Community Service Journal (CSJ)
Poltek Mardira Indonesia
Volume. 1 Number. 2, November 2025
ISSN: 3090-7691

Enhancing Integrated Competencies in Vocational Students Through Mechanical and Software Engineering Collaboration In the Era of Industry 4.0

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ABSTRACT
The rapid development of digital technology in the era of Industry 4.0 demands multidisciplinary collaboration competence, especially between Mechanical Engineering and Software Engineering students in vocational education. However, the gap in digital literacy and automation skills among students still persists due to sectoral curricula, limited facilities, and minimal involvement of industry. This community service program aims to optimize interdisciplinary collaboration through technology-based knowledge transfer for vocational school students. The method consists of needs identification, coordination with partners, material preparation, training implementation, and evaluation. The activity was held at SMK PGRI Kandanghaur Indramayu, focusing on the introduction of programming, digital-based system modelling, and data presentation tools used in industrial environments. The results indicate increased students' understanding of digital integration in mechanical systems and stronger motivation to pursue careers aligned with technological development. This initiative encourages the readiness of vocational education graduates to contribute to the transition toward Industry 4.0.

Keywords: *Mechanical engineering; Software engineering; Industry 4.0; Vocational education; Collaboration*

INTRODUCTION

The rapid advancement of digital technology and industrial automation in the Industry 4.0 era has significantly transformed workforce competency needs. Industries today demand human resources who are not only proficient in a specific technical domain but are also capable of adapting and collaborating across disciplines (Prasetyo & Sutopo, 2019). However, in Indonesia's vocational education—such as vocational high schools (SMK) and polytechnics—there remains a substantial skills gap between Mechanical Engineering and Software Engineering students.

Mechanical Engineering vocational students are typically skilled in machining, welding, and CAD modeling, but have limited exposure to programming and digital control systems. Meanwhile, Software Engineering vocational students only focused on mastering coding and application development. However, the student still lacks knowledge of mechanical engineering and the physical behavior of machines (Indrawan & Soeharto, 2020). This disciplinary fragmentation hinders students' ability to produce integrated Industry 4.0 solutions such as automation, robotics, and IoT-based monitoring systems.

A preliminary assessment at SMK PGRI Kandanghaur, which is located in Indramayu Regency, showed that more than 80% of students have never participated in cross-disciplinary project-based learning, and around 70% of teachers report a lack of facilities such as microcontrollers, sensors,

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and automation devices essential for supporting Industry 4.0 learning. This indicates a critical need for improving technology literacy and interdisciplinary collaboration in vocational schools.

The location of this school also has strong agricultural and coastal economic characteristics. Industrial potential in this area includes agricultural machinery fabrication, mechanical workshops, and digital technology should be adopted to support agricultural productivity. These characteristics stand out in the school's strategic role in preparing skilled graduates who can support regional industrial transformation.

Previous initiatives in similar institutions indicate that integrating multidisciplinary learning can enhance student readiness for industrial technology advancements (Widodo & Hartono, 2020; Puspitasari & Fauzan, 2021). However, efforts in this partner school have not yet been optimal due to limited industrial collaboration, the absence of competency certification opportunities, and theoretical-dominant assessments that do not fully measure practical competence.

Enhancing interdisciplinary skills through structured project-based learning and practical technology exposure is expected to produce vocational graduates who are innovative and competitive in the era of Industrial Revolution 4.0.

METHOD

The implementation method was designed in a gradual and systematic manner to fulfill the objectives of the program and to address the identified problems. The method consisted of six main stages as illustrated in the activity flow in Figure 1.

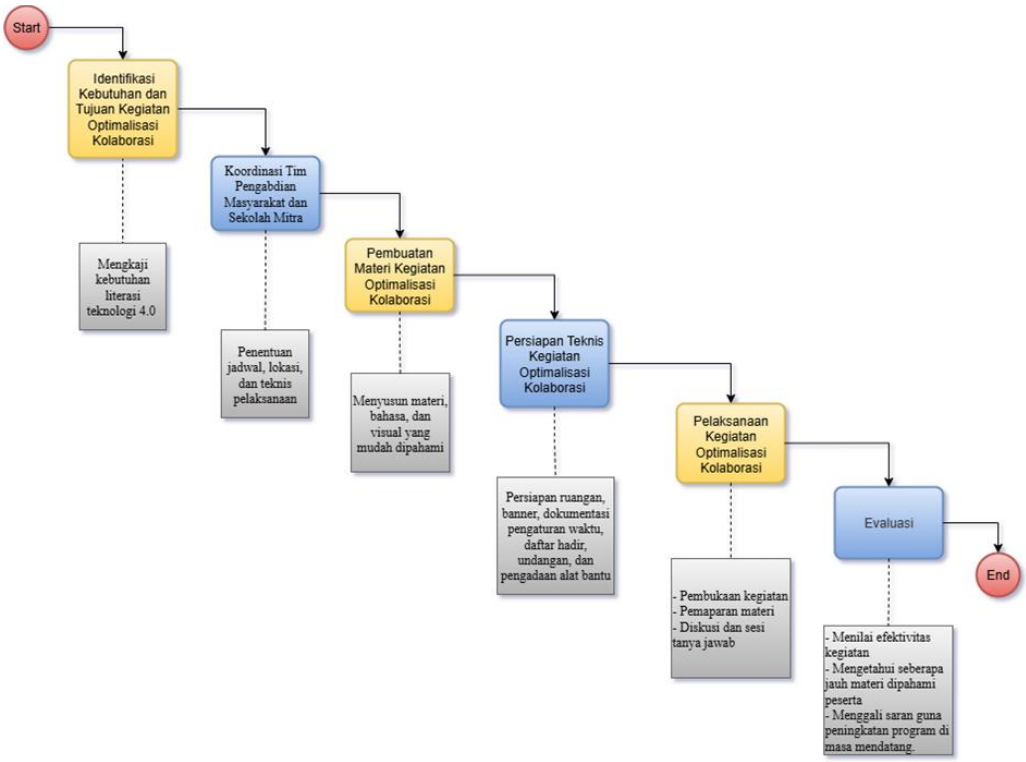

Figure 1. Implementation Method Scheme

1. Industry Needs Identification and Goal Setting

This initial stage ensured that the intervention aligns with the Industry 4.0 technology literacy needs of the students of SMK PGRI Kandanghaur.

Activities included:

- Mapping technology literacy gaps in Mechanical and Software Engineering students,
- Establishing program goals such as increasing exposure to digital technology and motivating students toward digital-mechanical integration careers.

2. Coordination with Partner School

A coordination meeting was held with the school to finalize:

- Activity schedules,
- Participant selection,
- Technical implementation procedures.

This ensured appropriateness and feasibility of implementation.

3. Development of Training Materials

Materials were developed based on interdisciplinary content using simple language and visually appealing media to support understanding.

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Output:

- Seminar presentation slides,
- Digital learning materials for self-learning.

4. Technical Preparation

This stage included logistical and venue readiness, such as:

- Classroom arrangement,
- Documentation set-up,
- Attendance records,
- Multimedia equipment (projector, microphone, banner).

5. Implementation of Program Activities

This was the main stage of knowledge transfer delivered interactively and communicatively. Activities included:

- Opening session conducted by the school,
- Presentation of material by the presenter,
- Interactive discussion and Q&A session.

6. Evaluation

Evaluation was conducted to measure the effectiveness and level of achievement of the service outcomes. Data were collected through questionnaires and descriptive assessments with the following measurable indicators:

Table 1. Evaluation Indicators of Program Success

Indicator	Measurement Type	Expected Output
Knowledge improvement of Industry 4.0 concepts	Cognitive test/questionnaire	Increase in understanding score
Student motivation toward digital-mechanical integration	Likert-scale survey	Positive shift in learning motivation
Student attitude and interest in cross-disciplinary collaboration	Observation + self-assessment	Increased engagement during activities

The level of success of this activity was assessed based on the improvement in student attitudes and motivation toward interdisciplinary collaboration, as well as students' awareness and readiness to face Industry 4.0 demands.

RESULTS AND DISCUSSION

3.1 Results

Participants in this community service activity were 14 students from SMK PGRI Kandanghaur, consisting of students from the Mechanical Engineering and Software Engineering departments. The activity successfully introduced the concept of integrated engineering in the context of Industry 4.0 and measured improvement through a structured evaluation mechanism.

Evaluation instruments were distributed before and after the session to analyze the improvement of cognitive understanding and interdisciplinary collaboration awareness. The processed data indicated a significant increase in student competencies.

Table 2. Improvement in Student Competencies

Indicator	Before (%)	After (%)	Improvement
Microcontroller understanding	29	86	+57%
Mechanical–digital integration understanding	21	79	+58%
Industry 4.0 awareness & career motivation	43	86	+43%

Based on the results, more than 80% of participants showed improved literacy in understanding the role of automation and digital systems in industrial operations. The data demonstrates that students are more prepared to collaborate in interdisciplinary smart-technology projects.

Figure 2. Documentation of Activity Implementation

This program has successfully disseminated knowledge related to the integration of mechanical systems and digital technology to vocational students. The learning approach provides **added value** in the form of:

Table 3. Added Value of the Program on Students' Competency and Behavioral Development

Added Value Type	Description
Social Behavior Change	Collaboration between different majors became more active; students gained confidence in interdisciplinary teamwork.
Educational Contribution	Introduced hands-on applied engineering concepts aligned with Industry 4.0 demands.
Long-term Skill Development	Increased aspirations toward future careers in automation, IoT, and digital manufacturing technology.

The success of the activity was measured by indicators including increased competency scores (Table 1), student enthusiasm and active involvement, and the ability to answer conceptual questions after the session. These reflect the achievement of program goals.

However, the outputs still have limitations:

- Learning is conceptual and lacks direct prototyping practice
- Limited hardware facilities, such as sensors and microcontrollers
- Activity duration is relatively short for deeper implementation

Despite these challenges, student responses indicated a high opportunity for future development, including:

- Mini-projects combining Mechanical & Software Engineering
- Introduction of IoT-based automation modules
- Industry collaboration to support real implementation

Thus, this activity not only increased technological literacy but also fostered a mindset shift, demonstrating strong potential to continue shaping competencies relevant to industrial transformation.

Figure 3. Implementation of the Community Service Program at SMK PGRI Kandanghaur

This figure illustrates the execution of the community service activity, where students received exposure to integrated mechanical and digital technology concepts. The learning session was conducted interactively, involving direct communication between presenters and students to enhance understanding and motivation toward Industry 4.0-related competencies.

Figure 4. Presentation of Integrated Mechanical and Software Engineering Concepts

This figure shows the presenter delivering learning materials that combine mechanical engineering fundamentals with digital technology concepts relevant to Industry 4.0. Students from both study programs actively participated in the session, demonstrating enthusiasm for understanding interdisciplinary collaboration through interactive discussions and real industrial examples.

3.2 Discussion

This program has successfully disseminated knowledge related to the integration of mechanical systems and digital technology to vocational students. The learning approach provides **added value** in the form of:

Table 4. Benefits Achieved through the Integrated Learning Approach

Added Value Type	Description
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CONCLUSION

This community service program was successfully carried out at SMK PGRI Kandanghaur and achieved its primary objective of enhancing the integrated competencies of vocational students in relation to Industry 4.0. Students demonstrated measurable improvements in their understanding of microcontroller applications, mechanical–digital system integration, and their motivation to pursue careers in digitally oriented engineering fields. These developments are strongly associated with the structured learning implementation and evaluation, reinforcing the effectiveness of interdisciplinary collaboration as a relevant approach for vocational education.

Moreover, the program positively influenced student behavior, particularly with respect to communication and teamwork across different vocational backgrounds. Although limited time and equipment remain challenges, the activity succeeded in fostering awareness and readiness for ongoing industrial transformation.

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