

Analysis of the Ability to Develop CNC Machine Part Programs for Vocational High School Students in Indonesia

Reynaldo Kurniawan and Bernardus S. Wijanarka

ABSTRACT

The aims of this study are (1) to analyze the effect of the ability to read technical drawings on the ability to make CNC program parts; (2) to analyze the effect of geometry skills on the ability to make CNC program parts; (3) to analyze the effect of cutting parameter knowledge on the ability to make CNC program parts; and (4) analyze the effect of the ability to read technical drawings, geometry skills, and knowledge of cutting parameters simultaneously on the ability to make CNC program parts. This research is quantitative correlational research. The subjects of the study were 360 students of SMK class XII in the field of Mechanical Engineering in the city of Palembang, Indonesia, using a random sampling technique by Isaac and Michael equations so that a total sample of 187 students was obtained. The data collection method uses the test method. The data analysis used is a correlational statistical analysis between the three dependent variables and one independent variable. The results of the study: (1) The ability to read technical drawings has a positive and significant effect on the ability to make CNC programs by 11.17%; (2) Geometry ability has no significant effect on the ability to make CNC programs; (3) Knowledge of cutting parameters has a positive and significant effect on the ability to make CNC programs by 75.36%; and, (4) the ability to read technical drawings, geometry skills, and knowledge of cutting parameters have a positive and significant effect on the ability to make CNC programs by 89.9%.

Keywords: CNC programs, cutting parameters machine tools, technical drawings, vocational training.

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I. INTRODUCTION

Vocational High School (VHS) focuses on learning in the vocational field and preparing graduates to have expertise and skills according to the field of work. Learning at Vocational Schools aims to shape students' work competence so that they are ready to enter the world of work (Fitriyanto & Pardjono, 2019; Nurjanah *et al.*, 2022). However, graduates of VHS are the highest contributor to the unemployment rate in Indonesia, according to the Central Bureau of Statistics Indonesia. The workforce with vocational high school graduates has an unemployment rate of 9.60%, different from expectations that everyone can get a job.

The success of the learning process is an essential factor that can be used as a benchmark for the quality of an educational institution. The Mechanical Engineering study program trains students with machine tool operating skills so they are ready to work as machine operators. The Machining Engineering skill competency teaches both theoretical and practical subjects. The core subjects that suit the needs of the industry are CNC and CAM Machining Engineering.

Learning materials in the curriculum are related to one

another. Students must master the basic vocational material and core vocational material in order to gain complete competency. For example, to be able to have the ability to make a CNC program, one must already have mastered technical drawing material. Learning success in each relative competency depends on students' understanding, persistence, interest, and motivation. Providing material and training by the teacher is an essential factor so that students are more motivated to learn (Kieu & Liu, 2018; Martono & Wagiran, 2016; Nahrowi *et al.*, 2020; Suwono *et al.*, 2022).

CNC machine tools are an essential part of the industry, and CNC machine technology is growing according to advances in computer technology. CNC machine tools are widely used to produce components in large quantities and quickly. Working with computer control as a system can regulate the work process. This system is used to obtain product results that comply with specifications and have high precision (Agrisa, 2020; K & Srinivasan, 2023; Ntemi *et al.*, 2022; Waluyo, 2020).

The process of making products using CNC machine tools includes several stages. First, analyze drawings to determine workpiece clamping, zero-point, machining process, and

selection of cutting tools. Second, the preparation of the part program considers the cutting conditions: cutting speed, depth of cut, and feed motion. Third, create a CNC part program, including writing programs in machine control or simulators/editing sources under program preparations. Fourth, run test: test the program's running using the test run/simulator facility, and run the program. Fifth is the machining process: setting the cutting tool, the zero point, and the test workpiece—finally, product manufacturing and inspection, which includes: manufacturing products and inspecting dimensions and results. Thus, the ability to read technical drawings, geometry, and cutting parameters is needed in making products using CNC machine tools.

The ability to read technical drawings is a student's knowledge competency in understanding drawing standards, working codes, drawing dimensions, working drawings, and size tolerances. Technical drawings function as a medium for conveying information and a medium for expressing ideas or ideas. Reading technical drawings is necessary for interpreting and understanding the blueprint of the product manufacturing process (Kadam *et al.*, 2021; Moreno-García *et al.*, 2019; Scheibel *et al.*, 2021; Sharma *et al.*, 2020).

Vocational essential competencies that students must master include mathematical abilities, which include arithmetic, geometry, and trigonometry. Geometry ability is an ability possessed by students in the field of spatial measurement. The geometry capability contains material regarding points, lines, angles, planes, volumes, and space. Geometry ability is also a process of obtaining information which is then resolved, and conclusions drawn (Dickson, 2017; Galitskaya & Drigas, 2020; Quezada, 2020; Saidou, 2019; Suprpto *et al.*, 2021).

Knowledge of cutting parameters is needed to determine the parameters of spindle rotation, feed motion, and depth of cut for machining processes (Albayrak *et al.*, 2022). The geometric quality of the workpiece is a goal in the machining process. Selection and calculation of cutting parameters are necessary for planning machining product work. Selection of the appropriate combination of cutting parameters will produce geometric quality and surface roughness as expected (Bodzas & Krakko, 2017; Fahrizal *et al.*, 2022; Katta, 2018; Kounta *et al.*, 2022; Nagandran, 2017).

The CNC program is several logical command sequences compiled for a CNC machine tool. The CNC program is prepared in a code and programming format that can be read and understood by the machine control unit. Compilation of programs for CNC machine tools includes determining and calculating codes, settings, parameters, zero shift, cutting parameters, and determining coordinates according to the workpiece to be made. Programming CNC machine tools is a programming art of automatic movement sequences in product manufacturing (Fatriyana, 2020; Wibisono *et al.*, 2020).

Based on the studies above, it is necessary to research the factors influencing students' abilities in preparing for the CNC program. This study aims to analyze the effect of the ability to read technical drawings, geometry skills, and knowledge of cutting parameters on the ability to make CNC programs for SMK students. The results of this study are expected to contribute to increasing the learning of CNC machining technology in vocational schools.

II. METHODS

This study uses a correlational quantitative research method. The subjects of this study were students of class XII Mechanical Engineering Vocational Schools in Palembang, Indonesia, namely: SMK 2 Palembang, SMK 4 Palembang, SMK 7 Palembang, SMK SUMSEL, SMK PGRI 2 Palembang, SMK YP Gajah Mada Palembang, dan SMK Pembangunan YPT Palembang. The technique used in determining the sample is Random Sampling using the Isaac and Michael equations with an error percentage of five so that for a population of 360 students, the total sample is 187 students.

The data collection method uses an objective test method (multiple choice). Objective tests are used to collect data regarding the ability to make CNC programs, read technical drawings, have geometry skills, and know cutting parameters.

The analysis requirements test was carried out to determine whether the data met the requirements to be analyzed before testing the hypothesis using multiple linear regression analysis. Analysis requirements include a normality test, linearity test, multicollinearity test, and heteroscedasticity test.

III. RESULTS AND DISCUSSIONS

The data obtained was then tested for analysis requirements and hypothesis testing using the SPSS version 25 application.

A. Test Requirements Analysis

Test requirements analysis in this study includes the normality, linearity, multicollinearity, and heteroscedasticity tests.

1) Normality Test

The normality test results were obtained using the Kolmogorov-Smirnov with a significance level of 0.05. The test results show a significance value of 0.058 ($0.058 > 0.05$), so the data distribution for each variable is normally distributed.

2) Linearity Test

The results of the linearity test were carried out using the Analysis of Variance (ANOVA) with a significance level of 0.05. Based on the test results, the value of Deviation from Linearity is larger than 0.05, the ability to read technical drawings is 0.064, the geometry ability (X_2) is 0.074, the knowledge of cutting parameters (X_3) is 0.061, so there is a linear relationship between the independent variables and the dependent variable.

3) Multicollinearity Test

Based on the results of the multicollinearity test, it can be obtained that the tolerance value is larger than 0.10 and the VIF value is smaller than 10, so there is no multicollinearity between the independent and dependent variables.

4) Heteroscedasticity test

The results of the heteroscedasticity test were carried out using Spearman's rho with a significance level of 0.05. Based on the test results, the significance values obtained were 0.567 for the ability to read technical drawings (X_1), 0.992 for

the geometry ability (X_2), and 0.432 for the knowledge of cutting parameters (X_3). Given that these values were all larger than 0.05, there was no heteroscedasticity in any of the independent variables.

B. Hypothesis Test

Hypothesis testing in this study was conducted to analyze the effect of the ability to read technical drawings, geometry skills, and knowledge of cutting parameters on the ability to make CNC programs either partially or simultaneously. The analysis technique used in testing this hypothesis is multiple linear regression analysis.

1) Effect of Ability to Read Drawings on Ability to Make CNC Programs

The results of the X_1 partial significance test analysis can be seen in Table I.

TABLE I: RESULTS OF PARTIAL SIGNIFICANCE TEST

Correlational	t	Significance	R^2
$X_1 \rightarrow Y$	3.996	0.000	0.1117
$X_2 \rightarrow Y$	0.743	0.458	
$X_3 \rightarrow Y$	15.806	0.000	

Based on Table I shows the significant value of the ability to read technical drawings (X_1) of 0.000 ($0.000 < 0.05$), so partially, there is a positive and significant influence of the ability to read technical drawings (X_1) on the ability to make CNC programs (Y). The magnitude of the influence can be seen from the value of the coefficient of determination R^2 of 0.1117 (11.17%). Partially, the ability to read technical drawings contributes 11.17% to the ability to make CNC programs.

2) The Effect of Geometry Ability on the Ability to Make a CNC Program

The results of the X_2 partial significance test can be seen in Table I. Based on the test results, it shows a significant value of geometry ability (X_2) of 0.458 ($0.458 > 0.05$), so there is no significant partial effect of geometry ability (X_2) on the ability to make CNC programs (Y). The magnitude of the influence can be seen from the coefficient of determination R^2 of 0.334 (3.34%). Partially, geometry skills only contribute 3.34% to the ability to make CNC programs.

3) Effect of Knowledge of Cutting Parameters on the Ability to Make CNC Programs

The results of the partial significance test X_3 can be seen in Table I. The test results show a significant value of cutting parameter knowledge (X_3) of 0.000 ($0.000 < 0.05$), so there is a partial positive and significant influence of cutting parameter knowledge (X_3) on the ability to make CNC programs (Y). The magnitude of the influence can be seen from the value of the coefficient of determination R^2 of 0.7536 (75.36%). Partially knowledge of cutting parameters contributes 75.36% to the ability to make CNC programs. Knowledge of cutting parameters is the most dominant variable contributing to the ability to make CNC programs.

4) The Influence of Ability to Read Engineering Drawings, Geometry Ability, and Knowledge of Cutting Parameters on Ability to Create CNC Programs

The results of the simultaneous significance test obtained the simultaneous significance value of the effect of X_1 , X_2 , and X_3 on Y is 0.000 ($0.000 < 0.05$). Thus, there is a positive

and significant influence between X_1 , X_2 , and X_3 on Y . The magnitude of the influence can be seen from the value of the coefficient of determination R^2 of 0.899 (88.9%). Simultaneously the ability to read technical drawings, geometry skills, and knowledge of cutting parameters has an effect of 89.9% on the ability to make CNC programs.

C. Multiple linear regression equation

The multiple linear regression equation aims to determine the effect of the ability to read technical drawings (X_1), geometry skills (X_2), and knowledge of cutting parameters (X_3) on the ability to make CNC programs (Y). The results of the multiple linear regression equation can be seen in Table II.

TABLE II: RESULTS OF MULTIPLE LINEAR REGRESSION CALCULATION

Model	Unstandardized Coefficients	
	B	Std. Error
Constant	0.644	0.492
$X_1 \rightarrow Y$	0.154	0.039
$X_2 \rightarrow Y$	0.040	0.054
$X_3 \rightarrow Y$	0.806	0.051

Based on Table II, the constant value is 0.644, the variable coefficient value for the ability to read technical drawings is 0.154, the coefficient value for the geometry ability variable is 0.040, and the coefficient value for the variable knowledge of cutting parameters is 0.806. The constant values and coefficient values are then substituted in the multiple linear regression equation so that the following equation will be obtained:

$$Y = 0.644 + 0.154 X_1 + 0.040 X_2 + 0.806 X_3$$

The information obtained from the multiple linear regression equation above shows: 1) For every one unit increase in the ability to read technical drawings, there is an increase in the ability to make CNC programs 0.154; 2) For every one unit increase in the geometry ability variable, there is an increase in the ability variable to make a CNC program by 0.040; 3) For every increase of one unit of knowledge variable in cutting parameters, there is an increase in the ability to make CNC programs by 0.806. Then the ability to read technical drawings, geometry skills, and knowledge of cutting parameters influence the ability to make CNC programs.

D. Discussions

1) The Effect of the Ability to Read Engineering Drawings on the Ability to Make CNC Programs

There is a positive and significant influence of the ability to read technical drawings on the ability to make CNC programs. Based on the results of this analysis, the higher the ability to read technical drawings of students, the higher the ability to make CNC programs. Conversely, the lower the student's ability to read technical drawings, the lower the ability to make CNC programs for Mechanical Engineering Vocational Schools students.

The amount of influence given by the ability to read technical drawings on the ability to make CNC programs based on influential contributions has an effect of 11.17%. The ability to read good technical drawings will help improve students' ability to make CNC programs (Xie *et al.*, 2022).

Based on the results of this study, it is necessary to learn to read technical drawings under the needs of the world of work. Reading technical drawings is an essential competency in machining vocational techniques that is indispensable in developing student competence as a CNC machine tool operator.

2) *The Effect of Geometry Ability on the Ability to Make CNC Programs*

This study's results indicate no significant effect of geometry ability on the ability to make CNC programs. The competence and application of geometry are essential for vocational school students in machining, but as a machine operator, this ability is optional. Some researchers say geometry skills are needed to make products (Otto & Mandolin, 2018; Sudo & Aoyama, 2020).

Although the effect of geometric correlation skills is minimal on the ability to make CNC programs, teaching geometry skills through learning mathematics is still necessary. Adaptive learning that contains mathematics and language skills can support the formation of comprehensive product manufacturing competencies, including planning, product manufacturing, and product quality control.

3) *Effect of Knowledge of Cutting Parameters on the Ability to Make CNC Programs*

Knowledge of cutting parameters possessed by students has a significant influence on the level of ability to make CNC programs. Knowledge of these cutting parameters is the most dominant factor influencing the ability to develop CNC programs, with a practical contribution of 75.36%. Other results of this study indicate that knowledge of cutting parameters affects the ability to make CNC programs (Anggoro *et al.*, 2022). Cutting parameters will help improve students' ability to make CNC programs.

Learning about the parameters of machine tool cutting has been taught in vocational schools according to the demands of the curriculum. This learning material needs to be deepened again regarding calculating cutting parameters for manual and CNC machine tools. Cutting parameter teaching material must be explicitly given to students so they are better prepared when facing the production process with CNC machine tools.

4) *The Effect of the Ability to Read Engineering Drawings, Geometry Ability, and Knowledge of Cutting Parameters on the Ability to Make CNC Programs*

Simultaneously there is a positive and significant influence between the ability to read technical drawings, geometry skills, and knowledge of cutting parameters on the ability to make CNC programs. The influence of the ability to read technical drawings, geometry skills, and knowledge of cutting parameters on the ability to make CNC programs is 89.9%. The higher the ability to read technical drawings, geometry skills, and knowledge of cutting parameters, the higher the ability to make CNC programs.

It is necessary to increase the ability to make CNC programs for SMK students considering the importance of this ability in entering the world of work. The ability to make CNC programs can be improved by increasing the ability to: (1) read technical drawings, (2) knowledge of geometry, and (3) knowledge of CNC cutting parameters. Through these improvement efforts, it is hoped that there will be an increase

in students' work readiness.

IV. CONCLUSION

Based on the results of this study, it can be concluded that 1) The ability to read technical drawings has a positive and significant effect on the ability to make CNC programs by 11.17%; 2) Geometry ability has no significant effect on the ability to make CNC programs; 3) Knowledge of cutting parameters has a positive and significant effect on the ability to make CNC programs by 75.36%; 4) The ability to read technical drawings, geometry skills, and knowledge of cutting parameters has a positive and significant effect on the ability to make CNC programs by 89.9%. Improving the ability to make CNC programs for Mechanical Engineering Vocational High School students needs to be followed up, considering the importance of the ability to make CNC programs for Mechanical Engineering Vocational High School students in entering the world of work.

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CONFLICT OF INTEREST

The author declares that he has no conflict of interest with the parties involved in this research.

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