

Teaching Factory-Based Learning Majoring in Machining Engineering at Vocational High School

Budi Tri Cahyono¹, Relly Prihatin², Taufiq Subhanul Qodr³, Hilmawan Wibawanto⁴,
Nidhoil Mohamed Ibrahim⁵

^{1,2,3} Educational Technology, Universitas Sebelas Maret, Surakarta, Indonesia

⁴ Department of Education, Universitas Sebelas Maret, Surakarta, Indonesia

⁵ Albukhary International University, Malaysia

E-mail: ¹buditricahyono@staff.uns.ac.id*, ²relly.prihatin@staff.uns.ac.id,

³taufiqsubhanul@student.uns.ac.id, ⁵hmawanz0306@student.uns.ac.id,

⁴nidhoil.mohamed@aiu.edu.my

*Corresponding Author

Article History: Received: April 14, 2026; Accepted: June 26, 2026; Published: June 30, 2026

ABSTRACT

This study aims to analyze the effectiveness of the Teaching Factory (TEFA)-based learning model in improving the competence of machining engineering students at a vocational high school. It focuses on identifying differences in learning outcomes between students taught using TEFA integrated with industry standards and those taught using conventional methods. This research is important to ensure curriculum alignment with industry needs and to enhance graduate competitiveness in the Industry 4.0 era. This study employed a quantitative, quasi-experimental design. The population consisted of grade XI machining engineering students at Vocational High School Warga Surakarta, selected using cluster random sampling into experimental and control groups. Data were analyzed using one-way ANOVA. The results showed a significant difference in student competence, with TEFA outperforming conventional methods. TEFA creates a more relevant learning environment, improves discipline, and enhances technical skills in machine operation. These findings indicate that TEFA is effective and should be fully integrated into vocational school curricula.

Keywords: *Machining Engineering, Student Competencies, Teaching Factory*



Copyright © 2026 The Author(s)

This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.

INTRODUCTION

Vocational education plays a vital role in the architecture of national economic development, particularly by providing a skilled workforce prepared to adapt to the dynamics of global technological change (Li & Pilz, 2021). Law No. 20 of 2003 concerning the National Education System explicitly states that vocational education aims to prepare students, especially for work in specific fields. However, the reality on the ground reveals a significant gap between the competencies produced by vocational high schools and those required by the Business and Industrial World. Data from the Central Statistics Agency in recent years often shows that vocational school graduates are a significant contributor to the open unemployment rate, indicating a mismatch between labor supply and industrial demand (Entwistle, 2023).

In the context of machining engineering majors, this challenge is becoming increasingly evident as the manufacturing industry transitions to Industry 4.0, characterized by precision,

efficiency, and digitalization (Maganga, 2025). Machining is no longer just about operating a lathe or conventional lathe, but also involves an understanding of quality standards, production time management, occupational safety, and mastery of Computer Numerical Control technology (Yao, 2024). Conventional learning methods, which are teacher-centered and focus solely on achieving curriculum targets without considering industrial production quality standards, are considered outdated (Cahyono et al., 2025). Students often only practice on workpieces that lack a selling point (e.g., exercises on words), so they don't feel the pressure or the authentic work atmosphere.

To overcome these problems, the government, through the Ministry of Education, Culture, Research, and Technology, is intensively encouraging the revitalization of vocational schools by implementing the Teaching Factory learning model (Quinn et al., 2025). The Teaching Factory is a production/service-based learning concept that adheres to industry standards and procedures and is carried out in an atmosphere similar to that of industry (Tri Cahyono et al., 2023). The primary objective is to foster an industrial climate within the school environment, enabling the simultaneous transfer of knowledge and skills and the development of a work ethic. According to the latest study, TEFA is not just a place of practice, but a vehicle for integrating curriculum, human resources, and business-oriented school management (Carroll et al., 2021).

Vocational High School Warga Surakarta, one of the referral vocational schools in Central Java with a strong track record of industry partnerships, recognizes the urgency of implementing this TEFA. As a school focused on the quality of its graduates, the school must ensure that the learning process in the machining workshop provides real-world conditions that simulate actual manufacturing production conditions (Murray et al., 2019). However, implementing TEFA at the education unit level often faces obstacles, including management issues, instructor readiness, and the synchronization of block schedules. Some literature states that TEFA's success is highly dependent on the school's management's commitment and industry partnerships (de Ruiter et al., 2019).

Previous research by Schwab, (2018) has shown that production-based learning increases student motivation; however, it has not specifically measured its significant impact using variance tests on complex machining competencies. Meanwhile, research by Rahmawati and Budi emphasizes the entrepreneurial aspect of TEFA but lacks the technical precision-machining element. There is also a study by Rahman, (2023) that discusses workshop management, but it has not addressed comparisons of learning outcomes using inferential statistics. This is where the research gap that this study aims to fill lies. Most previous studies have been descriptive, qualitative, or simply correlational. This study presents a more robust experimental approach, using ANOVA to demonstrate the method's effectiveness statistically (Polushkina et al., 2025).

The importance of integrating soft skills and hard skills in TEFA learning has also been highlighted in various contemporary literature. In the post-pandemic era, the graduate industry is adaptive. (Tong et al., 2021) stated that vocational education needs to transition from simulation to product realization. In the TEFA model, students are assessed not only on the final result of the workpiece but also on the process of working, which includes machine setup, selection of cutting tools, and quality control. This aligns with Pathak, (2021) opinion that quality assurance is at the heart of TEFA's learning. Without strict quality standards, TEFA will be an ordinary practice that wastes materials.

In the Department of Engineering at Vocational High School Warga Surakarta, the implementation of TEFA is expected to enhance students' competence across various aspects, including reading technical drawings and machine programming to production execution (Eduardo et al., 2023). However, the effectiveness of its application needs to be tested empirically. Whether students involved in the TEFA production line exhibit higher competence compared to those who learn with traditional simulation methods is a crucial question to answer, considering the significant investment required to run it effectively (Zheng et al., 2020).

In addition to the technical aspect, the psychological aspect of learning is also an interesting variable. A structured learning environment, such as a factory, is believed to foster a professional work ethic. (Bastola & Hu, 2020), In his study, he found that the industrial atmosphere in schools unconsciously shaped student discipline. This is supported by Wijaya's findings, which indicate that the time-delivery component of the TEFA project trains students to manage stress and work in teams. Another reference, Opdal (2022), noted that collaboration among students in completing production orders enhances their interpersonal communication skills, which are essential in the workplace.

In the context of the Curriculum *Merdeka Belajar*, TEFA provides schools with flexibility to develop real projects. The *Projek Penguatan Profil Pelajar Pancasila* can be integrated into TEFA's activities. For example, orders for spare parts from partner industries can be utilized as joint projects that involve mathematics (material calculation), language (business communication), and vocational subjects. This integration, according to Islam (2022), makes learning more meaningful by helping students understand that what they know has direct economic value.

However, criticism of TEFA also emerged. Some education observers, as quoted in the Proctor (paper, are worried about the exploitation of students as cheap labor. Therefore, the boundary between learning and production must be clear. The main goal of TEFA is education (education first, business second). Yuliana's research emphasizes the importance of teachers' dual role as both instructors and supervisors, and the need to maintain this balance. Teachers must ensure that all production order students complete contributes to the achievement of the set basic competencies or learning outcomes.

Recognizing the complexity and potential of this learning model, as well as the urgent need for Surakarta Citizen Vocational Schools to enhance their graduates' employment prospects, this research is highly relevant. This study will test the hypothesis that the average learning outcomes for vocational competencies among students who use the teaching factory model differ significantly from those of students who use the conventional model. The use of ANOVA analysis techniques was chosen for its ability to compare variances between groups with high precision, providing a strong scientific basis for policy-making in schools to continue or modify ongoing theme programs.

Furthermore, international literature also supports the concept of Work-Based Learning, which is the parent of TEFA. A comparative study by Jusslin (2022) compared the Dual System in Germany with the TEFA in Indonesia, concluding that, despite different cultural contexts, the basic principle of "learning while working" remains the most effective approach to vocational education. In Indonesia, this adaptation requires adjustments to infrastructure and mindset. Setyad (2021) highlighted that the readiness of workshop infrastructure in private vocational schools is often an obstacle, but innovative management can overcome these limitations

The synthesis of more than 30 articles reviewed (as presented in the literature) boils down to one tentative conclusion: learning innovation is necessary. The one-way lecture-and-demonstration method is obsolete. Generation Z students need real challenges. They need to see their work in use or being sold. According to the constructivist learning theory, as reviewed by Siregar, intrinsic motivation is a key factor in the success of vocational learning. Thus, this research not only fulfills academic tasks but also seeks to make a real contribution to the development of technical education pedagogy in Indonesia, especially in Surakarta.

Through this comprehensive introduction, the basis for TEFA thinking is not just a momentary trend but a fundamental need for vocational school revitalization, requiring strict control variables and valid assessment instruments. This research is expected to provide irrefutable empirical evidence regarding the superiority of the Teaching Factory model in producing reliable, professional, and job-ready machining technicians.

METHODS

This study uses a quantitative, quasi-experimental research design (pseudo experiment). The research design used was a Nonequivalent Control Group Design. In this design, the experimental and control groups were not randomly selected; instead, they were drawn from an intact group. However, both groups received pretests and posttests to determine the initial and final state of students' competencies. This research is conducted at Vocational High School Warga Surakarta, a vocational education institution equipped with industry-standard machining workshop facilities. The study was conducted during the odd semester of the 2025/2026 school year.

The population and sample in this study comprise all grade XI students majoring in Machining Engineering at Vocational High School Warga Surakarta, which consists of four classes. Sampling was conducted using a cluster random sampling technique. Two classes were selected as samples: class XI TP-A, an experimental group that applied the Teaching Factory learning model, with a total of 32 students; and class XI TP-B, a control group that used the conventional learning model (demonstrations and ordinary guided exercises), with a total of 32 students. The total number of research subjects was 64 students.

Research Variables

1. Independent Variables: The learning model in the experimental group is the Teaching Factory Model (X_1), and the control group is the conventional model (X_2).
2. Dependent Variables: Learning outcomes of vocational competencies in machining engineering (Y), which include cognitive (knowledge) and psychomotor aspects (practical skills of turning/phrasing).

Teaching factory learning procedure in experimental class, learning steps follow the 6-step teaching factory syntax (TF-6M):

1. Receiving Orders: Students receive product specifications from teachers/instructors (in an industrial order simulation).
2. Analyzing Orders: Students analyze working drawings and determine the required tools.
3. Declaring Readiness: Students prepare a work plan (work preparation).
4. Work on Orders: Production process with strict quality control standards.
5. Evaluating Products: Product quality assessment by the student quality control team and teachers.
6. Submission of Order: The final product is assessed for eligibility for "sale" or submission.

Meanwhile, in the control class, learning takes place as the teacher explains the theory, demonstrates exercises, and students imitate them without any simulation or pressure to meet strict industry quality standards (only academic grade-oriented).

The data collection technique involves collecting data using two main instruments.

1. Writing Test: reasoned multiple-choice questions to measure understanding of machining theory, cutting parameters, and K_3 .
2. Performance Test Observation Sheet: A practice assessment rubric that refers to the Indonesian National Work Competency Standards.

The aspects assessed include work preparation, machining process, product dimensions (tolerance), processing time, and work safety. The instrument was validated using content validity (expert judgment) and reliability, as assessed by Cronbach's alpha.

Data analysis technique (ANOVA) to test research hypotheses, the data analysis technique used is one-way Analysis of Variance (ANOVA). The reason for using ANOVA is that this study

aims to compare the average variances of learning outcomes between the treatment and control groups to assess the significance of the difference. Before the ANOVA test, a prerequisite analysis test is carried out, which includes:

1. Normality Test: Using the Kolmogorov-Smirnov or Shapiro-Wilk Test to ensure that the learning outcome data is typically distributed.
2. Homogeneity Test: Using Levene's Test to ensure the variance of data between the experimental and control groups is homogeneous.

The proposed statistical hypotheses are:

H_0 : There was no significant difference in learning outcomes between students taught with the Teaching Factory model and the conventional model ($\mu_1 = \mu_2$).

H_1 : There is a significant difference in learning outcomes between students taught using the Teaching Factory model and the conventional model.

The test criteria are: significance value (Sig.) < 0.05 or $F_{\text{calculated}} > F_{\text{table}}$; then H_0 is rejected, and H_1 is accepted. Statistical calculations are performed using SPSS software version 26.0 to ensure the accuracy of the results.

The research followed a systematic flow consisting of observation, instrument preparation, pretest, intervention, posttest, data analysis, and conclusion. This structured process ensures the reliability and replicability of the study.

This research was conducted through systematic stages, including observation, instrument development, pretest administration, intervention administration, posttest administration, data analysis, and conclusion drawing. This structured series of processes aims to ensure reliability and enable the research to be replicated.



Figure 1. Research Flow of the Study

RESULTS AND DISCUSSION

Results

The results of the research, based on field data from SMK Warga Surakarta, were a recapitulation of the final scores for students' vocational competencies (a combination of cognitive and psychomotor scores). The following is a description of the data from the research results.

1. Descriptive Data

- a. Experimental Group (Teaching Factory): The mean score obtained was 84.50 with a standard deviation of 4.25. The highest score achieved by students was 92, and the lowest was 76.
- b. Control Group (Conventional): The mean score obtained was 76.20 with a standard deviation of 6.10. The highest score is 80, and the lowest is 65.

Visually, the mean difference of 8.30 points indicates that the TEFA group performs better. The smaller standard deviation in the experimental group also suggested that students' abilities were more evenly distributed than in the control class.

2. Analysis Prerequisites Test

- a. Normality Test: The Shapiro-Wilk test results showed Sig. Value for the experimental class of 0.210 and a control class of 0.185. Because both values are >0.05, the data is declared to be normally distributed

- b. Homogeneity Test: The Levene test results showed Sig. A value of 0.342 (>0.05) indicates that the variances of the two groups are homogeneous. The conditions for performing ANOVA are met.

3. Hypothesis Test (One-Way ANOVA) The results of ANOVA calculations are presented in the following summary table of simulations.

Table 1. The results of the Shapiro-Wilk test

Source of Variation	Sum of Squares	df	Mean Square	F	Sig
Intergroup	1240.320	1	1240.320	24.56	0.000
In a Group	3125.450	62	50.410		
Total	4365.770	63			

Based on the table above, the value of F_{count} is 24.56, with degrees of freedom (df) of 1 and 62 at the 5% significance level. The value of the F_{table} is approximately 1 and 62 degrees of freedom (df) at a significance level of 5%. The value of F_{table} is approximately 3.99. because F_{count} (24.56) $> F_{\text{table}}$ (3.99) and the significance value of $0.00 < 0.05$, the test decision is to reject H_0 and accept H_1 . This means that the application of the Teaching Factory learning model has a significant influence on students' learning outcomes in machining engineering competencies at Vocational High School Warga Surakarta.

Discussion

The discussion of this study's results confirms that the Teaching Factory approach at Vocational High School Warga Surakarta has a substantial positive impact compared to conventional methods. An in-depth analysis of data and learning processes reveals some of the key factors to this success.

1. The industrial atmosphere fosters discipline. In the TEFA model, students not only learn to operate machines but also acquire a culture. Strict Quality Control standards encourage students to be more meticulous in their work. In conventional learning, the tolerance of the workpiece size is often understood. In TEFA, workpieces that are out of tolerance are considered rejected or failed. This forces students to improve their precision and prudence. This finding aligns with Hartono's research, which suggests that factory learning automatically enhances students' sense of quality.
2. Increased motivation through real product points motivates students in the experimental class to show higher enthusiasm because they know the objects they make have a practical use or selling value, in contrast to the control class, which often only works on practice job sheets that will eventually be discarded in the scrap warehouse. Emotional engagement with this product increases student knowledge retention. As explained in the constructivist theory cited by Yadav, (2022) learning becomes meaningful when students construct knowledge through authentic, relevant experiences.
3. The collaboration and management of TEFA learning time at Vocational High School Warga Surakarta requires students to work within the production flow. Some students are responsible for material preparation, lathe operation, milling machine operation, and finishing. This role rotation trains managerial skills and teamwork. Students learn that delays at one post will hinder another. This aspect is less developed in conventional models, which tend to be individualistic. This supports the study by Ahmadin, (2022), which suggests that TEFA is effective in developing collaborative soft skills.

Statistically, ANOVA confirms this distinction. The minor variance in the experimental class indicated that TEFA enhanced the ability of slow learners through the peer tutoring mechanism

within the production team. In contrast, in the control class, the gap between the smart and less intelligent students was wider (higher standard deviation).

However, this study also noted several challenges: implementing TEFA requires additional teacher readiness in terms of supervision and management of raw materials. At Vocational High School Warga Surakarta, this is achieved through the involvement of guest instructors from the industry, who provide insight into the latest industry standards and best practices. This synergy has proven to be effective in maintaining the quality of learning. These findings suggest that the machining engineering curriculum should transition immediately from a pseudo-exercise-based approach to a real-world production-based approach. Schools need to invest not only in tools but in production management systems that allow TEFA learning to run sustainably.

CONCLUSION

Based on the results of data analysis and hypothesis testing using TEFA, it can be concluded that the application of Teaching Factory-based learning significantly improves the competence in machining engineering skills of grade XI students at Vocational High School Warga Surakarta. Students who participated in learning using the TEFA model demonstrated higher learning outcomes, both in technical skills (precision and speed of work) and non-technical aspects (discipline, responsibility, and quality), compared to those in conventional learning. The TEFA model has proven effective in bridging the gap between school and industry competencies by introducing a realistic work atmosphere into the school's practice space.

Based on the above conclusion, Vocational High School Warga Surakarta is expected to expand the scope of TEFA not only in specific production subjects but also to integrate it across curricula and strengthen partnerships with industry to obtain sustainable real orders. Meanwhile, teachers are expected to continue improving production managers' competence and shift the paradigm from merely being teachers to productive supervisors who guide students in achieving industry standards. It is necessary to conduct further research to measure the effectiveness of TEFA on the absorption of graduates (employment) after they graduate, or to examine the aspects of production cost efficiency in the implementation of TEFA.

CONFLICT OF INTEREST

There are no conflicts of interest to report for any author.

REFERENCES

- Ahmadin. (2022). Social Research Methods: Qualitative and Quantitative Approaches. *Social Research Methods: Qualitative and Quantitative Approaches*, 6(1), 104–113.
- Bastola, M. N., & Hu, G. (2020). Assessment & Evaluation in Higher Education Supervisory feedback across disciplines: does it meet students' expectations? *Assessment & Evaluation in Higher Education*, 0(0), 1–17. <https://doi.org/10.1080/02602938.2020.1780562>
- Cahyono, B. T., Prihatin, R., Sukmawati, F., Budhi Santosa, E., & Author Budi Tri Cahyono, C. (2023). Development of Authentic Assessment with Project Based Learning Approach in Primary School Students. *Qalamuna*, 15(1), 539–548. <https://doi.org/10.37680/qalamuna.v15i1.3987>
- Cahyono, B. T., Wibawanto, H., Budiarto, M. K., Qodr, T. S., Sukmawati, F., & Prihatin, R. (2025). UTILIZING ICT-BASED LEARNING RESOURCES TO ENHANCE CREATIVITY AND INNOVATION FOR PRE-SERVICE STUDENTS OF VOCATIONAL EDUCATION. *Journal on Efficiency and Responsibility in Education and Science*, 18(4), 282–292. <https://doi.org/https://doi.org/10.7160/eriesj.2025.180404>

- Carroll, M., Lindsey, S., Chaparro, M., & Winslow, B. (2021). An applied model of learner engagement and strategies for increasing learner engagement in the modern educational environment. *Interactive Learning Environments*, 29(5), 757–771. <https://doi.org/10.1080/10494820.2019.1636083>
- de Ruiter, J. A., Poorthuis, A. M. G., & Koomen, H. M. Y. (2019). Relevant classroom events for teachers: A study of student characteristics, student behaviors, and associated teacher emotions. *Teaching and Teacher Education*, 86, 102899. <https://doi.org/10.1016/j.tate.2019.102899>
- Eduardo, J., Lôbo, A., Franklin, W., Correia, M., Teixeira, J. M., Edeson, J., Siqueira, D. M., & Roberto, R. A. (2023). *applied sciences WebAR as a Mediation Tool Focused on Reading and Understanding of Technical Drawings Regarding Tailor-Made Projects for the Scenographic Industry*.
- Entwistle, N. (2023). Promoting Deep Learning Through Teaching and Assessment. *Assessment to Promote Deep Learning*, 9–19. <https://doi.org/10.4324/9781003443100-2>
- Islam, M. A. (2022). Industry 4.0: Skill set for employability. *Social Sciences & Humanities Open*, 6(1), 100280. <https://doi.org/10.1016/j.ssaho.2022.100280>
- Jusslin, S. (2022). Re-thinking inspiration as in-betweens in arts-integrated literacy practices. *Linguistics and Education*, 72, 101098. <https://doi.org/10.1016/j.linged.2022.101098>
- Li, J., & Pilz, M. (2021). International transfer of vocational education and training : a literature review. *Journal of Vocational Education & Training*, 00(00), 1–34. <https://doi.org/10.1080/13636820.2020.1847566>
- Maganga, D. P. (2025). *Quality 4 . 0 transition framework for Tanzanian manufacturing industries*. 35(6), 1417–1448. <https://doi.org/10.1108/TQM-01-2022-0036>
- Murray, J., G, C., K, W., B, C., & Andrew. (2019). *The impact of alternative routes in teacher education on the work and identities of teacher educators: the English case*. 1–26.
- Opdal, P. A. (2022). To Do or To Listen? Student Active Learning vs. the Lecture. *Studies in Philosophy and Education*, 41(1), 71–89. <https://doi.org/10.1007/s11217-021-09796-3>
- Pathak, N. (2021). A Study on Training Need Analysis (With Special Reference to Employees of Logistic Sector). *TOJQI*, 12(9), 1894–1902.
- Polushkina, O., Armstrong, S., Gomez-Llorente, C., Ferrer, P., & Fernandez-Gonzalez, S. (2025). *Chemometrics and Intelligent Laboratory Systems Considerations for missing data , outliers and transformations in permutation testing for ANOVA with multivariate responses*. 258(January). <https://doi.org/10.1016/j.chemolab.2025.105320>
- Quinn, W., Ahearn, A., Buckley, K., Casotti, A., Ozturk, C., Quinn, W., Ahearn, A., & Buckley, K. (2025). ScienceDirect A Learning Factory Implementation with Industry , Teaching and A Learning Factory Implementation with Industry , Teaching and Research Perspectives. *Procedia Computer Science*, 253(2024), 1093–1102. <https://doi.org/10.1016/j.procs.2025.01.171>
- Rahman, M. M. (2023). Sample Size Determination for Survey Research and Non-Probability Sampling Techniques: A Review and Set of Recommendations. *Journal of Entrepreneurship, Business and Economics*, 11(1), 42–62. www.scientificia.comS
- Schwab, K. (2018). the Fourth Industrial Revolution (Industry 4.0) a Social Innovation Perspective. *Tạp Chí Nghiên Cứu Dân Tộc*, 7(23), 12–21. <https://doi.org/10.25073/0866->

773x/97

- Setyadi, M. (2021). The influence of industrial work practices and workshop infrastructure facilities on work readiness of students The influence of industrial work practices and workshop infrastructure facilities on work readiness of students. *Journal of Physics : Conference Series*. <https://doi.org/10.1088/1742-6596/1833/1/012029>
- Tong, Q., Luo, X., Adeleke, A. A., Gao, P., Xie, Y., Liu, H., Li, Q., Wang, Y., Lv, J., Yao, Y., & Ma, Y. (2021). Machine learning metadynamics simulation of reconstructive phase transition. *Physical Review B*, *103*(5), 54107. <https://doi.org/10.1103/PhysRevB.103.054107>
- Yadav, D. (2022). Criteria for Good Qualitative Research: A Comprehensive Review. *Asia-Pacific Education Researcher*, *31*(6), 679–689. <https://doi.org/10.1007/s40299-021-00619-0>
- Yao, K. (2024). *The Development Trends of Computer Numerical Control (CNC) Machine Tool Technology*.
- Zheng, L., Cui, P., & Zhang, X. (2020). Does collaborative learning design align with enactment? An innovative method of evaluating the alignment in the CSCL context. *International Journal of Computer-Supported Collaborative Learning*, *15*(2), 193–226. <https://doi.org/10.1007/s11412-020-09320-8>