

Reflection on Learning and Mathematics Learning Outcomes of Vocational High School Students: An Empirical Study on Several Materials

Widiharti¹, Surya Amami Pramuditya^{2*}

Mathematics Education, Universitas Swadaya Gunung Jati
Pemuda Raya Street, Cirebon, West Java, Indonesia

¹widiharti.125250001@ugj.ac.id; ^{2*}amamisurya@ugj.ac.id

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Abstrak

Pembelajaran matematika di Sekolah Menengah Kejuruan (SMK) memiliki karakteristik yang berbeda dibandingkan dengan pendidikan umum. Penelitian ini bertujuan untuk mengintegrasikan data dari tiga studi independen yang dilakukan di SMKN 1 Lelea. Penelitian ini menggunakan pendekatan kuantitatif dengan desain analisis lintas studi. Subjek penelitian adalah 65 (kelas 11) dan 90 (kelas 12) siswa dari SMKN 1 Lelea, Kabupaten Indramayu. Instrumen penelitian meliputi kuesioner refleksi pembelajaran skala Likert dan tes hasil belajar matematika. Teknik analisis yang digunakan adalah analisis Partial Least Squares (PLS) menggunakan program Smart PLS versi 4.1.1.6 untuk menganalisis variabel eksogen (Usia, Jenis Kelamin, Tingkat Kelas), variabel endogen (Refleksi Pembelajaran, Hasil Belajar), dan variabel mediasi (Refleksi Pembelajaran). Berdasarkan hasil studi empiris yang meneliti refleksi pembelajaran dalam pembelajaran matematika SMA Kejuruan, dapat disimpulkan bahwa refleksi pembelajaran belum menunjukkan dampak langsung yang konsisten terhadap hasil belajar matematika yang diukur secara kognitif.

Kata Kunci: Hasil Belajar Matematika; Pendidikan Matematika; Refleksi Pembelajaran; Sekolah Menengah Kejuruan; SEM-PLS.

Abstract

Mathematics learning in Vocational High Schools (SMK) has different characteristics compared to general education. This study aims to integrate data from three independent studies conducted at SMKN 1 Lelea. This study used a quantitative approach with a cross-study analysis design. The subjects were 65 (11th) and 90 (12th) grade students from SMKN 1 Lelea, Indramayu Regency. The research instruments included a Likert-scale learning reflection questionnaire and a mathematics learning outcome test. The analysis technique used Partial Least Squares (PLS) analysis using the Smart PLS program version 4.1.1.6 to analyze exogenous variables (Age, Gender, Grade Level), endogenous variables (Learning Reflection, Learning Outcomes), and the mediating variable (Learning Reflection). Based on the results of empirical studies examining learning reflection in vocational high school mathematics learning, it can be concluded that learning reflection has not shown a consistent direct impact on mathematics learning outcomes measured cognitively.

Keywords: Mathematics Learning Outcomes; Mathematics Education; Learning Reflection; vocational high school; SEM-PLS.

I. INTRODUCTION

Mathematics learning in Vocational High Schools (SMK) has different characteristics compared to general education. Mathematics in vocational high schools is not only required to build conceptual understanding, but also must be applicable and contextual according to the needs of the world of work and students' vocational competencies. Therefore, mathematics learning in vocational high schools ideally should be able to link abstract concepts to real-world situations relevant to students' areas of expertise (Billett, 2011; Johnson, 2002; National Council of Teachers of Mathematics [NCTM], 2000). However, in practice, these demands are often not fully met, resulting in low conceptual understanding and low mathematics learning outcomes among vocational high school students (Hiebert et al., 1997; Kilpatrick et al., 2001; Suprianto, 2025).

Various research reports indicate that vocational high school students' mathematics learning outcomes are still heterogeneous and tend to be low, particularly in materials requiring higher-order thinking skills. Data analysis and probability materials require students to understand statistical concepts, interpret data, and draw logical conclusions, while inverse functions and compositional functions require an understanding of abstraction and the interrelationships between complex functional concepts (Sarumaha et al., 2024; Anderson & Krathwohl, 2001; Bloom et al., 1956). Students' difficulties with these materials indicate that the problems in learning mathematics in vocational schools are not only related to procedural mastery, but

also to a lack of in-depth conceptual understanding (Hattie, 2009; Ali, Lestari, Rahayu, 2023; Kartika et al., 2025).

In this context, metacognitive skills become an important aspect in vocational mathematics learning. Metacognition enables students to be aware of what they have understood, identify learning difficulties, and organize learning strategies independently and effectively (Flavell, 1979; Schraw & Dennison, 1994; Noviyanti, Riyadi, & Indriati, 2024). Without adequate metacognitive skills, students tend to learn mechanically and are less able to connect mathematical concepts to their application contexts, resulting in shallow understanding and easily forgotten (Zimmerman, 2002; Kossahdasabitah & Zulkarnaen, 2025).

One strategy believed to be effective in developing students' metacognitive abilities is learning reflection. Learning reflection is an important part of self-regulated learning, where students consciously review their learning experiences to understand the process, outcomes, and strategies used during learning (Ernita, Isnarto, & Suyitno, 2024; Zimmerman, 2002; Boud et al., 1985). Through reflection, students are trained to focus not only on the final outcome but also on the underlying thought processes.

Learning reflection plays a role in helping students evaluate their level of understanding of the material, identify conceptual and procedural errors, and plan corrective steps for future learning. In mathematics learning, reflection enables students to understand the rationale for using a procedure, understand the relationships between concepts, and

correct any misconceptions that arise (Dewey, 1933; Schön, 1983; Schraw, 1998; Al-Qonuni & Afriansyah, 2023). Thus, learning reflection serves as a means to build a more meaningful and sustainable understanding.

In the context of vocational high schools, reflection on learning has strong relevance to work-based mathematics learning. The characteristics of vocational high school students, who are more closely connected to practical experiences, make reflection a bridge between mathematical concepts and their application in the workplace (Billett, 2011; Sabaruddin et al., 2023). Contextually designed reflection can increase students' awareness of the benefits of mathematics in their fields of expertise, while also encouraging higher engagement and motivation in learning (Zaki & Afriansyah, 2024; Brookfield, 2017; Johnson, 2002).

Although theoretically, reflection on learning is seen as having an important role in improving the quality of mathematics learning, empirical findings regarding the influence of reflection on learning outcomes still show mixed and inconsistent results. Some studies report a positive relationship between reflection on learning and mathematics learning outcomes, but with a relatively weak relationship strength, while other studies show an effect that is not statistically significant (Chyntia, Puspitasari, & Sundayana, 2025; Hattie, 2009; Schraw, 1998).

This situation is inseparable from the dominance of single-correlational and contextual research, focusing on a single mathematics topic and a single school

context. As a result, the generalizability of findings is limited and it is difficult to provide a comprehensive picture of the role of learning reflection in vocational high school mathematics instruction (Zimmerman, 2002; Moon, 2006; Astuti, 2024). Furthermore, studies specifically conducting empirical syntheses of research on learning reflection in mathematics in vocational high schools are still very limited.

Based on previous research reports, including studies on data analysis and probability, inverse functions and composition functions, as well as research using multivariate analysis approaches such as SEM-PLS, learning reflection often does not show a significant direct influence on mathematics learning outcomes. These findings indicate that the role of learning reflection needs to be understood more deeply through an empirical synthesis approach to identify patterns, consistencies, and factors that influence the effectiveness of learning reflection in the context of vocational high school mathematics (Dewi et al., 2025; Hiebert et al., 1997; Schön, 1983).

Based on the background and research gaps, this study aims to integrate data from three independent studies conducted at SMKN 1 Lelea. Furthermore, this study aims to compare the influence of learning reflection on various vocational high school mathematics materials and formulate pedagogical implications that can be used as a basis for developing more effective and meaningful mathematics learning (NCTM, 2000; Zimmerman, 2002).

In line with these objectives, the research questions raised in this study are: (1) what is the tendency of the relationship between learning reflection and mathematics learning outcomes of vocational school students based on existing empirical findings?; (2) is the role of learning reflection consistent across various vocational school mathematics materials?; and (3) what factors can explain the weak or insignificant influence of learning reflection on mathematics learning outcomes of vocational school students (Regitanurvikasari, Jana, & Umasugi, 2022; Hattie, 2009; Schraw & Dennison, 1994).

II. METHOD

This research uses a quantitative approach with a cross-study analysis design, namely comparing and integrating findings from several empirical studies that have similar variables, instruments, and research contexts to identify patterns and consistency of results.

The data sources in this study are in the form of empirical research reports from three quantitative studies that have been conducted in the context of vocational high school mathematics learning, namely: (1) correlational studies on the material on inverse functions and composition functions, (2) correlational studies on the material on data analysis and probability, and (3) explanatory studies using path analysis involving factors of age, gender, and class level.

The research subjects were 11th grade students (65 students) and 12th grade students (90 students) from SMKN 1 Lelea, Indramayu Regency. The research instruments included a Likert-scale-based

learning reflection questionnaire with four indicators (learning strategies, self-assessment, metacognition, participation and involvement) and a mathematics learning outcome test (multiple-choice questions on the material of inverse functions and composition functions, essay questions on the material of data analysis and probability). The research flow in this study was arranged in stages to obtain a comprehensive picture of the role of learning reflection in vocational high school mathematics learning. The first study was directed at examining the relationship between learning reflection and mathematics learning outcomes through a correlational approach on the material of data analysis and probability. This study aims to obtain initial empirical evidence regarding the strength and direction of the relationship between these two variables. Furthermore, a second study was conducted to test the consistency of the findings across different material contexts, namely inverse functions and composition functions, to determine whether the role of learning reflection is stable or contextual to the type of mathematics material. The third study expanded the analysis by examining additional explanatory factors, such as students' age, gender, and grade level, in relation to learning reflection and mathematics learning outcomes. Through this series of studies, the research is expected to provide a deeper and more comprehensive understanding of the mechanisms by which learning reflection influences vocational high school students' mathematics learning outcomes.

The analysis technique in this study uses Partial Least Square (PLS) analysis using the

Smart PLS Version 4.1.1.6 program tool to analyze exogenous variables (Age, Gender, Grade Level), endogenous variables (Learning Reflection, Learning Outcomes) and mediating variables (Learning Reflection).

The developed structural model positions learning reflection as a mediating variable that bridges student demographic factors with mathematics learning outcomes. Theoretically, learning reflection is an important part of self-regulated learning that contributes to improving the quality of mathematics learning processes and outcomes.

III. RESULT AND DISCUSSION

A. Results of Correlational Studies on the Material of Inverse Functions and Composition Functions

Based on descriptive statistical analysis of 65 students of class XI TJKT (Computer Network and Telecommunication Engineering), the average learning reflection score (X) was 66.57 with a standard deviation of 8.869, while the average mathematics learning outcomes (Y) were 93.45 with a standard deviation of 12.652. This shows that the level of students' learning reflection is in the moderate category and the mathematics learning outcomes on the material of inverse functions and composition functions tend to be high, although there are still variations between students.

Normality tests were conducted using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results showed that the learning reflection variable (X) was normally distributed (Sig. > 0.05) and the

mathematics learning outcome variable (Y) was not normally distributed (Sig. < 0.05). Thus, the normality assumption was not fully met, especially for the learning outcome variable. Therefore, in addition to parametric analysis, a nonparametric analysis was also conducted to strengthen the interpretation of the results.

Linearity test was conducted to determine whether the relationship between learning reflection and learning outcomes was linear. The ANOVA results showed a significance value of Sig. = 0.000, indicating that there is a general relationship between the two variables. However, caution is needed in concluding pure linearity due to the quite extreme variation in learning outcome scores (many maximum values are 100). The Pearson correlation value was $r = 0.234$ with Sig. = 0.060, making it statistically insignificant at $\alpha = 0.05$. Because the learning outcome data were not normal, a Spearman correlation test was conducted. The results showed a correlation coefficient of $\rho = 0.320$ with Sig. = 0.009, indicating a positive and significant relationship between learning reflection and mathematics learning outcomes. This indicates that nonparametrically, learning reflection has a significant relationship with learning outcomes.

The results of the simple linear regression analysis show an R Square value of 0.055, meaning that learning reflection only contributes 5.5% to the variation in mathematics learning outcomes. The F test yields a Sig. = 0.060, indicating that the effect of learning reflection on learning outcomes is not statistically significant at

the 5% level. Therefore, the hypothesis of a direct effect cannot be accepted based on the parametric regression analysis.

The results of the study indicate that learning reflection has a positive relationship with learning outcomes, although it is not yet statistically significant. This statistically insignificant result is thought to be due to the relatively short duration of learning reflection, vocational high school students' inexperience in conducting independent reflection, and the abstract nature of the inverse function and composition materials.

The pedagogical implication of this research is that learning reflection needs to be implemented continuously, not incidentally. Teachers need to provide structured reflection guidance. Reflection can be combined with discovery learning or problem-based learning models

B. Results of Correlational Studies on Data Analysis and Opportunity Materials

Based on descriptive statistical analysis of 90 students in grades XII TKRO (Light Vehicle Automotive Engineering) and XII TOI (Industrial Automation Engineering), the learning reflection variable has an average value of 64.23, with a standard deviation of 9.059. The minimum value of 33 and the maximum value of 84 indicate that the variation in students' learning reflection is quite diverse, but in general it is in the moderate-quite good category. Meanwhile, the mathematics learning outcome variable has an average of 49.78 with a standard deviation of 24.112, a minimum value of 10 and a maximum of 90. This indicates that students'

mathematics learning outcomes are still heterogeneous, with quite wide differences in abilities between students. Descriptively, the quality of students' learning reflection is quite good, but mathematics learning outcomes still vary greatly.

Normality tests were conducted using the Kolmogorov-Smirnov and Shapiro-Wilk tests, showing that variable X has a Sig. <0.05, and variable Y also has a Sig. <0.05. This means that both variables are not normally distributed. However, because the sample size is $n = 90 (> 30)$, correlation and regression analyses can still be conducted, with the addition of a nonparametric correlation test (Spearman) as a comparison. Although the data are not normally distributed, the large sample size allows the analysis to continue with consideration of nonparametric tests.

The linearity test results show a significance value of 0.103 (> 0.05), so the relationship between learning reflection and mathematics learning outcomes is linear and meets the assumptions of simple linear regression. The Pearson correlation coefficient value is -0.070 with a significance of 0.514 (> 0.05). This indicates that the relationship between learning reflection and mathematics learning outcomes is very weak, the direction of the relationship is negative, and not statistically significant. As a comparison, the Spearman test produces a coefficient of -0.017 with a significance of 0.875 (> 0.05). These results confirm that there is no significant relationship between the two variables.

Both parametric and nonparametric tests show that the relationship between learning reflection and mathematics

learning outcomes is very weak and not significant.

The regression results show an R value of 0.070 and R Square of 0.005, meaning that learning reflection only explains 0.5% of the variation in learning outcomes. Sig. value = 0.514 (> 0.05). The regression coefficient B value = -0.186, $t = -0.656$, Sig. = 0.514. This shows that learning reflection does not have a significant effect on students' mathematics learning outcomes. Statistically, learning reflection does not have a significant effect on students' mathematics learning outcomes in the material of data analysis and probability.

These findings indicate that learning reflection has not had a direct impact on improving math test scores. Reflection likely has a greater impact on metacognitive aspects, long-term conceptual understanding, or learning attitudes. Other factors such as prior ability, motivation, teaching methods, and the intensity of practice exercises have a more dominant influence on learning outcomes.

C. The Results of the Explanatory Study Using Path Analysis Involving Factors of Age, Gender, and Grade Level

Data analysis was conducted using SmartPLS with a structural model that positions learning reflection as a mediator variable between demographic factors (age, gender, and grade level) and mathematics learning outcomes. The model yielded two endogenous constructs: learning reflection and mathematics learning outcomes. The coefficient of determination (R^2) values indicated that

learning reflection had an R^2 of 0.079, while mathematics learning outcomes had an R^2 of 0.512. These findings demonstrate differences in the strength of the models in explaining variation in each endogenous construct.

Learning Reflection ($R^2 = 0.079$). The R^2 value of 0.079 indicates that the variables of age, gender, and grade level simultaneously only explain 7.9% of the variation in student learning reflection. This indicates that the influence of demographic factors on learning reflection is very weak. This finding suggests that learning reflection cannot be understood as a direct consequence of student demographic characteristics, but rather is more influenced by other internal and pedagogical factors, such as learning motivation, learning habits, the quality of learning interactions, and the learning environment. Thus, learning reflection is more appropriately viewed as a cognitive-metacognitive process that develops through learning experiences, rather than as a result of differences in age, gender, or grade level alone.

Mathematics Learning Outcomes ($R^2 = 0.512$). The R^2 value of 0.512 indicates that age, gender, grade level, and learning reflection together explain 51.2% of the variation in students' mathematics learning outcomes. This value indicates that the model has moderate to strong explanatory power, making it substantively suitable for use in educational research contexts. This finding suggests that mathematics learning outcomes are influenced by a combination of demographic factors and the learning

process, although the contribution of each variable varies.

Table 1.
Path Analysis

Influence	Learning Reflection	Learning outcomes
Age	-0.097	-0.203
Gender	-0.531	-1.072
Grade Level	0.131	-1.072
Learning Reflection		-0.028

The path coefficient of age on learning reflection is negative and small (-0.097), indicating that age has no significant effect on learning reflection. This finding indicates that older students do not automatically have better reflective skills. Learning reflection does not simply develop with age, but rather requires habituation and learning that explicitly trains students' metacognitive awareness.

The effect of gender on learning reflection showed a negative trend (-0.531). This finding indicates a difference in the tendency of learning reflection between male and female students. The statistical significance of this relationship was further confirmed through bootstrapping analysis. The analysis results showed that the effect of gender on mathematics learning outcomes was not statistically significant (p-value = 0.706). This finding indicates that there is no significant difference between the mathematics learning outcomes of male and female students. Thus, gender does not play a role as a determining factor in achieving mathematics learning outcomes in the context of this study. These results indicate that students' mathematics abilities are relatively equal across genders, so differences in learning achievement are more influenced by learning factors and

individual student characteristics than by gender differences.

Grade level showed a positive but weak influence on learning reflection (0.131). This indicates that increasing grade level tends to be followed by an increase in learning reflection, although the contribution is relatively small. Thus, grade level is not a primary determinant in shaping students' learning reflection.

The analysis results show that learning reflection does not have a significant direct influence on mathematics learning outcomes (-0.028). This finding indicates that the applied learning reflection has not been optimally internalized as a learning strategy that directly impacts the achievement of cognitive values. This condition may be caused by reflection that is still administrative in nature, has not been guided in depth, and has not been integrated with concrete learning follow-up. This finding cannot be viewed as a failure of learning reflection, but rather as a critical finding that indicates a gap between reflection practices and the expected metacognitive function.

Age had a weak negative effect on learning outcomes (-0.203), indicating that older students do not always perform better. This could be related to grade repetition, academic boredom, or less supportive prior learning experiences. Gender did not show a strong direct effect on mathematics learning outcomes, indicating that gender differences are not a dominant factor in mathematics achievement. This finding supports the principle of equality of mathematical ability between male and female students.

In contrast, grade level showed the strongest, relatively negative effect on learning outcomes. This finding indicates that the higher the grade level, the greater the challenges students face in learning mathematics, which is related to the increasing complexity of the material, cognitive load, and learning readiness that is not fully commensurate.

Table 2.
Bootstrapping Results on SEM-PLS Model

Influence	Learning Reflection	Learning outcomes
Age	0.720	0.033
Gender	0.322	0.706
Grade Level	0.835	0.001
Learning Reflection		0.827

Bootstrapping results showed that age did not significantly influence learning reflection ($p = 0.720$). This finding indicates that differences in student age do not directly determine the level of learning reflection. Theoretically, learning reflection is a metacognitive skill that develops through experience and learning habits, not solely as a function of biological age maturity.

Furthermore, the effect of gender on learning reflection was also insignificant ($p = 0.322$). This indicates that there is no significant difference in learning reflection between male and female students. This finding indicates that learning reflection is more influenced by the quality of the learning experience than by gender differences.

Similarly, grade level did not show a significant effect on learning reflection ($p = 0.835$). This finding suggests that increasing grade level does not automatically lead to an increase in students' reflective abilities.

Overall, these results confirm that learning reflection in this model is not significantly influenced by demographic factors.

The analysis results showed that learning reflection did not have a significant effect on mathematics learning outcomes ($p = 0.827$). This finding indicates that the applied learning reflection has not had a direct impact on the achievement of learning outcomes measured cognitively. This condition may be caused by learning reflection that is still formal or administrative in nature, has not reached metacognitive depth, and has not been followed up with directed learning strategy follow-up. This finding is an important empirical result because it indicates a gap between reflection practices and the expected metacognitive function in mathematics learning.

In contrast to learning reflection, age showed a significant effect on mathematics learning outcomes ($p = 0.033$). This indicates that differences in student age are associated with variations in learning outcomes. In the context of vocational high school education, age differences are often related to previous learning experiences, including the possibility of repeating a grade, which can influence mathematics learning outcomes.

Gender did not show a significant effect on mathematics learning outcomes ($p = 0.706$), meaning there was no significant difference in learning outcomes between male and female students. This finding indicates that students' mathematical abilities are relatively equal across genders, so differences in learning outcomes are

more influenced by learning factors than by gender differences.

In contrast, grade level showed a significant effect on mathematics learning outcomes ($p = 0.001$). This finding is one of the main findings of the study, indicating that the higher the grade level, the greater the challenges faced by students in learning mathematics. This is related to the increasing complexity of the material, cognitive load, and demands for higher conceptual understanding, which are not fully balanced by students' readiness and learning strategies.

Based on the SEM-PLS bootstrapping results in Table 2, it can be concluded that demographic factors do not significantly influence learning reflection, and learning reflection also has no significant effect on mathematics learning outcomes. However, age and especially grade level show a significant direct influence on mathematics learning outcomes. These findings indicate that learning reflection in the context of this study does not yet function as a connecting mechanism between student characteristics and learning outcomes, so it is necessary to strengthen the quality and design of learning reflection so that it can play a more effective role in vocational high school mathematics learning.

Based on the results of the path analysis, learning reflection did not function as an effective mediator between demographic factors and mathematics learning outcomes. The weak path from demographic factors to learning reflection and the very weak path from learning reflection to learning outcomes resulted in no mediation effect.

Table 3.
Pattern of Findings Across Studies

Case study	Material	Method	The Role of Reflection
1	Inverse Functions and Composition	Correlation	Positive, weak
2	Opportunity data analysis	Regression	Not significant
3	Multi-material	Path Analysis	Not a mediator

These findings indicate that reflection on learning is not the sole determinant of learning outcomes. In vocational schools, context and learning quality are more dominant. Therefore, reflection needs to be strengthened pedagogically, not just measured quantitatively.

Learning reflection plays a limited and contextual role in vocational high school mathematics learning. Reflection has not yet functioned as an effective mediator, so improving mathematics learning outcomes depends more on the quality of the learning design and pedagogical support provided to students.

The study results show that learning reflection has a positive relationship with mathematics learning outcomes in the inverse function and composition function topics, although this relationship is relatively weak and not yet statistically significant. In the data analysis and probability topics, learning reflection did not show a significant relationship or influence on student learning outcomes.

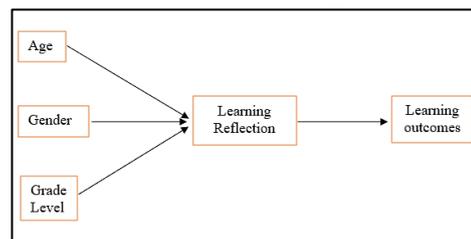


Figure 1. Path Analysis

The results of the path analysis indicate that demographic factors such as age, gender, and grade level have a strong contribution in explaining variations in students' mathematics learning outcomes. However, learning reflection has not yet effectively acted as a mediator between demographic factors and learning outcomes. This finding indicates that learning reflection has not been optimally internalized in the learning process of vocational high school students.

Theoretically, the results of this study reinforce the view that learning reflection is a process that requires scaffolding and habituation. Without adequate pedagogical support, learning reflection tends to be procedural in nature and is unable to significantly impact learning outcomes (Kartikasari, Rahman, & Ahyan, 2023; Zimmerman, 2002; Efklides, 2011). Therefore, the implementation of learning reflection needs to be designed systematically and integrated with active learning models.

In general, the results of the study report indicate that studies of reflection on mathematics learning in vocational schools are still relatively limited. In terms of research methods, most studies use a quantitative approach with correlational and linear regression designs to test the relationship between reflection on learning and mathematics learning outcomes. Several other studies use multivariate analysis approaches, such as Structural Equation Modeling–Partial Least Squares (SEM-PLS), to examine the role of reflection on learning in a more complex way, along with other variables, such as learning

motivation and student characteristics. The dominance of non-experimental methods indicates that studies of reflection on learning in vocational schools are still at the exploratory and relationship-testing stage, rather than at the learning intervention stage.

In terms of mathematics, the analyzed studies cover a wide range of topics, with a primary focus on data analysis and probability, as well as inverse functions and composition functions. Both materials represent the characteristics of vocational high school mathematics learning, which demands conceptual understanding, procedural skills, and the ability to relate mathematics to applied contexts.

The results of empirical studies indicate that the relationship between learning reflection and mathematics learning outcomes in vocational high school students tends to be dominated by weak or statistically insignificant relationships. Most studies report a positive relationship between learning reflection and learning outcomes, but with a low coefficient. In fact, in some studies, the effect of learning reflection on learning outcomes did not reach the established level of statistical significance.

This pattern is consistent with findings from studies examining data analysis and probability, where learning reflection did not directly improve students' test scores. Similarly, for inverse functions and composition functions, learning reflection tended not to show a significant effect on cognitive learning outcomes as measured by written tests. This consistency of findings indicates that the role of learning

reflection in vocational high school mathematics learning is not a direct and linear effect on learning outcomes, but rather operates through more complex mechanisms.

A comparison of findings based on material type indicates differences in the nature of the influence of learning reflection. For more procedural material, learning reflection tends to have less impact on improving learning outcomes as measured quantitatively. This is likely because success in procedural material is more influenced by repeated practice and mastery of algorithms than by the reflective process.

Conversely, for conceptual material that requires an understanding of the relationships between concepts, reflection on learning has the potential to make a more meaningful contribution, although it is not always directly reflected in final test scores. Cognitive load and material complexity are also important factors influencing the effectiveness of reflection. For material with a high level of complexity, reflection requires more intensive guidance to help students manage their thinking processes effectively.

The study findings also showed that reflection on learning had a more visible impact on the learning process, such as increasing students' awareness of errors and learning strategies, than on the final learning outcomes measured cognitively. This reinforces the view that reflection on learning functions as a facilitator of the learning process, not as a direct predictor of grade achievement.

The predominance of weak and insignificant findings between learning

reflection and mathematics learning outcomes demands a more critical discussion. One suspected contributing factor is the practice of learning reflection, which remains largely administrative, for example, simply filling out a reflection sheet without clear follow-up. In such circumstances, reflection does not function as a profound metacognitive process, but rather as a routine activity.

Furthermore, learning reflection is often not integrated with follow-up learning strategies, such as error correction, enrichment, or teacher-guided reflective discussions. As a result, student reflection results are not optimally utilized to improve the quality of subsequent learning. Another contributing factor is the dominance of learning outcome measurement in the cognitive domain, while the impact of learning reflection is more evident in the metacognitive and affective domains, which are rarely explicitly measured.

However, empirical studies show that learning reflection has a relatively stronger impact on students' learning awareness, self-regulation, and long-term understanding. These impacts are indirect and take time, so they are not always detected through short-term learning outcome measurements. Therefore, the weak influence of learning reflection on cognitive learning outcomes does not necessarily indicate that learning reflection is unimportant in vocational high school mathematics learning.

Based on the results of the study and critical discussion, learning reflection needs to be designed in a more structured and meaningful way in vocational high school mathematics instruction. Reflection should

not simply be given as a final assignment; it should be guided through clear, reflective questions relevant to the learning objectives. Teachers also need to integrate student reflection results with advanced learning strategies, such as providing feedback, class discussions, and improving learning.

Furthermore, the design of learning reflection needs to be adapted to the characteristics of vocational high school mathematics material. For conceptual and complex material, reflection should focus on understanding concepts and relationships between ideas, while for procedural material, reflection can be directed toward understanding the rationale behind the procedures used. With a contextual and integrated reflection design, learning reflection has the potential to be an effective metacognitive strategy for improving the quality of mathematics learning in vocational high schools.

IV. CONCLUSION

This study is limited to one school (SMKN 1 Lelea). Based on the results of empirical studies examining various studies examining learning reflection in vocational high school mathematics learning, it can be concluded that learning reflection has not shown a consistent direct impact on mathematics learning outcomes measured cognitively. Most empirical studies report a weak or statistically insignificant relationship between learning reflection and learning outcomes, particularly in the material of data analysis and probability as well as inverse functions and composition functions. This finding confirms that the

role of learning reflection in the context of vocational high school mathematics is not linear and simple.

However, this empirical study suggests that learning reflection plays a stronger role as a metacognitive process that supports students' learning awareness, self-regulation, and long-term understanding. Learning reflection serves as a means for students to review their thinking processes, recognize errors, and plan more effective learning strategies, although its impact is not always directly reflected in final test scores. Therefore, learning reflection should be understood as an integral part of the learning process, not merely as a predictor of quantitative learning outcomes.

The implications of these findings indicate the need to develop a more meaningful and structured model of reflective learning in vocational high school mathematics instruction. Reflection needs to be systematically integrated with learning follow-up, such as teacher feedback, reflective discussions, and improvements to learning strategies, so that reflection's metacognitive potential can be optimally utilized. Without such integration, reflection risks becoming an administrative activity that has little impact on improving the quality of learning.

As a recommendation for further research, experimental studies are needed to test the effectiveness of learning reflection, designed in a structured and contextual manner according to the characteristics of vocational high school mathematics material. Furthermore, measurement of learning outcomes needs

to be expanded beyond the cognitive domain to include metacognitive and affective domains, so that the impact of learning reflection can be captured more comprehensively. Further research using this approach is expected to provide a deeper understanding of the working mechanisms of learning reflection in improving the quality of mathematics learning in vocational high schools.

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AUTHOR'S BIOGRAPHY

Widiharti, S.Pd.



The author is a master's student in Mathematics Education at Universitas Swadaya Gunung Jati, Cirebon. The author's obtained her Bachelor's degree in Mathematics Education from Wiralodra University, Indramayu, in 2010 and completed the Mathematics Teacher Professional Education Program (PPG) at Universitas Negeri Medan in 2023. The authors have teaching experience as a mathematics teacher at vocational high schools in Indramayu, serving at SMKN 1 Balongan from 2010 to 2023 and currently teaching at SMKN 1 Lelea.

Dr. Surya Amami Pramuditya, M.Si.



The author is the author is a lecturer in the Mathematics Education Study Program, Universitas Swadaya Gunung Jati Cirebon. The author's research focus is digital learning technology and mathematical digital communication which has been published in various national and international journals. Books that have been published by the author include Making Android-based educational games as a medium for learning mathematics and Mathematical digital communication skills.