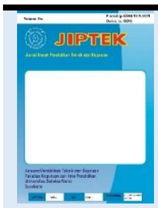

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Factors Affecting Machining Competency in Vocational Education: A Path Analysis Approach

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ABSTRACT

This study aims to analyze the direct influence of achievement motivation and workshop facilities, as well as the indirect influence through independent learning and practical machining learning, on students' machining competency. A quantitative ex post facto research design was employed and conducted in vocational high schools offering Machining Engineering programs. The sample consisted of 116 twelfth-grade students, selected through proportional random sampling from a population of 166 students. Data were collected using validated Likert-scale questionnaires to measure achievement motivation, workshop facilities, independent learning, and practical machining learning, while machining competency was measured using students' competency assessment scores. Data analysis was performed using path analysis in SPSS. Before analysis, the data satisfied the assumptions of normality, linearity, multicollinearity, and homoscedasticity. The results indicate that workshop facilities exert the strongest direct effect on machining competency (β = 0.307), followed by independent learning (β = 0.259), practical machining learning (β = 0.177), and achievement motivation (β = 0.170). In addition, achievement motivation and workshop facilities also influence machining competency indirectly through independent learning and practical machining learning. The structural model explains 49.9% of the variance in machining competency (R^2= 0.499). Overall, these findings confirm that direct and indirect learning-related factors play a significant role in shaping machining competency and provide empirical evidence to support the development of more effective vocational learning strategies aligned with the demands of the modern manufacturing industry.

Keywords*: Achievement Motivation, Workshop Facilities, Independent Learning, Practical Machining Learning, Machining Competence*

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INTRODUCTION

In the era of the Fourth Industrial Revolution, vocational education plays a strategic role in preparing competent, adaptive human resources capable of responding to rapid technological transformation. Automation, digitalization, and the integration of cyber-physical systems have fundamentally reshaped work processes in the engineering and manufacturing sectors. Consequently, vocational education is required not only to emphasize technical skills, but also to foster critical thinking, problem-solving abilities, and technological literacy so that graduates can adapt to dynamic and complex workplace demands (Apri Nuryanto et al., 2024; F. López et al., 2023; T A Prasetya et al., 2025). Recent studies indicate that vocational education institutions are increasingly shifting from traditional skill-based training toward developing a future-ready workforce that is resilient to industrial uncertainty (E. J. López et al., 2024).

The gap between graduate competencies and industry needs remains a significant global issue. More than 50% of the global workforce needs to undergo reskilling and upskilling to adapt to technological changes in the industry (L. Li, 2024). This challenge is evident in the manufacturing and precision engineering sectors, where vocational education graduates often do not fully master digital manufacturing technology, automation, and data-based processing (Spöttl & Windelband, 2021). This phenomenon indicates that vocational curricula and learning are not yet fully aligned with industry needs, particularly in machining, which demands precision, efficiency, and mastery of digital manufacturing technology.

Machining competency is a key indicator of mechanical engineering graduates' readiness for the workplace. This competency includes the ability to operate conventional and Computer Numerical Control (CNC) machines, read technical drawings, and use Computer-Aided Manufacturing (CAM) software. Competency is defined as an individual's ability to perform as required by the job through the integration of knowledge, skills, and professional attitudes. (Harjanto, 2026; Sutopo, Setiadi, Prasetya, et al., 2024). In the context of vocational education, the achievement of machining competencies is greatly influenced by both internal factors, such as motivation and independent learning, and external factors, such as workshop facilities and the quality of practical learning.

Previous studies have sought to identify factors influencing the competence of vocational students in mechanical engineering. The availability of workshop facilities and teacher support has a significant effect on students' practical skills (Djatmiko et al., 2020; Van Nguyen et al., 2023). Project-based learning is essential in improving the machining skills and critical thinking abilities of vocational students (Tri Adi Prasetya et al., 2025; Sutopo, Setiadi, Nashir, et al., 2024). However, most of these studies remain limited to descriptive and simple correlational analyses, without comprehensively exploring causal relationships among factors.

Several research gaps require further exploration. First, there is still a limited number of quantitative studies employing path analysis to simultaneously examine the direct and indirect effects of achievement motivation, learning independence, workshop facilities, and practical learning on the machining competence of vocational students. Most existing studies emphasize simple bivariate relationships and fail to explain the structural mechanisms underlying competency formation as an integrated process. Although previous studies have confirmed the contribution of student learning activities and creativity to vocational learning outcomes (T. A. Prasetya et al., 2021)These studies predominantly relied on regression-based analyses and did not develop a comprehensive causal framework to explain the interrelationships among motivation, learning environments, learning processes, and machining competence.

Second, previous studies have focused more on the technical aspects of learning. In contrast, affective and psychological dimensions such as achievement motivation and learning independence have not been empirically studied in the context of machining. Achievement motivation correlates positively with practical achievement (Guo et al., 2021). However, no model simultaneously maps the interactions among achievement motivation, facilities, and learning quality in their influence on students' final competence (Wibowo et al., 2020). Thus, there is still room for further research to develop a model that more comprehensively explains the multidimensional relationship among these factors.

This study aims to analyze the factors influencing the machining competency of vocational high school students in Indonesia using a path analysis approach. In the Indonesian vocational education system, machining competency is a core learning outcome mandated by the curriculum, but its achievement is often constrained by uneven workshop facilities, limited integration of industrial practices, and variations in student learning autonomy. Although previous studies have largely relied on descriptive methods or bivariate correlations to examine vocational competency, these approaches have not adequately captured the structural relationships among motivational, instructional, and environmental factors. This study addresses this gap by applying a structural path model to explicitly examine the direct and indirect relationships between achievement motivation, workshop facilities, learning autonomy, and practical machining learning. The novelty of this study lies in the development of an integrated causal model grounded in the reality of vocational high schools in Indonesia, where learning autonomy and practical machining learning are positioned as key mediating variables linking curriculum implementation, workshop conditions, and student competency outcomes. These findings contribute theoretically by expanding the competency development framework through empirical validation of mediating mechanisms in vocational education, and practically by providing evidence-based and context-sensitive guidance for vocational high schools and industrial partners to strengthen workshop facilities, align practical learning with industry standards, and enhance students' motivation and autonomy in responding to the demands of the modern manufacturing industry.

RESEARCH METHODS

This study uses a quantitative approach with an ex post facto design, because the variables studied, achievement motivation, workshop facilities, learning independence, practical machining learning, and machining competency, have occurred naturally and cannot be manipulated experimentally, so it is appropriate to study the cause-and-effect relationship in the context of vocational education. The study was conducted at two Vocational High Schools in Bantul Regency that organize Mechanical Engineering Expertise Programs with Machining Engineering Expertise Competencies. The study population was 166 grade XII students, and based on the calculation of sample determination, 116 students were obtained as research samples determined using proportional random sampling techniques, because the population is considered homogeneous in terms of level and study program. The number of samples was then proportionally divided into each class in both Vocational High Schools in Bantul Regency to ensure balanced representation of respondents.

The research data were collected using a Likert-scale questionnaire developed to measure four independent variables that influence machining competency (Y): achievement motivation (X_1), workshop facilities (X_2), learning independence (X_3), and machining practice learning (X_4). Meanwhile, the dependent variable, machining competency, was measured using student performance-based assessment results. The instrument’s validity was assessed using the Pearson product-moment correlation to examine the relationship between item scores and the total score. Based on the validity test results, 105 items were deemed valid, while 10 were disqualified. Furthermore, the instrument's reliability was assessed using Cronbach's alpha, and the results showed values above 0.90 for all variables, indicating very high reliability (Trinchera et al., 2018). Thus, the research instrument was deemed suitable for primary data collection.

Before conducting a path analysis, prerequisite tests are performed to ensure that the model's statistical assumptions are met. This testing includes four stages, namely: (1) Normality Test; (2) Linearity Test; (3) Multicollinearity Test; and (4) Homoscedasticity Test (Douma & Shipley, 2021). All tests are conducted using SPSS statistical software to ensure the model's validity and the appropriateness of the data for the path analysis.

Data analysis was conducted using path analysis techniques, which allow for the examination of both direct and indirect influences among variables within a complex causal structure. This approach was selected to explain the relationships between achievement motivation, workshop facilities, learning independence, practical machining learning, and machining competency in a single structural model. Path coefficients were derived from standardized regression coefficients (β), enabling the assessment of the relative contribution of each causal variable to machining competency as the outcome variable (Sahli et al., 2025). Based on the proposed conceptual framework, this study formulated 12 hypotheses encompassing the direct effects of achievement motivation and workshop facilities on learning independence, practical machining learning, and machining competency, as well as the direct effects of learning independence and practical machining learning on machining competency. In addition, indirect effects were hypothesized, in which achievement motivation and workshop facilities influence machining competency through the mediating roles of learning independence and practical machining learning. This hypothesis structure allows for a comprehensive evaluation of how direct and indirect factors interact to shape machining competency in vocational education.

RESULTS OF RESEARCH AND DISCUSSION

Result of Prerequisite Analysis Test

Normality Test

The normality test in this study used the Kolmogorov–Smirnov test in SPSS, with the criterion that the data were declared normally distributed if the significance value (p-value) was greater than $\alpha = 0.05$. Based on the results shown in Table 1, all variables had significance values above 0.05, namely achievement motivation (0.199), workshop facilities (0.719), learning independence (0.518), machining practice learning (0.569), and machining competence (0.100). Thus, all data in this study were assumed to be normally distributed. These results indicate that the distributions of each variable meet the assumption of normality, so the analysis can proceed with a path analysis using a valid and reliable parametric statistical approach.

Table 1. Normality Test

		Achievement Motivation	Workshop Facilities	Learning Independence	Machining Practical Learning	Machining Competence
N		116	116	116	116	116
Normal Parameters[a,b]	Mean	107.3966	146.4483	87.5603	115.8534	85.9310
	Std. Deviation	7.69854	12.13070	7.38893	10.72523	2.81216
Most Extreme Differences	Absolute	.100	.065	.076	.073	.114
	Positive	.069	.050	.062	.042	.073
	Negative	-.100	-.065	-.076	-.073	-.114
Kolmogorov-Smirnov Z		1.074	.695	.816	.785	1.223
Asymp. Sig. (2-tailed)		.199	.719	.518	.569	.100

Linearity Test

A linearity test was conducted to ensure that the relationship between the independent and dependent variables in this study was linear, thereby making it feasible to analyze using parametric statistical methods. The test was conducted in SPSS using the Deviation from Linearity analysis, with the criterion that the relationship between variables is linear if the F_{count} value is < F_{table} and the significance value is < 0.05. Based on the results in Table 2, all variables show a linear relationship to machining competence, namely achievement motivation ($F_{count} = 1.039 < 4.22$), workshop facilities ($F_{count} = 1.172 < 4.11$), learning independence ($F_{count} = 1.868 < 4.24$), and learning machining practices ($F_{count} = 1.638 < 4.11$). These results indicate a significant linear relationship between all independent variables and machining competence. Thus, the linearity assumption has been met, so the research data are suitable for proceeding to the path analysis stage to identify direct and indirect influences between variables.

Table 2. Summary of Linearity Test Results

No	Linearity Variable	Linearity	Meaning	F_{count}	F_{table}	Conclusion
1	Achievement Motivation to Machining Competence	0,000	Mean	1,039	4,22	Linear
2	Workshop Facilities for Machining Competence	0,000	Mean	1,172	4,11	Linear
3	Learning Independence to Machining Competence	0,000	Mean	1,868	4,24	Linear
4	Machining Practical Learning for Students' Machining Competence	0,000	Mean	1,638	4,11	Linear

Multicollinearity Test

The test was conducted by examining the Pearson correlation coefficient (r), Tolerance, and Variance Inflation Factor (VIF) values in SPSS. Based on the results in Table 3, all pairs of variables have correlation values below 0.80, tolerance values greater than 0.10, and VIF values less than 10. This condition indicates no serious multicollinearity among the independent variables, such as achievement motivation, workshop facilities, learning independence, and machining practice learning, towards machining competency. Thus, it can be concluded that the regression model in this study meets the assumption of no multicollinearity, and it is suitable to proceed to the path analysis stage.

Table 3. Summary of Multicollinearity Test Results

Variable Pair		Correlation Value	Tolerance	VIF	Description
X_1	X_3	0,447	0,776	1,288	Multicollinearity Free
X_2	X_3	0,389	0,776	1,288	Multicollinearity Free
X_1	X_4	0,479	0,776	1,288	Multicollinearity Free
X_2	X_4	0,457	0,776	1,288	Multicollinearity Free
X_1	Y	0,525	0,776	1,288	Multicollinearity Free
X_2	Y	0,598	0,776	1,288	Multicollinearity Free
X_3	Y	0,379	0,731	1,368	Multicollinearity Free
X_4	Y	0,423	0,731	1,368	Multicollinearity Free

Homoscedasticity Test

The homoscedasticity test was conducted to ensure that the residual variance was constant across levels of the independent variable, so that the regression model met the classical assumptions and produced unbiased estimates. The test was conducted using Levene's Test in SPSS, with the decision-making criterion that if the significance value (Sig.) was greater than 0.05, the data were considered to have a homogeneous variance and to meet the homoscedasticity assumption. Based on the results shown in Table 4, all pairs of variables had significance values above 0.05, indicating no heteroscedasticity in this research model. Thus, it can be concluded that the data on achievement motivation, workshop facilities, learning independence, and learning machining practices regarding machining competency are homoscedastic. Hence, the regression model is suitable for further analysis.

Table 4. Summary of Homoscedasticity Test Results.

Variable Pair		Sig Value	α	Description
X_1	X_3	0,089	0,05	Homoscedasticity
X_2	X_3	0,064	0,05	Homoscedasticity
X_1	X_4	0,095	0,05	Homoscedasticity
X_2	X_4	0,061	0,05	Homoscedasticity
X_1	Y	0,100	0,05	Homoscedasticity
X_2	Y	0,144	0,05	Homoscedasticity
X_3	Y	0,076	0,05	Homoscedasticity
X_4	Y	0,130	0,05	Homoscedasticity

Analysis Test

The analysis of correlative and causal relationships in this study used path analysis to determine the direct and indirect effects of exogenous variables on endogenous variables. Before the analysis, a preliminary test ensured there was no multicollinearity among the independent variables. Next, Pearson correlation coefficients were calculated among the research variables, including achievement motivation, workshop facilities, learning independence, machining practice learning, and student machining competency. Hypothesis testing was performed using SPSS, with the results presented as a correlation matrix of variables in Table 5, which serves as the basis for determining the direction and strength of influence in the path model.

Table 5. Correlation Matrix between Variables

Correlation	X_1	X_2	X_3	X_4	Y
X_1	1,000				
X_2	0,473	1,000			
X_3	0,506	0,501	1,000		
X_4	0,450	0,456	0,492	1,000	
Y	0,525	0,598	0,586	0,520	1,000

Based on the correlation coefficient, further testing of the research hypothesis can be conducted. The hypothesis testing in this study will be explained in more detail below:

First Path Hypothesis Testing

The influence of achievement motivation (X_1) and workshop facilities (X_2) on learning independence (X_3) can be assessed by testing the first-path hypothesis. This first path hypothesis will address both hypotheses in this study.

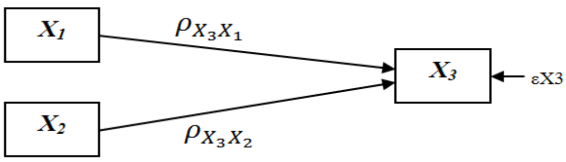

Figure 1. First Path Hypothesis Diagram

The influence of achievement motivation (X_1) and workshop facilities (X_2) on learning independence (Achievement motivation (X_1) influences learning independence (X_3) (β = 0.347; p = < 0.05), and workshop facilities (X_2) have a significant influence on learning independence (X_3) (β = 0.337; p = < 0.05). Based on the results of the analysis, the two hypotheses proposed reject Ho and accept Ha. So, achievement motivation (X_1) has a direct and significant influence on learning independence (X_3), and workshop facilities (X_2) have a direct and significant influence on learning independence (X_3). The partial determination coefficient shows that achievement motivation makes the most significant contribution to learning independence (12.5%), followed by workshop facilities (11.8%). The results of the multiple regression analysis show F_{count} (29.651) > F_{table} (3.09) and $p < 0.05$. The correlation value (R) = 0.587 is significant at the 0.05 level. The coefficient of determination (Adjusted R^2) = 0.333 indicates that achievement motivation and learning facilities variables account for 33.3% of the variance in learning independence.

Second Path Hypothesis Testing

The influence of achievement motivation (X_1) and workshop facilities (X_2) on learning machining practices (X_4) can be tested using the second-path hypothesis. This second path hypothesis will address both hypotheses in this study.

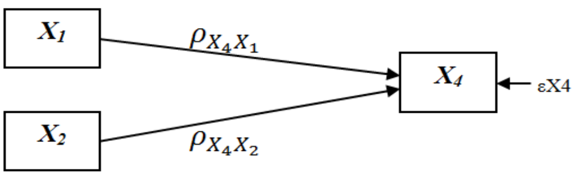

Figure 2. Second Path Hypothesis Diagram

Achievement motivation (X_1) has an influence on learning machining practice (X_4) (β = 0.301; p = <0.05), and workshop facilities (X_2) have a significant influence on learning independence (X_3) (β = 0.313; p = <0.05). Based on the analysis, the two proposed hypotheses reject Ho and accept Ha. So, achievement motivation (X_1) has a direct and significant influence on learning machining practice (X_4), and workshop facilities (X_2) have a direct and significant influence on learning machining practice (X_4). The partial determination coefficient indicates that workshop facilities have the largest contribution to learning machining practice (9.5%), followed by achievement motivation (8.8%). The results of the multiple regression analysis show that Fcount (21.780) > Ftable (3.09) and $p < 0.05$. The correlation value (R) = 0.527 is significant at the 0.05 significance level. The coefficient of determination (Adjusted R^2) = 0.265 indicates that achievement motivation and learning facilities variables account for 26.5% of the variance in learning machining practices.

Third Path Hypothesis Testing

The influence of achievement motivation (X_1), workshop facilities (X_2), learning independence (X_3), and machining practice learning (X_4) on students' machining competency (Y) can be tested using this third-path hypothesis. This third path hypothesis will answer the four hypotheses in this study.

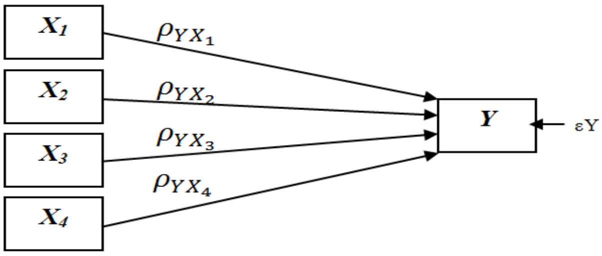

Figure 3. Third Path Hypothesis Diagram

Achievement motivation (X_1) influences machining competence (Y) (β = 0.170; p = < 0.05), workshop facilities (X_2) have a significant influence on machining competence (Y) (β = 0.307; p = < 0.05), learning independence (X_3) has a significant influence on machining competence (Y) (β = 0.259; p = < 0.05), and machining practice learning (X_4) has a significant influence on machining competence (Y) (β = 0.177; p = < 0.05). Based on the results of the analysis, the four hypotheses proposed reject Ho and accept Ha. Thus, achievement motivation (X_1) has a direct and significant effect on machining competence (Y), workshop facilities (X_2) have a direct and significant effect on machining competence (Y), learning independence (X_3) has a direct and significant effect on machining competence (Y), and learning machining practice (X_4) has a direct and significant effect on machining competence (Y). The partial determination coefficient indicates that workshop facilities make the largest contribution to machining competence (11.2%), followed by learning independence (7.8%), learning machining practice (4.2%), and achievement motivation (3.7%). The results of the multiple regression analysis show F_{count} (21.780) > F_{table} (3.09) and p < 0.05. The correlation value (R) = 0.719 is significant at the 0.05 significance level. The determination coefficient (Adjusted R^2) = 0.499 indicates that achievement motivation and learning facilities variables contribute 49.9% to machining practice learning.

Fourth Path Hypothesis Testing

The influence of achievement motivation (X_1) on machining competence (Y) can be indirectly tested through learning independence (X_3) using this fourth path hypothesis.

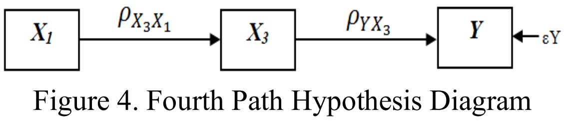

Figure 4. Fourth Path Hypothesis Diagram

To determine the indirect path coefficient of achievement motivation (X_1) towards machining competence (Y) through learning independence (X_3), it can be calculated manually using the formula: $\rho_{yx_1-x_3}$= ($\beta_{x_3x_1}$)(β_{yx_3}) = (0,347)(0,259)=0,09. The indirect effect of achievement motivation (X_1) on machining competence (Y) through learning independence (X_3) is 0.09. Because the path coefficient value $\beta_{x_3x_1}$ and β_{yx_3} are above 0.05 and have p = <0.05, the proposed hypothesis rejects Ho and accepts Ha. The indirect effect of achievement motivation (X_1) on machining competence (Y) via learning independence (X_3) is significant.

Fifth Path Hypothesis Testing

The influence of workshop facilities (X_2) on machining competency (Y) can be indirectly tested through independent learning (X_3) using the fifth path hypothesis.

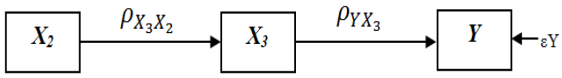

Figure 5. Fifth Path Hypothesis Diagram

To determine the indirect path coefficient of workshop facilities (X_2) on machining competency (Y) through independent learning (X_3), it can be calculated manually using the formula: $\rho_{yx_2-x_3}$= $(\beta_{x_3x_2})(\beta_{yx_3})$ = (0,337)(0,259)=0,087. The indirect effect of workshop facilities (X_2) on machining competence (Y) through learning independence (X_3) is 0.087. Because the path coefficient value $\beta_{x_3x_2}$ and β_{yx_3} are above 0.05 and have p = <0.05, the proposed hypothesis rejects Ho and accepts Ha. Thus, the indirect effect of workshop facilities (X_2) on machining competence (Y) through learning independence (X_3) is significant.

Sixth Path Hypothesis Testing

The influence of achievement motivation (X_1) on machining competence (Y) can be indirectly tested through machining practice learning (X_4) using the sixth path hypothesis.

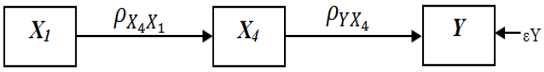

Figure 6. Sixth Path Hypothesis Diagram

To determine the indirect path coefficient of achievement motivation (X_1) towards machining competence (Y) through machining practice learning (X_4), it can be calculated manually using the formula: $\rho_{yx_1-x_4}$= $(\beta_{x_4x_1})(\beta_{yx_4})$ = (0,301)(0,177) = 0,053. The indirect effect of achievement motivation (X_1) on machining competence (Y) through machining practice learning (X_1) is 0.053. Because the path coefficient value $\beta_{x_4x_1}$ and β_{yx_4} are above 0.05 and have p = <0.05, the proposed hypothesis rejects Ho and accepts Ha. The indirect effect of achievement motivation (X_1) on machining competence (Y) via machining practice learning (X_4) is significant.

Seventh Path Hypothesis Testing

The influence of workshop facilities (X_2) on machining competency (Y) can be indirectly tested through learning machining practices (X_4) using the seventh path hypothesis.

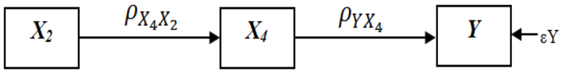

Figure 7. Seventh Path Hypothesis Diagram

The indirect path coefficient of workshop facilities (X_2) on machining competency (Y) through learning machining practices (X_4) can be calculated manually using the formula: $\rho_{yx_2-x_4}$= $(\beta_{x_4x_2})(\beta_{yx_4})$ = (0,313)(0,177)=0,055. The indirect effect of workshop facilities (X_2) on machining competency (Y) through machining practice learning (X_4) is 0.055. Because the path coefficient value $\beta_{x_4x_2}$ and β_{yx_4} are above 0.05 and have p = <0.05, the proposed hypothesis rejects Ho and accepts Ha. The indirect effect of workshop facilities (X_2) on machining competency (Y) via machining practice learning (X_4) is significant.

The next step is to test the significance of the path coefficient. The path coefficient's significance is tested by examining the effect of each independent variable on the dependent variable using the regression t-value. If the t-value is $F_{count} > F_{table}$ and $p < 0.05$, the Beta value used as the path coefficient is considered significant, and vice versa.

The path significance criterion is based on the principle that if the path coefficient is less than 0.05, the direct path coefficient is considered insignificant (Kwak, 2023). If the Beta value between the exogenous and endogenous variables is insignificant, the path coefficient is also negligible and is removed from the causal model. The results of the path coefficient significance test are then followed by stepwise regression, eliminating insignificant paths. The final results are shown in Figure 8.

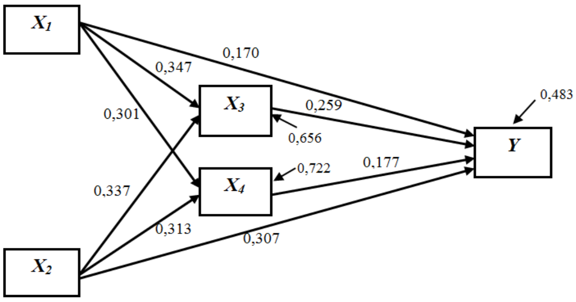

Figure 8. Final Model of Empirical Causal Relationships

Discussion

The path analysis results indicate that achievement motivation and workshop facilities significantly influence independent learning and practical machining learning. This finding confirms that internal factors, such as individual motivation, and external factors, such as supporting facilities, play a crucial role in shaping students' readiness for independent learning in an industry-based learning context. These results reinforce the theory of self-directed learning, which holds that a supportive learning environment and intrinsic motivation increase individuals' responsibility for their learning process.

The test results indicate that all four variables, achievement motivation, workshop facilities, independent learning, and practical machining learning significantly influence machining competency. Simultaneously, these four variables account for 49.9% of the increase in machining competency. This indicates that the improvement of adaptive machining skills is not solely determined by technical ability but also by psychological readiness and a supportive learning environment. This finding aligns with previous studies that highlight the importance of integrating personal factors and learning facilities into manufacturing vocational education (Y. Li & Leong, 2025).

This study also found a significant indirect effect of achievement motivation on machining competency through the variables of independent learning and practical machining learning, mediated by workshop facilities. This indirect effect demonstrates that practical activities do not solely drive student competency improvement but are also supported by independent learning enabled by adequate workshop infrastructure. These results address a gap in previous research, which has tended to focus solely on the direct relationship between learning facilities and learning outcomes, without considering mediating variables such as learning independence and contextualized practical experience.

The resulting empirical causal model indicates that workshop facilities are the most influential factor in machining competency, followed by learning independence, practical learning, and achievement motivation. These findings demonstrate that, in the context of machining learning, the quality of the learning environment and student independence in managing the learning process are key to developing machining competency(Harjanto & Surono, 2020). This strengthens the argument that the resulting path analysis model can serve as a reference in equipping students with academic competencies for employment in the modern manufacturing industry.

The results of the study indicate that machining competency is significantly influenced by both direct and indirect factors, with workshop facilities being the strongest direct predictor, while independent learning and practical machining learning act as mediating variables, strengthening the influence of achievement motivation and the learning environment on competency. These findings confirm that the development of machining competency is not linear but rather the result of an interaction among motivational factors, the availability of learning resources, and the quality of practical experience. Theoretically, these results reinforce the theories of independent learning and experiential learning, which emphasize that vocational competency develops optimally when students are actively involved in contextual practice supported by an adequate learning environment. Compared with previous research, which generally examines competency factors partially or uses simple correlational analysis, this study makes a novel contribution by presenting an integrated causal model based on path analysis that explains the mechanisms of machining competency development through direct and indirect pathways.

These findings imply that vocational high schools should prioritize improving and modernizing workshop facilities to align with industry standards, as these facilities not only directly impact competency but also enhance the effectiveness of practical learning. Furthermore, the design of machining practical learning should focus on authentic, industry-oriented activities that require active student involvement to strengthen skill transfer. Learning strategies also need to focus on developing independent learning through project-based approaches, problem-solving, and reflection, so that students can manage their learning process independently. However, this study has limitations in terms of geographic coverage and an ex post facto design, which limit the causal conclusions that can be drawn experimentally. Therefore, further research is recommended to involve a broader vocational high school context, use a longitudinal or experimental design, and include additional variables, such as digital literacy or industry involvement, to enrich the machining competency model.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results of the path analysis, it can be concluded that workshop facilities and learning independence are the most dominant variables in improving students' machining competence, both directly and indirectly through practical machining learning. This study also demonstrates a significant mediating path, in which the influence of achievement motivation and workshop facilities on machining competence is strengthened through learning independence and machining practice. The developed causal model shows strong explanatory power, with a determination coefficient (R^2) of 0.499, indicating that 49.9% of the variation in students' machining competence can be explained by the combination of achievement motivation, workshop facilities, learning independence, and machining practice learning variables. This finding has important implications for vocational education in machining, especially in designing learning aligned with the demands of the modern manufacturing industry by emphasizing the strengthening of practical facilities, contextual learning, and the development of student independence.

Suggestion

Based on the findings of this study, vocational education institutions are encouraged to strengthen achievement motivation, learning independence, and the quality of practical machining learning through learner-centered and practice-oriented instructional strategies, as these factors significantly contribute to machining competence. The improvement and modernization of workshop facilities should also be prioritized to better align learning environments with industrial standards, given their strong direct and indirect effects on competency development. For future research, it is recommended to extend the proposed causal model by including additional variables such as digital literacy, industry-based learning experiences, or instructor competence, as well as to apply longitudinal or experimental designs to further validate the causal relationships identified in this study and enhance the generalizability of the findings across different vocational contexts.

REFERENCE

Apri Nuryanto, Tri Adi Prasetya, & Chrisna Tri harjanto. (2024). *Soft skills pada pendidikan vokasional : panduan praktis untuk mengembangkan mahasiswa siap kerja*. UNY Press.

Djatmiko, R. D., Adhitama, R. K., & Prasetya, T. A. (2020). The analysis of machining job risk in vocational workshop. *Journal of Physics: Conference Series*, *1446*(1). https://doi.org/10.1088/1742-6596/1446/1/012026

Douma, J. C., & Shipley, B. (2021). A multigroup extension to piecewise path analysis. *Ecosphere*, *12*(5). https://doi.org/10.1002/ecs2.3502

Harjanto, C. T. (2026). Development of a Team-Based Experimental Learning (TeBEL) Model to Enhance Higher-Order Thinking Skills in Industrial Product Problem-Solving Desarrollo de un modelo de aprendizaje experimental basado en el trabajo en equipo (TeBEL) para mejorar las h. *Salud, Ciencia y Tecnología*, *6*. https://doi.org/10.56294/saludcyt20262534

Harjanto, C. T., & Surono, S. (2020). Faktor-faktor yang Mempengaruhi Kompetensi Pemesinan Siswa pada Pendidikan Kejuruanan. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *17*(2), 177–187. https://doi.org/http://dx.doi.org/10.23887/jptk-undiksha.v17i2.25198

Kwak, S. (2023). Are Only p-Values Less Than 0.05 Significant? A p-Value Greater Than 0.05 Is Also Significant! *Journal of Lipid and Atherosclerosis*, *12*(2), 89–95. https://doi.org/10.12997/jla.2023.12.2.89

Li, L. (2024). Reskilling and Upskilling the Future-ready Workforce for Industry 4.0 and Beyond. *Information Systems Frontiers*, *26*(5), 1697–1712. https://doi.org/10.1007/s10796-022-10308-y

Li, Y., & Leong, W. Y. (2025). Employment status analysis and response strategies of students majoring in mechanical manufacturing and automation in vocational colleges under the background of Industry 5.0. In *Industry 5.0: Design, standards, techniques and applications for manufacturing* (pp. 415–448). https://doi.org/10.1049/PBME026E_ch19

López, E. J., Leyva, P. A. L., López, A. A., Estrella, F. J. O., Vázquez, J. J. D., Velázquez, B. L., & Molina, V. M. M. (2024). Mechanics 4.0 and Mechanical Engineering Education. *Machines*, *12*(5). https://doi.org/10.3390/machines12050320

López, F., Contreras, M., Nussbaum, M., Paredes, R., Gelerstein, D., Alvares, D., &

Chiuminatto, P. (2023). Developing Critical Thinking in Technical and Vocational Education and Training. *Education Sciences*, *13*(6), 590. https://doi.org/10.3390/educsci13060590

Prasetya, T. A., Harjanto, C. T., & Frayudha, A. D. (2021). The Effect of Students' Learning Activities and Creativity on The Learning Outcomes in The Aerodynamics. *Jurnal Dinamika Vokasional Teknik Mesin*, *6*(1), 69–76.

Prasetya, T A, Munadi, S., Sukardi, T., & Setiyawan, A. (2025). Essential Soft Skills for Engineering in Industry 4.0: A Systematic Literature Review. *International Journal of Engineering Education*, *41*(5), 1376–1385.

Prasetya, Tri Adi, Munadi, S., Sukardi, T., & Setiyawan, A. (2025). Developing Industry-Relevant Soft Skills Through Peer-Engaged Project Application Model (PEPA): A Vocational Education Perspective. *Journal of Applied Engineering and Technological Science*, *7*(1), 296–305. https://doi.org/https://doi.org/10.37385/jaets.v7i1.7146

Sahli, A., Ebnou Abdem, S. A., Hanafi, M., & El Hadri, Z. (2025). Extending El-Hadri-Sahli-Hanafi procedure for path analysis with non standardized variables. *Quality and Quantity*, *59*(1), 175–190. https://doi.org/10.1007/s11135-024-01932-8

Spöttl, G., & Windelband, L. (2021). The 4th industrial revolution–its impact on vocational skills. *Journal of Education and Work*, *34*(1), 29–52. https://doi.org/10.1080/13639080.2020.1858230

Sutopo, S., Setiadi, B. R., Prasetya, T. A., Harjanto, C. T., Sasongko, B. T., & Saputri, V. H. L. (2024). Peer-Project-Based Learning in CNC Simulation Programming Courses. *TEM Journal*, *13*(4), 3079–3085. https://doi.org/10.18421/TEM134-42

Sutopo, Setiadi, B. R., Nashir, I. M., Lutviana, V. H., Saputri, Arifin, A., Prasetya, T. A., Harjanto, C. T., Tri, B., & 1, S. (2024). Enhancing students ' self-efficacy and creativity in computer numerical control machining through peer-assisted project-based learning. *Jurnal Pendidikan Vokasi*, *14*(2), 232–243.

Trinchera, L., Marie, N., & Marcoulides, G. A. (2018). A Distribution Free Interval Estimate for Coefficient Alpha. *Structural Equation Modeling*, *25*(6), 876–887. https://doi.org/10.1080/10705511.2018.1431544

Van Nguyen, T., Nguyen, H. T., Cao, C. D., & Vu, H. T. T. (2023). Activities of the practice teaching organization and vocational teaching facilities in collaboration between the vocational school and units employing. *Journal of Education and E-Learning Research*, *10*(2), 243–249. https://doi.org/10.20448/jeelr.v10i2.4588

Wibowo, H., Setiawan, H. S. D., Prasetya, T. A., & Kusnantoro, M. I. (2020). Effect of attitude and motivation on turning practice. *Journal of Physics: Conference Series*, *1700*(1). https://doi.org/10.1088/1742-6596/1700/1/012014