conducted with awareness and enthusiasm, fostering students' independence in learning mathematics. Algebraic forms in the Merdeka curriculum are a mathematics topic for seventh-grade students. In learning algebraic forms, students often make errors in manipulating algebraic expressions, as they do not yet fully understand the material (Kurniawan et al., 2022). Therefore, actions are needed to address issues in algebraic forms to improve the welfare of mathematics education and enhance its quality.

Based on the above complexity, it can be deduced that further research on the PBL and PjBL learning models is necessary, given previous findings indicating conflicting effectiveness between the two models. Moreover, previous studies did not focus on algebraic forms. Therefore, it is crucial to conduct further research to provide additional empirical evidence on whether there is a difference in effectiveness between the PBL and PjBL models, and if so, which model proves more effective.

Consequently, this study was conducted to assess the effectiveness of the PBL and PjBL learning models and to compare their effectiveness to determine the more effective model, thereby maximizing learning outcomes in terms of students' self-regulated learning and mathematical reasoning. Furthermore, this research was undertaken because both learning models applied to the two experimental groups, have the potential to produce different effects on students' self-regulated learning and mathematical reasoning in algebraic forms. Through this study, it is hoped that students will become more interested and actively participate in the mathematics learning process at school, explore their ideas, acquire new knowledge independently, and thereby apply the meaning of mathematics learning in their daily lives, especially seventh graders studying algebraic forms.

2. Research Methods

This study used a quantitative approach using a quasi-experimental design, specifically a nonequivalent comparison group design, with pre-tests and post-tests conducted on both experimental groups to compare the outcomes of the treatments given. The research was conducted at an A-accredited public junior high school in Metro City, Lampung, during the even semester of the 2023/2024 academic year. The population of this study included all students in 8 parallel seventh-grade classes. From this population, samples were selected using a purposive sampling technique, with class VII 1 using the PBL model and class VII 3 using the PjBL model, each class consisting of 30 students.

Data collection instruments included a self-regulated learning questionnaire comprising 25 items (16 positive and 9 negative statements) and 5 descriptive items for the student mathematical reasoning test. The non-test self-regulated learning instrument was developed from 9 indicators based on metacognition, motivation, and behavior aspects. Meanwhile, the student mathematical reasoning test instrument for each descriptive item included three indicators: presenting mathematical statements in written or pictorial form, performing mathematical manipulation, and drawing conclusions with reasoning or evidence for solution correctness. The instruments were validated by experts, achieving a medium validity of 0.72 for the non-test self-regulated learning instrument and a high validity of 1.00 for the mathematical reasoning test instrument. Reliability testing was conducted using RStudio software, which yielded very high reliability for both instruments, with scores of 0.94 for the non-test self-regulated learning instrument and 0.82 for the mathematical reasoning test instrument. Thus, it can be concluded that the instruments are both valid and reliable for use in research.

Data analysis in this study used descriptive and inferential analysis. Descriptive analysis involved describing the implementation of learning and the results of the data obtained, then converting the interval of the self-regulated learning questionnaire, deemed effective if it scored above 83.34, and mathematical reasoning was considered effective if it scored above the established competency threshold of 67 in mathematics subjects at the school. For inferential analysis using RStudio software, the first step involved conducting multivariate normality assumption tests and homogeneity of covariance matrix tests.

The normality test aimed to determine whether the samples came from a population with a normal distribution. The data tested included pre-scale and post-scale scores from self-regulated learning and pre-test and post-test results from student mathematical reasoning. Multivariate normality tests utilized correlation between Mahalanobis distance and Chi-Square, with a significance level set at 0.05 and a correlation coefficient for 30 study samples obtained from the Pearson correlation coefficient table at 0.9652. The criterion for this test was that if the value was greater than the Pearson correlation coefficient table value, then the sample came from a multivariate normal distribution population. The homogeneity test aimed to determine whether the two samples had homogenous covariance matrices. Data tested included pre-scale and post-scale scores from self-regulated learning and pre-test and post-test results from student mathematical reasoning. Homogeneity of covariance matrices tests in this study used Box's M test, with a significance level set at 0.05, and the decision criterion was if the p-value > 0.05, then the two samples had homogeneous covariance matrices.

Subsequently, if the multivariate normality assumption was met, the effectiveness test of the learning models was conducted to assess the effectiveness of the PBL and PjBL models in terms of self-regulated learning and student mathematical reasoning. The statistical test used was a one-sample mean vector test (Johnson & Wichern, 2007), conducted to test whether the average score of student self-regulated learning equaled 83.34 and the average score of student mathematical reasoning equaled 67 simultaneously. With a significance level set at 0.05, if the p-value < 0.05, the results indicated a difference, followed by a one-sample t-test (Ronald et al., 2011). The decision criterion for this test was set at a significance level of 0.05; if the $t_{hit} > t_{(\alpha;n-1)}$ or *p-value* < 0.05, the results indicated effective learning.

The final step was to conduct a comparison test of the effectiveness of learning using a two-sample mean vector test. Data analyzed included pre-treatment data with learning models from both experimental groups given different treatments to determine if the initial capabilities of both groups were the same and post-treatment data with learning models from both experimental groups given different treatments to compare effectiveness. The hypothesis test used to calculate the comparison of effectiveness was Hotelling's T^2, and after obtaining the T^2 value, it was transformed to obtain the F-distribution value (Pituch & Stevens, 2015). The decision criterion for this test was set at a significance level of 0.05; if the p-value < 0.05, the results indicated a difference in capabilities between the two experimental groups.

If the results indicated a difference in initial capabilities between the two experimental groups, further testing was conducted by analyzing the post-test results using Multivariate Analysis of Covariance (MANCOVA) with initial capability scores as covariates. MANCOVA testing involved three steps: linearity test (Λ_2) between initial capabilities and student self-regulated learning and mathematical reasoning, homogeneity of slope test (Λ_3) for the PBL and PjBL learning models, and mean difference test (Λ_1) for the PBL and PjBL learning models in terms of self-regulated learning and student mathematical reasoning after adjusting for initial capabilities. However, if the results indicated no difference in initial capabilities between the two experimental groups, further testing was conducted by analyzing the post-test results using a two-sample mean vector test.

Based on the above final capability tests, if the results indicated no difference in effectiveness between the two experimental groups, the testing would be considered sufficient as it would mean both learning models applied had the same effectiveness in terms of student self-regulated learning and mathematical reasoning. However, if the results indicated a difference in effectiveness between the two experimental groups, the more effective model could be determined from the obtained results, meaning the two learning models applied had different effectiveness in terms of student self-regulated learning and mathematical reasoning.

3. Results and Discussion

The implementation of the study using the PBL and PjBL models began and ended with the completion of self-regulated learning questionnaires and tests on students' mathematical reasoning. In both experimental classes, learning activities were based on teaching modules that had been prepared and adapted according to the steps of each learning model. The steps in the PBL model included orienting students to the problem, organizing students for learning, guiding the investigation, developing outcomes, and analyzing the problem-solving process. The steps in the PjBL model involved defining core questions, planning the project, scheduling, monitoring, assessing outcomes, and evaluating.

To determine the implementation of the learning activities, observation sheets were used. According to observations by the observers, the implementation of learning in both experimental classes, which each held 5 sessions, achieved 100% compliance, indicating that the implementation of the learning activities proceeded very well. Although there were several notes generally for each session in both experimental classes, these notes decreased in subsequent meetings as students became accustomed to learning using the PBL and PjBL models.

Further, the effectiveness of the PBL and PjBL learning models was described in terms of students' self-regulated learning and mathematical reasoning. The data described in this study were obtained from pre-treatment (pre-scale and pre-test) and post-treatment data (post-scale and post-test). The pre-scale and post-scale data were obtained from the self-regulated learning questionnaire scores, and the pre-test and post-test data were derived from the results of the student's mathematical reasoning tests in both the PBL and PjBL experimental classes.

Descriptive statistics for students' self-regulated learning data, consisting of pre-scale and post-scale scores, are presented in Table 1 as follows:

Table 1: Descriptive Statistics for Self-Regulated Learning Data

Self-Regulated Learning Description	PBL Class		PjBL Class	
	Pre-scale	Post-scale	Pre-scale	Post-scale
Average	99.67	100.30	87.13	88.23
Standard Deviation	11.15	12.15	13.62	13.54
Variance	124.30	147.67	185.64	183.36
Ideal Minimum Score	0	0	0	0
Minimum Score	74.00	74.00	61.00	65.00
Ideal Maximum Score	125	125	125	125
Maximum Score	120.00	121.00	118.00	114.00

Based on Table 1, it is evident that the average scores in each class improved from before to after the interventions were applied. In the PBL class, the average increased by 0.63, resulting in a post-treatment average of 100.30, while in the PjBL class, the average increased by 1.1, leading to a post-treatment average of 88.23. The post-scale scores for the PBL class fall into the very high category, whereas the PjBL class scores fall into the high category, defined as scores above 83.34. The next step is to analyze the percentage achievement of each indicator used to determine the accomplishment of each self-regulated learning indicator for students in each experimental class. The largest percentage of students achieving each self-regulated learning indicator before and after the intervention in both PBL and PjBL classes was in the indicator emphasizing the obligation to complete school tasks. Notably, in the PjBL class, besides the aforementioned indicator, the largest percentage increase post-intervention also occurred in the indicators of managing emotions and self-motivation in learning. The analysis also shows that the overall percentage increase in both experimental classes was 0.71% for the PBL class and 0.99% for the PjBL class, indicating a greater increase in the PjBL class compared to the PBL class. However, considering the average pre-scale scores, the PBL class scored higher than the PjBL class.

The different pre-scale averages between the two experimental classes may be due to class VII 1, which is considered the elite class among the 8 parallel classes, being selected for the PBL learning model experiment, while class VII 3 was chosen for the PjBL learning model experiment to maintain comparability with the elite class. Therefore, the PBL class had a higher initial capability than the PjBL class. Interestingly, after the interventions, the average post-scale scores in the PjBL class increased more significantly than in the PBL class. This outcome may be attributed to the increased independence in learning among students in the PjBL class due to the projects they needed to complete during the learning process.

Additionally, the descriptive statistics for students' mathematical reasoning data, consisting of pre-test and post-test scores, are presented in Table 2 as follows:

Table 2: Descriptive Statistics for Mathematical Reasoning Data

Mathematical Reasoning Description	**PBL Class**		**PjBL Class**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Average	34.83	88.44	33.17	81.28
Standard Deviation	8.81	6.89	9.43	8.85
Variance	77.65	47.50	88.96	78.29
Ideal Minimum Score	0	0	0	0
Minimum Score	20.00	71.67	15.00	68.33
Ideal Maximum Score	100	100	100	100
Maximum Score	58.33	100.00	55.00	98.33

Based on Table 2, it can be observed that the average scores in each class improved from before to after the interventions were applied. The PBL class experienced an average increase of 53.61, resulting in a post-treatment average of 88.44, while the PjBL class experienced an average increase of 48.11, leading to a post-treatment average of 81.28. These post-test scores exceeded the KKTP set by the school at 67. The next step involves analyzing the percentage achievement of each indicator used to determine the accomplishment of each mathematical reasoning indicator for students in each experimental class. The largest percentage of students achieving each mathematical reasoning indicator before and after the intervention in both the PBL and PjBL classes was in the first indicator: presenting mathematical statements in written or pictorial form. This was followed by the second indicator: performing mathematical manipulations, with the smallest percentage in the third indicator: drawing conclusions with reasoning or evidence for the solution's correctness.

This occurrence is because, during the pre-test and post-test processes, students must sequentially follow the indicators of mathematical reasoning from the first to the third indicator. In this context, there is a linkage between indicators. Some students understand the questions well, thus progressing logically in solving problems at point a, which involves the first indicator. However, some students make errors in this step, leading to difficulties in the subsequent step at point b, which involves the second indicator. Similar difficulties occur at point c, involving the third indicator, especially if errors were made in solving point b. The analysis also shows that the overall percentage increase in both experimental classes was significant, with the PBL class increasing by 53.62% and the PjBL class by 48.11%. This means the PBL class experienced a greater increase compared to the PjBL class. Consistently, the average pre-test scores were also higher in the PBL class compared to the PjBL class.

Before conducting hypothesis testing, assumption tests were first performed to determine the normality and homogeneity of the experimental groups. The normality and homogeneity tests involved the pre-scale and post-scale scores of students' self-regulated learning and the pre-test and post-test results of students' mathematical reasoning. The normality test in this study used a multivariate normality test with the Mahalanobis distance formula (d_i^2). A significance level of 0.05 was used, with a correlation coefficient for 30 research samples obtained from the Pearson correlation coefficient table at 0.9652. The results of the multivariate normality test are presented in Table 3 as follows:

Table 3: Multivariate Normality Test Results

Class	**Data**	r_Q	**Correlation Coefficient**
PBL	Before Treatment	0.9893354	0.9652
	After Treatment	0.9882939	0.9652
PjBL	Before Treatment	0.9697356	0.9652
	After Treatment	0.9849895	0.9652

Based on Table 3 above, it is observed that both experimental classes, both before and after treatment, have correlation coefficients r_Q greater than the correlation value, allowing us to conclude that there is a significant correlation and that the samples come from a multivariate normal distribution population. Furthermore, the results of the homogeneity of covariance matrices test can be seen in Table 4 as follows:

Table 4: Homogeneity Test Results for Covariance Matrices

	Before Treatment	**After Treatment**
Chi-Squared Value	0.3470	0.5910
P-value	3.3040	1.9129

Based on Table 4 above, it can be seen that both experimental classes, both before and after treatment using Box's M Test, have a p-value > 0.05, which leads us to conclude that both samples have homogeneous covariance matrices.

In this study, there are two hypothesis tests: the test of the effectiveness of learning and the comparative effectiveness test. The learning effectiveness test is conducted to assess the effectiveness of the PBL and PjBL learning models from the perspectives of self-regulated learning and students' mathematical reasoning. During the effectiveness testing, the statistical test used is the one-sample mean vector test using Hotelling's formula T^2. The results of the one-sample mean vector test can be seen in Table 5 as follows:

Table 5: One Sample Mean Vector Test Results

Class	**T.2**	**P-value**
PBL	299.6300	0.0000
PjBL	80.7640	0.0000

Based on Table 5 above, with a p-value < 0.05, it can be concluded that there are significant differences in the averages of self-regulated learning and mathematical reasoning between students using the PBL and PjBL learning models. Therefore, a one-sample t-test is conducted to determine which average components differ significantly. The results of the one-sample t-test can be seen in Table 6 as follows:

Table 6: One Sample T-test Results

Variable	**PBL**		**PjBL**	
	t	**P-value**	**t**	**P-value**
Self-Regulated Learning	7.6445	0.0000	1.9793	0.0287
Mathematical Reasoning	17.0420	0.0000	8.8376	0.0000

Based on Table 6, with a p-value < 0.05, it can be concluded that the average self-regulated learning scores of students in both experimental classes meet the high category, defined as scores above 83.34, thus indicating the effectiveness of both the PBL and PjBL learning models from the perspective of students' self-regulated learning. Similarly, it can be concluded that the average mathematical reasoning scores of students in both experimental classes meet the KKTP set by the school, which is above 67, demonstrating the effectiveness of the PBL and PjBL models from the perspective of students' mathematical reasoning. Therefore, the overall conclusion from Tables 5 and 6 is that both the PBL and PjBL learning models are effective in terms of enhancing students' self-regulated learning and mathematical reasoning.

The data analysis results show that both learning models are effective in terms of students' self-regulated learning. An example of student self-regulated learning in the classroom concerning behavioral aspects includes the indicator of building strategies while learning. This is demonstrated by students paying attention to the teacher’s explanations and taking notes on key points to facilitate learning, actively discussing with their groups, and asking questions to the teacher or peers when they do not understand the material on algebraic forms in mathematics. Furthermore, the data analysis results indicate that both learning models are effective in terms of students' mathematical reasoning. One example of significant improvement in mathematical reasoning is seen in the third indicator: drawing conclusions with reasoning or evidence for the correctness of solutions. This was evidenced by students who previously could not correctly solve problems up to this third indicator, thus failing to reach the correct conclusions. During learning activities, students were trained to sequentially address problems according to the mathematical reasoning indicators from the first to the third, which can be seen in Figure 1 as follows:

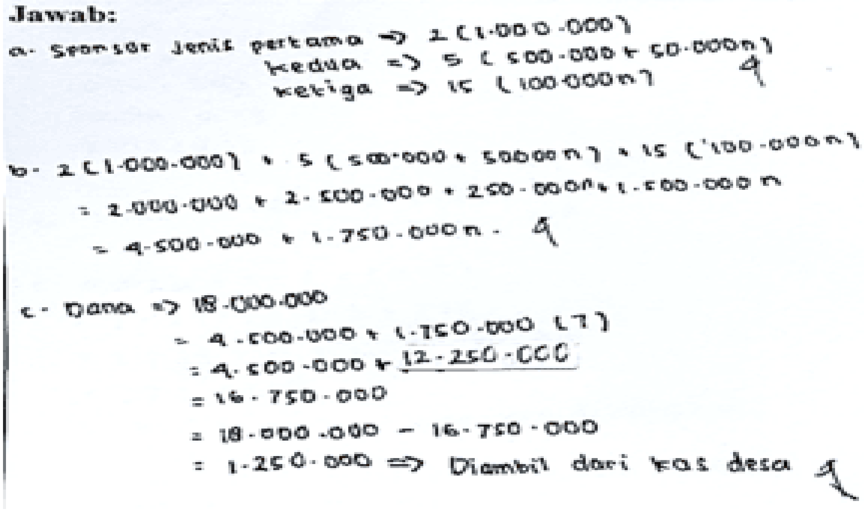


Figure 1: Example of Student Answers in the Post-test of Mathematical Reasoning

Based on Figure 1, which showcases an example of student responses to post-test question number 4, it is evident that the students understood the problem well, enabling them to systematically solve the issue. In point a, which includes the first indicator of presenting mathematical statements either in writing or diagrammatically, the figure shows that students were able to present written mathematical statements. However, some students were inaccurate in this step, leading to difficulties in the subsequent step at point b, which involves the second indicator of performing mathematical manipulations. A similar issue was encountered at point c, which involves the third indicator of drawing conclusions with reasoning or evidence for the solution's correctness. This problem was compounded by students' lack of focus and fear of running out of time when faced with reading the typically lengthy story problems.

Furthermore, a comparative effectiveness test of the PBL and PjBL learning models was conducted to determine which model is more effective than the two in terms of self-regulated learning and students' mathematical reasoning. The data analyzed included data from before the learning model interventions and data after the interventions from both experimental groups which received different treatments. The hypothesis test used to calculate the comparative effectiveness of learning was Hotelling's T^2. The results of the comparative effectiveness test can be seen in Table 7 as follows:

Table 7: Comparative Effectiveness Test Results

	Hotelling's T^2 (Before Treatment)
P-value	0.0009

Based on Table 7, it can be seen that in the test conducted before the learning model interventions, or the initial capability test, with a p-value < 0.05, it can be concluded that there is a significant difference in the initial capabilities between the two experimental classes. Therefore, it was necessary to check whether all variables differed significantly. According to the tests of between-subjects effects, the value for self-regulated learning was significant with $p < 0.001$, while the value for students' mathematical reasoning was not significant, $p = 0.482$.

This means that there is a difference in the average initial capabilities between the two experimental classes in terms of self-regulated learning, but no significant difference in terms of students' mathematical reasoning. This is supported by the mean difference in the descriptive statistics of the self-regulated learning pre-scale scores, which showed a considerable difference of 12.54 between the two classes, whereas the descriptive statistics for the mathematical reasoning pre-test scores showed a smaller difference of 1.66. In other words, the initial conditions of self-regulated learning in the PBL and PjBL classes were not the same, leading to further testing by analyzing the post-test results using the Multivariate Analysis of Covariance (MANCOVA) with initial self-regulated learning scores as covariates. The results of the MANCOVA test can be seen in Table 8 as follows:

Table 8: MANCOVA Test Results

MANCOVA Test	P-value
Linearity Test (Λ_2): 0.5258	0.0000
Slope Homogeneity (Λ_3): 0.9704	0.4374
Mean Difference Test (Λ_1): 0.9234	0.1074

Based on the results from Table 8, it is evident that the first step, the linearity test (Λ_2), shows a p-value < 0.05, indicating a linear relationship between the initial self-regulated learning capabilities and students' self-regulated learning and mathematical reasoning outcomes. In the second step, the slope homogeneity test (Λ_3) yielded a p-value > 0.05, concluding that both the PBL and PjBL learning models exhibit homogeneity in slopes. In the final step, the mean difference test (Λ_1) with a p-value > 0.05 concludes that there is no difference in effectiveness between the PBL and PjBL learning models in terms of students' self-regulated learning and mathematical reasoning after adjusting for initial self-regulated learning capabilities.

Thus, it can be concluded from the mean difference test (Λ_1), which assesses the post-intervention capabilities using MANCOVA where the initial self-regulated learning scores serve as covariates, that there is no difference in effectiveness between the two experimental classes regarding students' self-regulated learning and mathematical reasoning. Therefore, the testing is sufficient as it indicates that both the PBL and PjBL learning models are equally effective in enhancing students' self-regulated learning and mathematical reasoning.

The comparable effectiveness of the PBL and PjBL models is evidenced by the similar enthusiasm for learning observed in students from both experimental classes. They actively engage in discussions within their groups, employing their mathematical reasoning skills to solve problems presented in their worksheets. One problem presented in the PBL learning model worksheet involves an organization planning a competition and drafting a funding proposal to obtain sponsors. Details of the sponsors already secured are attached, and assuming a variety of competitions with one variable, students are asked to create algebraic forms for the amount of funding from each type of sponsor and the funds received, as well as to calculate the funds that must be drawn from the treasury because the sponsor funds are insufficient to cover the known expenses of the competition. This problem relates to algebraic forms concerning the properties and operations of algebra. Each group has its unique way of resolving the problem, such as the work of one group in the PBL class, which can be seen in Figures 2 and 3 as follows:

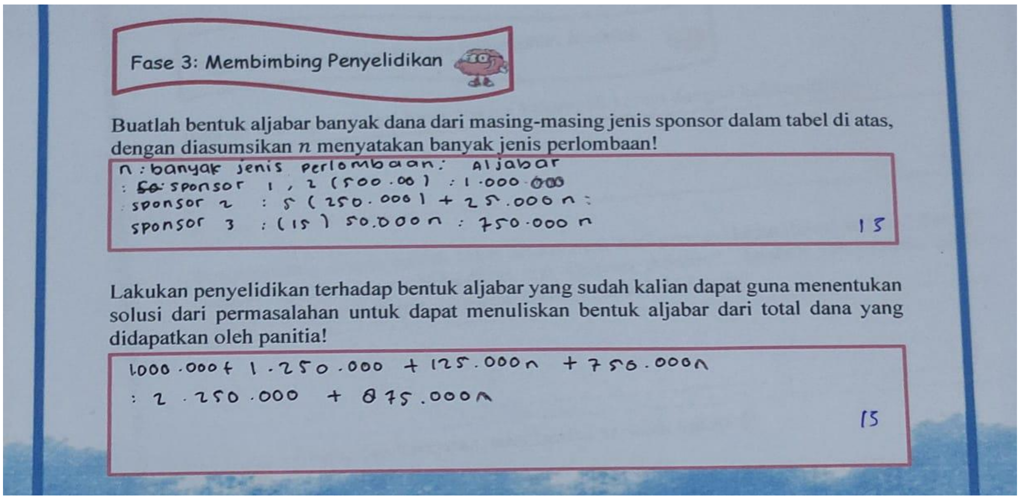
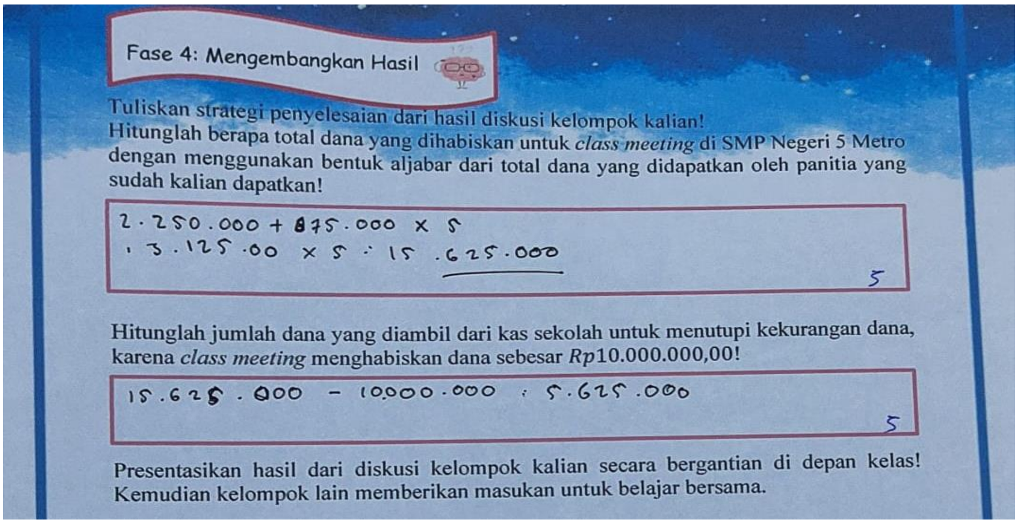


Figure 2: Student Work on the Worksheet in the PBL Class


Fase 4: Mengembangkan Hasil

Tuliskan strategi penyelesaian dari hasil diskusi kelompok kalian!
Hitunglah berapa total dana yang dihabiskan untuk *class meeting* di SMP Negeri 5 Metro dengan menggunakan bentuk aljabar dari total dana yang didapatkan oleh panitia yang sudah kalian dapatkan!

2.250.000 + 875.000 × 5
= 3.125.00 × 5 = 15.625.000
5

Hitunglah jumlah dana yang diambil dari kas sekolah untuk menutupi kekurangan dana, karena *class meeting* menghabiskan dana sebesar *Rp*10.000.000,00!

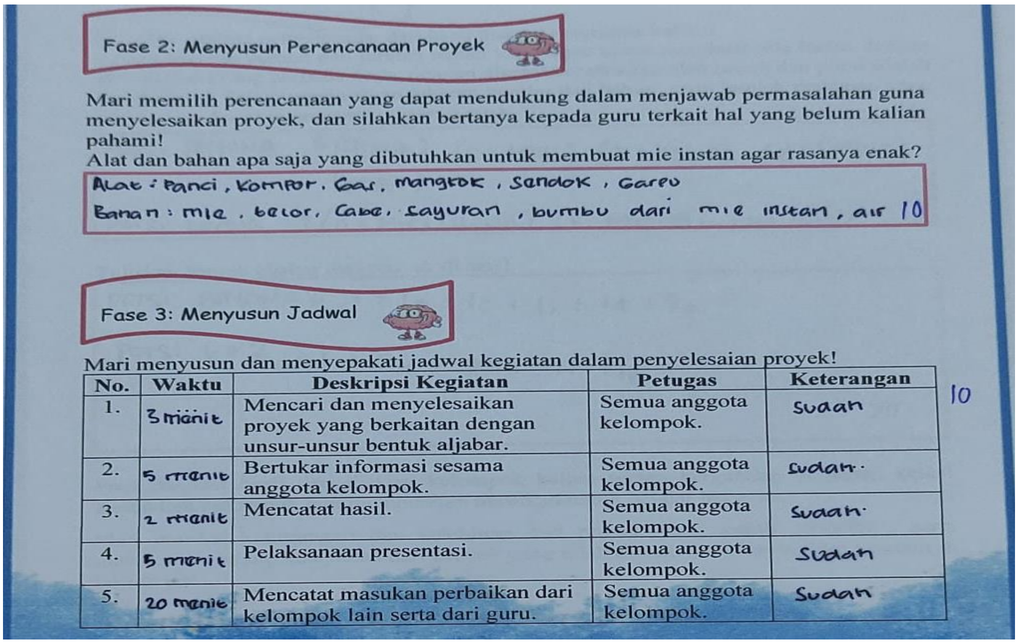
15.625.000 − 10.000.000 = 5.625.000
5

Presentasikan hasil dari diskusi kelompok kalian secara bergantian di depan kelas! Kemudian kelompok lain memberikan masukan untuk belajar bersama.

Figure 3: Continuation of Student Work on the Worksheet in the PBL Class

Based on Figures 2 and 3, the work of a student group in the PBL class can be reviewed. In Figure 2, students correctly solved the problem of creating algebraic forms representing the amount of funding from each type of sponsor. However, they were not meticulous in summing the final algebraic forms from one type of sponsor. In the subsequent step, students accurately wrote the algebraic form for the total funds obtained by the committee. In Figure 3, students were imprecise in operating numbers, resulting in an incorrect total amount of funds that needed to be drawn from the treasury to cover the shortfall.

Another project included in the PjBL model worksheet involves calculating the correct seasoning measures and quantities of ingredients for preparing dishes with varying portions. In this case, the amounts of ingredients and portions serve as variables. Besides ensuring the correct measures of seasonings and ingredients, and sufficient quantity of food, it is also crucial to ensure the food tastes good. This project relates to the elements of algebraic forms in algebra. The work of one group in the PjBL class can be seen in Figures 4 and 5 as follows:


Fase 2: Menyusun Perencanaan Proyek

Mari memilih perencanaan yang dapat mendukung dalam menjawab permasalahan guna menyelesaikan proyek, dan silahkan bertanya kepada guru terkait hal yang belum kalian pahami!
Alat dan bahan apa saja yang dibutuhkan untuk membuat mie instan agar rasanya enak?

Alat : Panci, Kompor, Gas, Mangkok, Sendok, Garpu
Bahan : mie, telor, Cabe, Sayuran, bumbu dari mie instan, air 10

Fase 3: Menyusun Jadwal

Mari menyusun dan menyepakati jadwal kegiatan dalam penyelesaian proyek!

No.	Waktu	Deskripsi Kegiatan	Petugas	Keterangan
1.	3 menit	Mencari dan menyelesaikan proyek yang berkaitan dengan unsur-unsur bentuk aljabar.	Semua anggota kelompok.	Sudah
2.	5 menit	Bertukar informasi sesama anggota kelompok.	Semua anggota kelompok.	Sudah.
3.	2 menit	Mencatat hasil.	Semua anggota kelompok.	Sudah.
4.	5 menit	Pelaksanaan presentasi.	Semua anggota kelompok.	Sudah
5.	20 menit	Mencatat masukan perbaikan dari kelompok lain serta dari guru.	Semua anggota kelompok.	Sudah

10

Figure 4: Student Work on the Worksheet in the PjBL Class

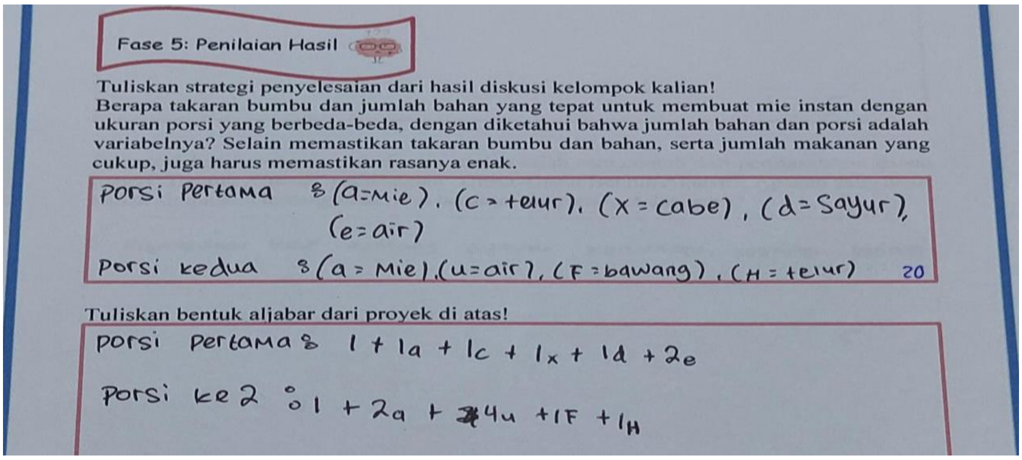


Figure 5: Continuation of Student Work on the Worksheet in the PjBL Class

Based on Figures 4 and 5 above, we can observe the results from a student group in the PjBL class. In Figure 4, students accurately completed the project by listing various tools and ingredients needed to make instant noodles. They also effectively planned and agreed upon a project completion schedule. However, in Figure 5, students were less meticulous in crafting an instant noodle recipe that tasted good, as the ingredients varied between the two portions they prepared. This inconsistency led to inaccuracies in forming algebraic expressions.

During the completion of the problems in the worksheet, students practiced reasoning effectively. Additionally, they were active in presenting the results of their group discussions to solicit feedback and learn collectively. In both experimental classes, students actively presented the outcomes of their group discussions. In this process, they utilized their self-regulated learning skills to take turns presenting the group discussion findings included in the worksheets. Subsequently, students from other groups provided feedback for collective improvement. Therefore, both the PBL and PjBL learning models are equally effective in terms of enhancing students' self-regulated learning and mathematical reasoning. Another factor contributing to the equal effectiveness of both models includes the same instructor (researcher), an equal number of learning sessions, identical instructional materials, and consistent instructor quality.

However, from smaller notes on the percentage of each indicator, analysis results show that the overall percentage of self-regulated learning indicators among students in both experimental classes increased, with the PBL class increasing by 0.71% and the PjBL class by 0.99%. This indicates a greater increase in the PjBL class compared to the PBL class. Nonetheless, the average pre-scale score was higher in the PBL class than in the PjBL class. From these smaller notes, it can be inferred that students in the PjBL class experienced a more substantial improvement in self-regulated learning compared to those in the PBL class.

Moreover, smaller notes on the percentage of each indicator reveal that the overall percentage of mathematical reasoning indicators among students in both experimental classes increased, with the PBL class increasing by 53.62% and the PjBL class by 48.11%. This means that the PBL class experienced a more significant improvement compared to the PjBL class. In line with this, if we look at the average pre-test scores, the PBL class also scored higher than the PjBL class. From these observations, it can be concluded that, based on the small notes on the percentage of each indicator, students in the PBL class experienced a better improvement in mathematical reasoning compared to those in the PjBL class.

4. Conclusion

Based on the results of the study comparing the effectiveness of PBL and PjBL models from the perspectives of self-regulated learning and mathematical reasoning in the context of algebraic forms, it can be concluded that both the PBL and PjBL models are effective. Additionally, the PBL model is found to be as effective as the PjBL model in enhancing students' self-regulated learning and mathematical reasoning. Furthermore, this research implies that both the PBL and PjBL models have proven to be effective and can serve as alternative reference models for educational implementation in schools, particularly in algebra. Students will become more accustomed to identifying and solving problems by integrating mathematical learning into daily life, especially to facilitate self-regulated learning and enhance mathematical reasoning in education. This enables students to develop better independence in learning and to effectively solve problems through reasoning.

Additionally, from this study, it is recommended that similar research should be conducted on other subjects to further assist students and teachers in selecting the most appropriate learning models for their educational processes.

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