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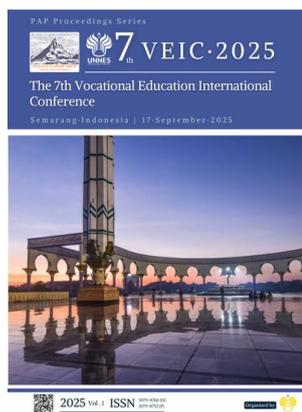
Development of a Technopreneurship-Based Teaching Factory to Prepare Competencies Vocational School Graduates

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Abstract: Vocational high schools (SMK) play a strategic role in producing competent and competitive graduates who meet the needs of industry and the business world. The challenges of globalization and technological developments require learning that is not only oriented towards technical skills but also technology-based entrepreneurship (technopreneurship). Teaching factories (Tefa) are one effort to improve the quality of education in the era of industry 4.0 and 21st-century learning. Teaching factories are the basis for a new model of integration between the academic world and industry. Only 5% of SMK have implemented teaching factories. The research method used a systematic literature review. The results of the study indicate that the development of teaching factories integrated with technopreneurship can create learning experiences and environments in accordance with industrial culture. Technopreneurship-based teaching factories also improve student competencies in both soft and hard skills. This model not only prepares SMK graduates who are ready to work but also encourages the development of technopreneurship. The integration of teaching factories and technopreneurship is expected to strengthen the role of SMK in increasing innovation in vocational education.

Keywords: technopreneurship; teaching factory; vocational schools; project-based learning; LTHPC

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1. Introduction

Currently we are in the era of globalization and industry 4.0, where changes occur very quickly and unpredictably [1]. Industry 4.0 describes a shift in economic paradigm that brings opportunities to increase process efficiency and the potential for developing and transforming new value-added and business models for companies or industries [2]. The industrial era 4.0 has an impact on many aspects of life, one of which is vocational education [3]. Most of the research in industry 4.0 is focused on the manufacturing sector at 53% [4]. The Industrial Revolution 4.0 era will have an impact on the development of Vocational High Schools [5].

To face global challenges and needs, one of the problems faced is education, including governance and management, as well as specific graduates [6]. Based on data from the Central Statistics Agency (BPS), unemployment among vocational high school

graduates in 2023 was the highest at 9.31% compared to graduates of other educational levels (BPS, 2023). National growth in every country is highly dependent on vocational education [7].

One of the causes of high unemployment among vocational school graduates is that vocational schools are unable to produce graduates that meet industry needs. To mitigate this, vocational school graduates need to be equipped with complex competencies. Complex competencies, technology-based learning changes, and demands for non-cognitive skills are all part of 21st-century education [8]. Vocational school graduates must be prepared to possess the skills necessary to compete and be job-ready. Therefore, improving the quality of education in vocational schools is necessary, in line with Sustainable Development Goal 4, namely quality education [9-13]. The current entrepreneurship rate in Indonesia is still very low, at 3.47% of the total population. The average developed country has 12% entrepreneurs. To become a developed country, the minimum is 4% [14]. Technopreneur is one part of the development of entrepreneurship (entrepreneur), providing an overview of entrepreneurship using technology-based innovation [15].

Vocational school graduates need to be encouraged to develop creativity and innovation skills, which can be achieved through teaching factories (TeFa). Teaching factory learning aims to prepare graduates who can be directly absorbed by industry [16]. Teaching factory is the basis for a new model of integration between academia and industry [17]. A study of management, learning, human resources, facilities and cooperation is needed in implementing a teaching factory [18,19].

Increasing technopreneurship capabilities will increase innovation [20]. Technopreneurship enables the integration of technology in the creative industries, which creates new opportunities in sectors such as digital media, design, and technology-based applications [21]. The role of technopreneurship in the creative economy is also supported by government policies that encourage innovation and the use of technology [22]. The increase in technopreneurship is in line with the 9th (ninth) Sustainable Development Goal, namely innovation in industry [23-25]

The objectives of this research are (1) to develop a technopreneurship-based teaching factory management model to prepare the competencies of vocational school graduates.

2. Materials and Methods

This research is a qualitative study. Data were taken from journal references on teaching factories, technopreneurship, vocational high schools, and competency. The object of this study was machine drawing competency in the machining engineering concentration of grade IX. Data analysis used was descriptive analysis.

3. Results

The research findings achieved in this study include conceptual and hypothetical models for a technopreneurship-based teaching factory management model to improve the quality of education and industrial innovation in vocational schools. The conceptual model for a technopreneurship-based teaching factory management model to improve the quality of education and industrial innovation in vocational schools, in accordance with management principles, consists of planning, organization, implementation, and control and evaluation.

Planning is a crucial initial stage in directing the Teaching Factory learning process so that it is structured according to industry standards. This stage ensures that the entire learning process not only produces tangible products but also equips students with competencies relevant to the world of work. Planning activities include: (a) identifying competency needs, (b) product design, (c) production planning, (d) Human Resources (HR) planning, and (e) curriculum integration.

The competency needs identification activity, along with the teaching team, determined the basic competencies (KD) for Grade 10 Machining Engineering relevant to the manufacture of nuts and bolts. These competencies include skills in reading technical drawings, selecting appropriate materials, using lathes and milling machines, and the manufacturing process.

Figure 1 illustrates a product for Tefa-based Project-Based Learning. Teaching Factory (TeFa) in vocational education aims to integrate learning activities with real production processes based on industrial needs. One concrete example of the application of this model is the project to manufacture nuts and bolts for a Low Temperature High Pressure (LTHP) pressure cooker, which is used as a learning medium in manufacturing engineering subjects. Within a managerial framework, the planning stage is carried out by designing an industry-based curriculum, preparing a Lesson Implementation Plan (RPP) using the Project-Based Learning approach, and developing learning strategies that enable students to actively participate in the production process. The evaluation model used is authentic and rubric-based, with a focus on innovative capabilities and technical accuracy of the resulting product.

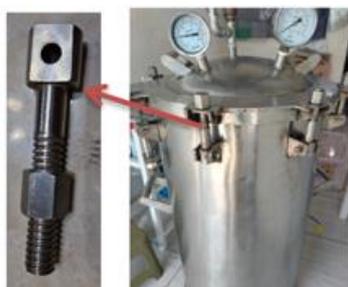


Figure 1. Project-Based Learning Products for Teaching Factory.

Product design activities, with nut and bolt specifications, are based on ISO or SNI standards, including diameter, thread pitch, length, raw materials, and tolerances. This ensures that production results strictly comply with common industry standards. In this case, the products to be produced are nuts and bolts for a pressure cooker, as shown in Figure 2.

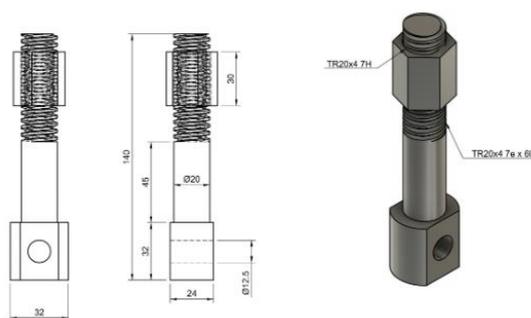


Figure 2. Detail Drawing for project-based learning implementation based on Teaching Factory.

Production planning activities, where teachers develop a project-based learning schedule that mimics the industrial production process. Students will be involved in all stages, from planning and production to quality control.

Resource planning involves determining all production support needs, including raw materials such as low-carbon steel, machine tools and measuring instruments, safety instruments, and documentation such as student worksheets, Standard Operating Procedures (SOPs), and work processes.

Curriculum integration ensures a link between theoretical subjects such as technical drawing and basic machining and the practical aspects of nut and bolt production, providing students with a comprehensive and contextual learning experience.

Organizational functions are carried out through a structured division of roles within the project. The managerial team, consisting of a coordinating teacher and the head of the expertise program, oversees the overall process. Productive teaching staff and technicians assist students in operating production machines, such as lathes and CNC equipment. The student accounting unit calculates material requirements, estimates production costs, and prepares project financial reports. Meanwhile, the marketing unit, which also involves students, is responsible for designing promotional strategies and connecting innovative products with market needs or industry partners.

The organizational stage is the process of structuring the work structure within the Teaching Factory so that the production of nuts and bolts can proceed in a manner similar to an industrial environment. Through this organization, students not only learn technical skills but also understand the division of roles, responsibilities, and communication flows within a production system. Organizational activities include: (a) Division of teacher roles, (b) organizational structure of the teaching factory, (c) SOP (Standard Operating Procedure):

- 1) Role allocation: The teacher acts as the production supervisor/manager, while students are divided into teams based on their work functions. For example, the planning and design team (reading drawings and determining dimensions), the production team (lathe, milling, and tapping machine operators), the quality control team (dimension measurement and quality testing), and the administration and marketing team (production record keeping and distribution simulation).
- 2) Teaching factory organizational structure: A simple organizational structure is created, resembling a small factory, with coordinators, operators, and quality controllers. This trains students to work within a clear and professional system.
- 3) SOP (Standard Operating Procedure): Each production process has a standard operating procedure, from cutting materials, turning, threading, quality control, and packaging. This way, students become accustomed to following measurable and disciplined industrial procedures.

The implementation phase is the core of the Teaching Factory activity, where students undergo the nut and bolt production process according to their assigned roles. At this stage, learning truly mimics industrial work systems, so students gain real-world practical experience while understanding the importance of quality, productivity, and occupational safety. Implementation activities include: (a) initial briefing, (b) production process, (c) teamwork practice, (d) implementation of K3, and (e) production reports.

The initial briefing is conducted with the teacher providing direction regarding production targets, quality standards to be achieved, and work procedures to be followed. The production process is carried out in stages, starting from cutting materials, turning bolt shafts and nut holes, threading (external threads using a lathe and internal threads using a tap), and finishing using a milling or polishing machine. Teamwork practices are implemented, with students working in groups or shifts according to assigned roles. Each team member contributes according to the instructions outlined, while still coordinating to achieve optimal results. Implementation of Occupational Safety and Health (K3): All students are required to wear PPE (Personal Protective Equipment) such as goggles, gloves, and safety shoes. In addition, students are also trained to be disciplined in maintaining a clean and safe work area. Production Report: Each group maintains a daily record in the form of a production logbook, covering the number of products produced, any obstacles encountered, and corrective solutions.

During the implementation phase, students collaboratively carry out a series of technical activities including CAD/CAM design of nuts and bolts, machining processes, thread strength and dimensional precision testing, and product validation through high-

pressure simulations. This project also includes product marketing strategies and technical documentation as part of strengthening technopreneurship competencies. Thus, this activity is not only oriented towards achieving technical competencies, but also developing soft skills in entrepreneurship and problem-solving. The final stage in the management cycle is control, which is carried out through periodic evaluations by school leaders and supervising teachers, as well as receiving feedback from end-users or industry partners. The results of these evaluations serve as the basis for improving the quality of learning and continuous improvement in subsequent production processes.

The final stage is to ensure control and evaluation, aimed at achieving learning objectives and ensuring product quality meets standards. This stage also serves as a means of reflection for students and teachers to improve subsequent learning processes. Control and evaluation activities include: (a) product quality control, (b) student performance evaluation, (c) teacher feedback, (d) learning reflection, and (e) continuous improvement.

Product quality control involves checking using measuring instruments such as calipers, micrometers, and thread gauges to ensure dimensions and tolerances meet standards. Surface smoothness and thread alignment are also checked.

Student performance evaluation is conducted by teachers assessing students across three aspects: knowledge (theory of making nuts and bolts), skills (machine operation and accuracy of work), and attitudes (discipline, cooperation, responsibility, and compliance with OHS). Teacher feedback is provided directly to students to help them understand the strengths and weaknesses of the production process. Learning reflection involves students being asked to share their work experiences, challenges encountered, and strategies for resolving them. This fosters communication skills and a professional attitude. Continuous improvement: Based on the evaluation results, teachers and students develop recommendations for improvements to ensure the next production cycle is more efficient, high-quality, and meets industry standards.

Through the integration of these four management functions, the LTHP pressure cooker bolt-nut project serves as an innovative learning platform that produces ready-to-use products and strengthens students' competencies in precision manufacturing engineering and technological entrepreneurship. Furthermore, this model creates an educational ecosystem relevant to the business and industrial worlds and supports the creation of a sustainable economy through school-based innovation.

In project-based learning, the mechanical components are special nuts and bolts used in pressure cooker assemblies, which functionally and geometrically reflect the results of precision work in the field of machining. Based on this object, competencies that can be developed in vocational high school students majoring in Mechanical Engineering include understanding and skills in reading and interpreting technical drawings, selecting appropriate materials, and operating machine tools such as lathes, milling machines, and threading tools. This project also requires students to apply precision measurements using measuring tools such as micrometers and vernier calipers to ensure dimensions meet standards. In addition, skills in work process planning, quality control, and understanding occupational safety aspects are also integral to achieving competency. The implementation of product-based projects such as this not only strengthens theoretical understanding but also encourages problem-solving skills, collaboration, and technical innovation relevant to the needs of the precision manufacturing industry. Thus, this approach is aligned with the Teaching Factory (TeFa) principle which integrates the learning process with direct and measurable industrial practices.

Figure 3 shows a conceptual model of technopreneurship-based teaching factory management to improve the quality of education and industrial innovation in vocational schools. This model consists of management elements, namely planning, organization, implementation, and evaluation. This model is used as the basis for developing a teaching factory management model in vocational schools.

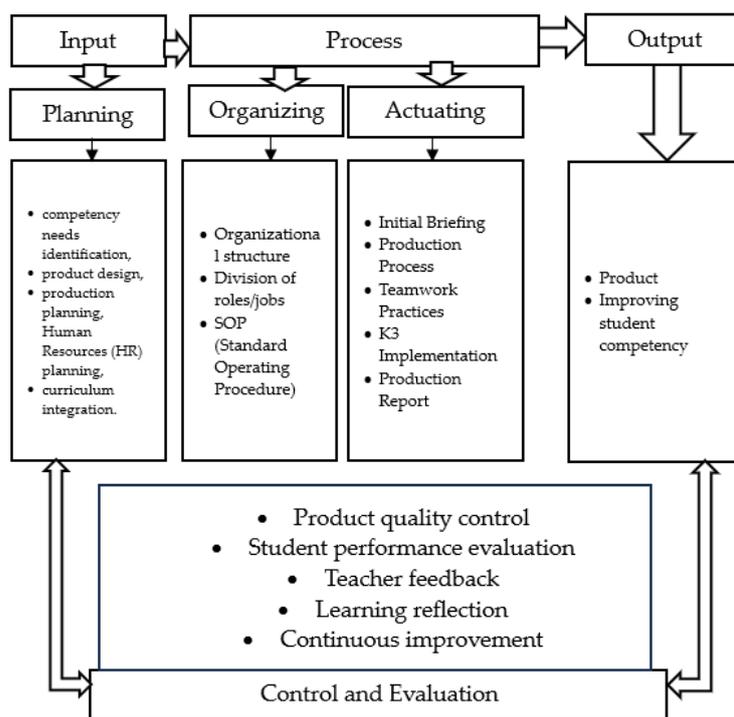


Figure 3. Technopreneurship-Based Teaching Factory Management Model to Improve the Competence of Vocational School Graduates.

In general, after completing this course, students will be able to:

- 1) Integrate knowledge of mechanical engineering drawings in the mechanical component design process.
- 2) Apply planning, organization, implementation, control, and evaluation methods in a high-pressure pressure cooker lid design project.
- 3) Produce mechanical design products that are efficient, safe, and meet technical standards.
- 4) Develop critical thinking, team collaboration, and problem-solving skills in a manufacturing industry context.

Based on figure 3. more specifically, each stage:

1. Planning

- 1) CLO1: Students are able to identify the technical and non-technical competency requirements in mechanical design.
- 2) CLO2: Students are able to create an initial design (sketch/concept) for a high-pressure pressure cooker lid, taking into account functional and safety aspects.
- 3) CLO3: Students are able to develop a production plan for working drawings (2D & 3D) according to machine drawing standards.

2. Organization

- 1) CLO4: Students are able to structure a project team, assigning roles according to team member competencies.
- 2) CLO5: Students are able to develop a simple SOP for the machine drawing design process.

3. Implementation

- 1) CLO6: Students are able to create mechanical working drawings for a pressure cooker lid (detail & assembly drawings) using CAD.
- 2) CLO7: Students are able to apply OHS principles in computer-based project work and team discussions.
- 3) CLO8: Students are able to prepare a mechanical design report containing efficiency and safety analysis.

4. Output

- 1) CLO9: Students are able to produce efficient and safe machine drawing designs (2D and 3D) for high-pressure pressure cooker lids.
- 2) CLO10: Students are able to demonstrate improved machine drawing competency through project results.

5. Control & Evaluation

- 1) CLO11: Students are able to evaluate the quality of working drawings based on industry standards (accuracy, completeness, neatness).
- 2) CLO12: Students are able to reflect on learning and conduct continuous improvement in subsequent projects.

The mapping of Intended Learning Outcomes (ILO) to Course Learning Outcomes (CLO), along with assessment methods and rubrics, is presented in Table 1. This matrix shows how each stage of the project, from planning to evaluation, corresponds to specific learning objectives and assessment strategies.

Table 1. ILO – CLO – Assessment – Rubric Matrix design.

ILO (Intended Learning Outcomes)	CLO (Course Learning Outcomes)	Assessment (Penilaian)
1. Integrate technical drawing knowledge in mechanical design	CLO1: Mengidentifikasi kebutuhan desain & standar teknis	test / discussion
	CLO2: Create initial design (sketch/concept)	Simple manual / CAD sketch
	CLO3: Prepare a working drawing plan	Work plan / design flow
2. Implement team organization and collaboration methods	CLO4: Establish team work structure & roles	Teacher observation & team work report
	CLO5: Develop design SOPs	Project SOP document
	CLO6: Create 2D/3D CAD working drawings (details and assemblies)	CAD working drawing products
3. Produce mechanical design products according to industry standards	CLO7: Implementing K3 in projects	Teacher observation during practice
	CLO8: Prepare mechanical design reports	Project report
4. Produce efficient and safe design products	CLO 9: Produces an efficient & safe pressure cooker lid design	Final product (CAD drawings & analysis)
	CLO10: Demonstrates increased machine drawing competency	Comparison of initial – final results
5. Conduct evaluation & continuous improvement	CLO11: Evaluate product quality	Presentation / product design test
	CLO12: Learning reflection & continuous improvement	Student journal/reflection

The implementation stages refer to the model diagram you provided:

a. Input (Planning)

- 1) The teacher explains the project: designing a high-pressure pressure cooker lid.
- 2) Students identify design needs, conduct literature reviews, and develop initial concepts.

b. Process

- 1) Organization: Students are divided into teams, each member assigned a role (CAD designer, report recorder, safety analyst, etc.).
- 2) Implementation: Students create CAD drawings (2D & 3D), assembly drawings, and efficiency & safety analysis reports.

c. Output

- 1) The product consists of final working drawings (2D detail, 3D assembly), plus a design report.
 - 2) The final results reflect students' increased competency in machine drawing.
- d. Control & Evaluation
- 1) The teacher evaluates the quality of the product based on a rubric.
 - 2) Students engage in self-reflection and continuous improvement.
 - 3) The teacher's feedback serves as the basis for improvements in the next project.

4. Discussion

The advantages of the Model are (a) it is in accordance with the demands of the Independent Curriculum (project-based learning, hands-on learning), (b) it hones technical competencies (hard skills) as well as non-technical competencies (soft skills) such as teamwork, discipline, and communication, (c) it provides a learning experience that is close to the real world of work (link and match vocational schools with industry). So, this concept is mature enough to be tested in the classroom, where teachers can start with a simple project (CAD mechanical design), such as the nut and bolt example in Figure 1. The assessment rubric and learning schedule can be presented from the start so that students know the target achievement (see Table 2). After the trial, both the rubric and CLO can be adjusted to reflect the actual classroom situation.

Table 2. learning schedule design.

Meeting	Learning Activities	CLO	Student Activities	Assessment Form	Instrument/ Rubric	Percentage (%)
1	Project introduction & needs identification	CLO1	Discuss the function & standard of pressure cooker lid	Oral test, discussion	Needs identification rubric	3%
2	Literature study & benchmarking	CLO1, CLO2	Search design references, compare standards	Group assignment	Literature completeness rubric	3%
3	Initial design (concept sketch)	CLO2	Create manual design sketches	Sketch product	Initial design rubric	4%
4	Production plan & working drawings	CLO3, CLO4	Prepare design flow & role distribution	Work plan document	Planning systematization rubric	4%
5	Preparation of design SOP	CLO5	Write team SOP & CAD workflow	SOP document	SOP rubric	3%
6	Introduction to CAD (2D)	CLO6	Practice drawing basic parts	CAD file	Basic drawing rubric	4%
7	Creation of detailed drawings (2D)	CLO6	Draw detailed components of pressure cooker lid	CAD 2D file	Detailed drawing rubric	6%
8	Review & revision of 2D drawings	CLO6, CLO11	Peer review & revise drawings	Revised product	Quality evaluation rubric	4%

9	Introduction to CAD (3D)	CLO6	Practice 3D modeling of components	CAD 3D file	Basic 3D drawing rubric	4%
10	Creation of assembly drawing (3D)	CLO6	Develop pressure cooker lid assembly	CAD assembly file	Assembly rubric	6%
11	Efficiency & safety analysis	CLO7, CLO9	Analyze potential leakage & material strength	Discussion, analysis notes	Safety analysis rubric	5%
12	Preparation of design report	CLO8	Write project report (concept, drawings, analysis)	Report document	Design report rubric	8%
13	Mid-project presentation	CLO9, CLO11	Present initial design (mid review)	Presentation & feedback	Mid-presentation rubric	6%
14	Design product improvement	CLO9, CLO10	Revise drawings & report	Revised product	Design improvement rubric	5%
15	Final project presentation	CLO9	Final presentation: 2D, 3D, assembly & report	Final presentation	Final presentation rubric	10%
16	Reflection & project evaluation	CLO12	Self-assessment & continuous improvement	Reflection journal	Student reflection rubric	5%

The 16-session implementation provides students with real-world experience in: Applying industry standards through the creation of mechanical engineering drawings (2D details, 3D modeling, and assembly). Enhancing technopreneurship skills, namely efficient and innovative thinking, and producing designs with market value. Honing 21st-century skills such as critical thinking, problem-solving, teamwork, and continuous reflection.

5. Conclusion

The project-based Teaching Factory (TeFa) learning model, focusing on the mechanical design of a high-pressure pressure cooker lid, has proven effective in integrating technical competencies (machine drawing, 2D/3D CAD, design analysis) with non-technical competencies (collaboration, communication, project management, and technopreneurship). This model adopts an Input-Process-Output-Control/Evaluation flow, systematically guiding students from the planning stage, teamwork organization, design implementation, and product evaluation. Each stage is accompanied by Course Learning Outcomes (CLOs) and weighted assessments to ensure comprehensive learning outcomes are achieved. Thus, this learning model is not only oriented towards achieving machine drawing skills, but is also directed at strengthening the technopreneurship spirit of vocational school students, so that graduates are better prepared to face the world of work and create independent business opportunities in the engineering and manufacturing fields.

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