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ENHANCING STUDENTS' CREATIVITY, ENGINEERING SKILLS, AND ENTREPRENEURIAL ABILITY IN CNC LEARNING THROUGH MARKETPLACE-BASED TEACHING FACTORY: CLASSROOM ACTION RESEARCH

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Abstract

The rapid transformation brought by Industry 4.0 and Society 5.0 demands vocational education to produce graduates who are not only technically competent but also creative and entrepreneurial. This study aims to enhance student creativity in CNC (Computerized Numerical Control) learning by implementing a marketplace-based Teaching Factory model. Using a Classroom Action Research (CAR) design, the study involved 20 students of the Mechanical Engineering Education Program over two learning cycles. Each cycle included planning, implementation, observation, and reflection stages. The results showed significant improvements across four assessed aspects: technical skills (from 74.1 to 86.6), product design (from 75.1 to 87.9), marketing (from 73.5 to 86.5), and reflective learning (from 78.2 to 91.0). The marketing aspect experienced the highest gain, indicating that digital marketplaces provide an effective platform for practical entrepreneurial learning. This study concludes that integrating marketplace platforms into Teaching Factory learning can significantly foster creativity and entrepreneurial skills in vocational students.

Key words: Teaching Factory, CNC Learning, Marketplace Integration, Vocational Education, Student Creativity, Digital Entrepreneurship.

INTRODUCTION

The development of modern manufacturing requires the world of education, especially vocational training, to continue to adapt and innovate in its learning processes. One of the most important skills that engineering students must master is the ability to operate CNC (Computerized Numerical Control) machines, which have become the backbone of high-precision production processes.

The Industrial Revolution 4.0 and Society 5.0 require the world of vocational education to focus not only on mastering technical skills alone. Although operating CNC at a basic level does require caution and strict operational standards to avoid machine damage, this does not negate the importance of developing soft skills such as an innovative digital attitude and digital entrepreneurship skills. In the context of Industry 4.0, technical work is often integrated with digital systems, so students need to be trained to have problem-solving skills, think creatively, and be able to analyze market needs based on data. Society 5.0 further strengthens this urgency by encouraging humans to be the center of technological solutions, not just operators. Therefore, CNC learning is no longer enough if it only focuses on technical aspects, but also needs to develop adaptive and innovative ways of thinking that are in accordance with the digital technology-based industrial environment. An innovative digital attitude has been shown to have a positive effect on digital entrepreneurial intention, which is further moderated by digital entrepreneurship education (Lopes et al., 2025). In this case, vocational education is required to be able to integrate technical and digital entrepreneurship skills in a balanced manner (Fatmawati, 2020).

Based on the results of initial observations in the CNC learning process in the Mechanical Engineering Education Study Program, it was found that student creativity is still relatively low. Students tend to only follow technical procedures when operating CNC machines without trying to develop innovative product designs or adapt them to market needs. In addition, the marketing strategy for their products has not shown a creative approach based on market data. This problem is an obstacle in efforts to develop students' entrepreneurial abilities, especially in the context of digital and creative industries. Therefore, a learning model is needed that not only emphasizes technical aspects but also encourages students to think creatively and be able to innovate in designing and marketing their products directly through digital platforms.

The Teaching Factory (TeFa) learning model is the answer to this challenge. TeFa is a production- or service-based learning approach that mimics real industrial conditions. This model is capable of bridging the gap between theory and practice and conveying the values of professionalism in the workplace. (Dwi Yunanto, 2017) Explain that Teaching Factory can bridge the world of education and the world of industry by providing students with direct experience in participating in real production activities and enabling them to develop skills required by industry. This approach allows students to gain practical experience performing production tasks relevant to industry requirements.

In this study, the term used consistently is Teaching Factory. Teaching Factory is different from Training Factory both in concept and purpose. Teaching Factory is a manufacturing education paradigm that integrates the learning process and the industrial world through two-way knowledge transfer between academics and industrial practitioners. This concept resembles the teaching hospital model in medical education, where the learning and practice processes take place in parallel (Chryssolouris et al., 2016).

Teaching Factory not only focuses on technical skills training (as in Training Factory) but also includes the development of problem-solving, innovation, and decision-making abilities in the real context of industry. This model emphasizes collaboration between educational institutions and the world of work through real projects, the use of information technology, and continuous feedback systems to improve student competencies holistically (Chryssolouris et al., 2016).

Therefore, all sections of this manuscript will use the term Teaching Factory consistently to reflect a more comprehensive educational approach and in accordance with the context of digital marketplace integration.

However, the implementation of Teaching Factory (TeFa) still requires innovation, particularly in integrating digital platforms that align with Industry 4.0 and Society 5.0 developments. One promising strategy is the incorporation of digital marketplaces, which not only provide commercial functionality but also foster real-world engagement, market analysis, and entrepreneurship. As highlighted by (Zervas & Stiakakis, 2024)Digital platforms enhance vocational learning by simulating industrial environments and encouraging learner autonomy. Marketplaces offer students the ability to perform real-time product testing, receive feedback, and refine their work based on consumer demand (Escobar-Castillejos et al., 2024). Furthermore, such platforms support the development of soft skills like digital communication and customer service, which are essential in today's labor market (Zervas & Stiakakis, 2024). Studies have shown that learning environments enriched with e-commerce elements significantly improve students' creative thinking and innovation capacity (Fais WA, 2023). According to (Syed et al., 2024) E-marketplace participation encourages students to link technical skills with entrepreneurial strategies, preparing them for digitally driven economic ecosystems. Moreover, integrated platforms act as learning laboratories where students experience iterative product design and marketing cycles, enhancing both technical depth and business acumen (Vionita[1] et al., 2024). Digital entrepreneurship education significantly influences students' entrepreneurial intentions, with self-efficacy and digital policy cognition serving as key mediators (Xin & Ma, 2023).

The marketplace platform serves as a real-world medium that fosters students' entrepreneurial spirit and enhances their creativity. Market research, product design, and marketing strategies can be more easily accessed through this digital platform. This supports the view of (Vionita[1] et al., 2024), who stated that marketplaces offer students the opportunity to develop creativity and innovation because they can interact directly with consumers and understand what the market wants. Thus, students are not only taught technical skills but are also encouraged to think creatively and thus meet market demands. Marketplace-based learning environments promote real-time product validation, creative experimentation, and entrepreneurial mindset development (Nurfauzi et al., 2020).

By combining a training factory and marketplace in CNC learning courses, students not only learn how to manufacture CNC-based components but are also encouraged to market their production results directly to consumers. As explained by (Nguyen & Nguyen, 2024)The integration of industry-based learning and digital marketing through a marketplace platform enables students to be better connected to the market and refine their creativity in product design and marketing strategies. This is intended to enhance students' creativity, both in terms of product design and marketing strategies, and their ability to develop innovations based on market needs. Integrating entrepreneurship elements into technical education not only enhances students' vocational competencies but also strengthens their preparedness for participation in the digital economy (Singh & Dwivedi, 2022).

This integration makes learning more contextual, challenging, and meaningful. Students' creativity is fostered through community needs identification, product design, production with CNC machines, and the development of adaptive digital marketing strategies. Therefore, this study is important to investigate the effectiveness of implementing marketplace-based teaching factory learning in improving students' creativity in CNC courses.

This research aims to improve three main aspects in CNC learning, namely: (1) student creativity in designing products and marketing strategies, (2) technical skills in operating CNC machines, and (3) digital entrepreneurship skills through the integration of marketplace platforms in the Teaching Factory learning model.

METHODS

Research Design

This study uses the Classroom Action Research (CAR) method, which aims to improve students' creativity in learning CNC courses through the implementation of marketplace-based Teaching Factory learning. CAR was chosen because this approach allows researchers to directly engage students in the learning process, which is conducted in multiple cycles, with each cycle followed by reflection for improvement in the next cycle. CNC education supported by project-based learning strategies leads to increased student creativity, problem-solving ability, and self-efficacy (Nugroho & Sukardi, 2019). According to several recent studies, CAR enables profound, immediate, and incremental changes in learning practices (Wayan, 2016).

This research was conducted in two cycles, each consisting of planning, implementation, observation, and reflection. Each cycle focuses on the application of learning that integrates the Teaching Factory method with the use of a digital marketplace in the CNC course. The phases of this research are as follows:

1. Planning: Create a learning plan that includes CNC materials, production tasks using CNC machines, and integration with the marketplace for marketing products.
2. Implementation: Students are tasked with manufacturing components using CNC machines, which are then sold on the market according to identified market trends and needs.
3. Observation: Observations are used to assess students' technical skills in using CNC machines, as well as their creativity in designing and marketing products.
4. Reflection: Evaluate learning outcomes based on observations and assessments conducted to improve the learning process in the next cycle.

Participants

This study involved students in the Mechanical Engineering Education program who were taking the CNC course. The number of students involved was 20, who were divided into small groups to facilitate monitoring and direct interaction during learning. As stated by (Wayan, 2016) Classroom action research offers teachers and students the opportunity to collaboratively create a more creative and effective learning environment.

Instruments and Assessment Criteria

The tools used in this study include an assessment framework that measures students' technical skills in using CNC machines, as well as their creativity in designing and marketing products to the marketplace. This assessment framework was developed based on the following criteria:

1. Technical Skills (30%):
   a. Ability to properly operate CNC machines.
   b. The quality of manufactured components is in line with technical specifications.
   c. Accuracy of production results.
2. Creativity in Product Design (30%):
   a. Innovation in the design of manufactured products.
   b. Originality and attractiveness of the product in line with market trends.
   c. Efficient and creative use of materials and technology.

In this study, student creativity is operationally defined as the ability to generate novel, practical, and market-oriented ideas in both product design and marketing execution. Creativity is measured based on dimensions adapted from contemporary research by (Said-Metwaly et al., 2017), which emphasize fluency (the number of ideas), originality (uniqueness of solutions), and usefulness (applicability in real-world contexts). These indicators are contextualized in CNC learning as follows: (1) uniqueness and functionality of product design aligned with consumer demand; (2) innovative use of materials or production techniques; and (3) originality in digital marketing strategies such as product branding, pricing, and promotion on marketplace platforms. This multi-indicator approach ensures that students' creative performance can be assessed both quantitatively and qualitatively in a vocational education setting.

3. Marketplace Marketing and Sales Strategy (30%):
   a. Ability to use marketplace platforms to market products.
   b. Effective marketing strategies that meet market needs.
   c. Active involvement of students in interacting with consumers through the marketplace.
4. Reflection and Self-Development (10%):
   a. Students' ability to reflect on learning experiences and evaluate their work.
   b. Students' efforts to improve their creativity and innovation in each learning cycle.

The assessment in this study uses numerical values to provide a quantitative picture of students' learning outcomes. Grades are assigned based on a predetermined grading grid and calculated at the end of each learning cycle. The numerical values used are on a scale of 0-100, with the following categories:

- 85 - 100: Very good (A)
- 70 - 84: Good (B)
- 55 - 69: Adequate (C)
- 40 - 54: Less (D)
- <40: Fail (E)

2.4 Data Collection and Analysis

Data obtained from student observations and assessments will be analyzed descriptively. Each cycle will be evaluated to determine the

Table 1. Descriptive Summary of Student Performance per Cycle

Cycle	N	Highest Score	Lowest Value	Mean	Std. Deviation
Cycle 1	21	76	74	75,2	0,79
Cycle 2	29	87	84	85,1	0,79

improvement in students' technical skills and creativity in product design and marketing. Data analysis was conducted by comparing the assessment results in each cycle to identify developments or improvements that occurred after the implementation of the marketplace-based learning method Teaching Factory. The results of this evaluation are consistent with the opinion of (Assiddiqi et al., 2025), who stated that data analysis in CAR is conducted to evaluate the impact of interventions on changes occurring in the class as a whole.

2.5 Success Indicators

The success indicators of this research include:

1. Increased student creativity: Evident by the improvement in assessment results in the areas of creativity in product design and marketing strategies in the marketplace.
2. Improved technical skills: Evaluate the quality and accuracy of products manufactured using CNC machines.
3. Improvement of entrepreneurial skills: Evidenced by students' ability to market products and interact with consumers through marketplace platforms.

Through this CAR method, students are expected to acquire not only technical skills but also develop entrepreneurial skills relevant to the development of the manufacturing industry and today's digital world. This is consistent with the view of (Syed et al., 2024), who stated that entrepreneurial learning that combines technology and practical skills can increase students' competitiveness in the industrial world.

RESULTS AND DISCUSSION

The findings show an overall improvement in all assessed areas after implementing the marketplace-based Teaching Factory model. As presented in Table 1, the most significant increase occurred in marketing skills, suggesting that the use of marketplace platforms effectively facilitated the practical application of digital marketing strategies.

Involvement in marketplace activities increases students' awareness of consumer behavior and market trends. In addition, the growth in technical and design competencies reflects the impact of real-world projects on motivation and performance. Reflection scores also improved significantly, which may be attributed to structured feedback cycles, self-evaluation, and peer review processes. Entrepreneurship education contributes to the enhancement of students' entrepreneurial capacity, which in turn influences their entrepreneurial intentions (Hidayat & Yunus, 2019). These findings support the notion that iterative learning and digital exposure promote critical thinking and innovation.

The assessment was conducted in two cycles, before and after the application of the method. Four aspects were assessed: technical skills, product design, commercialization through the market, and learning reflection.

Table 2. Average Value Per Aspect

Assessment Aspect	Average Cycle 1	Average Cycle 2
Technical	74,1	86,6
Product Design	75,1	87,9
Marketing	73,5	86,5
Reflection	78,2	91,0

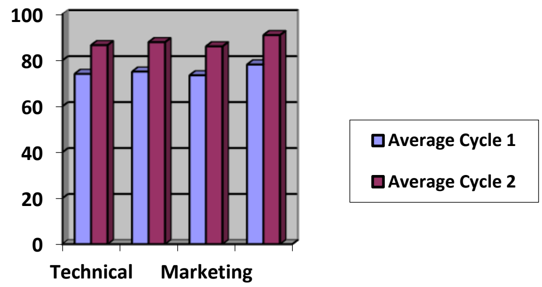

Figure 1. Comparison of Average Values per Aspect

In the first cycle, learning focused on introducing the concept of a marketplace-based Teaching Factory and basic training in using CNC machines to produce simple components. Students were given the task of creating products based on individual or group designs and marketing them through a marketplace platform with limited guidance. Observation results showed that most students were still lacking in creativity in product design and marketing strategies. Some students only copied common designs, and interaction on the marketplace platform was still minimal. Technical skills were quite good, but there were still errors in the settings and results of CNC cutting. The average score for all aspects was in the good category, but not optimal.

The lecturer found that students needed more detailed guidance regarding the exploration of innovative designs and digital communication techniques for marketing. In addition, instructions on utilizing marketplace features were still not evenly understood. Therefore, in the next cycle, the lecturer designed an intervention in the form of creative design training, digital marketing simulations, and providing structured feedback through group discussions.

In the second cycle, students began to show improvements in aspects of design creativity and marketing strategies. Students were able to develop variations in product designs based on market trends and make more attractive price and promotion adjustments. In terms of technicality, the level of machine operational errors decreased significantly because students were accustomed to conducting design simulations before production. Interaction in the marketplace also increased, marked by increased student responses to consumer questions and initiatives to create attractive product descriptions. Lecturers noted that after the intervention was carried out, there was a significant increase in students' reflective abilities towards their learning process. Students began to get used to conducting independent evaluations of the design, production, and marketing strategies used. Lecturers also realized the importance of integrating project-based learning with formative evaluation and real-time feedback so that students remain adaptive and innovative.

After implementing the marketplace-based Teaching Factory model, significant improvements were observed in all aspects of the assessment. The marketing aspect saw the largest increase, from an average of 73.5 to 86.5. This demonstrates that using the marketplace as a direct practice medium is highly effective in improving students' skills in real-world marketing of CNC products. Digital entrepreneurship education positively affects digital entrepreneurial intention and social media usage, with social media serving as a mediator (Wibowo et al., 2023).

Marketplace integration into teaching and learning activities can increase students' competitiveness and creativity in the digital industrial world.

Improvements in technical and design aspects also demonstrate that real project-based learning can motivate students to produce high-quality products. A teaching factory connected to the real-world environment can improve students' skills and sense of responsibility for the results of their work.

The data also suggests that the reflection students conducted after the production process also had a positive impact. They were able to conduct a self-assessment of their performance, increasing the average reflection score to 91.0.

Despite the positive outcomes, this study has several limitations that must be acknowledged. First, the relatively small sample size (n = 20) limits the generalizability of the findings beyond the specific context of the Mechanical Engineering Education program. Second, the implementation period was constrained to two learning cycles, which may not capture long-term effects or sustainability of the learning gains. Third, the digital marketplace used was limited to a general platform without the integration of analytics or advanced consumer behavior tracking, which could further enrich students' marketing insights. Lastly, student creativity was measured using context-specific criteria, and while validated by literature, a more comprehensive psychometric instrument could yield more robust data in future studies. These limitations provide opportunities for further research to apply the model in diverse educational settings, over longer durations, and with expanded digital toolsets.

CONCLUSIONS

Based on the results of the research and discussion, it can be concluded that:

1. Student creativity has increased significantly, as indicated by an increase in the ability to design innovative products and digital marketing strategies through the marketplace.
2. Students' technical skills in operating CNC machines have also increased, as evidenced by the quality of products that meet specifications and the accuracy of production results.
3. Students' entrepreneurial abilities develop through direct involvement in product marketing activities on digital platforms, which fosters market understanding and real interaction with consumers.

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