Utilization of the Internet of Things to Optimize Teaching Factory in Vocational Schools: Industry 5.0-Based Learning Innovation

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ABSTRACT

Background. The Industrial Revolution 5.0 demands innovation in the education sector, particularly in Vocational High Schools (SMK), to prepare graduates capable of competing in the digital era and smart industry. This research explores the integration of the Internet of Things (IoT) within the Teaching Factory concept in SMK as a strategy to optimize industry-based learning. IoT technology enables the Teaching Factory to simulate real industrial environments, allowing students to be actively involved in production processes supported by real-time data and automation.

Purpose. The purpose of this study is to analyze the benefits of IoT implementation in the Teaching Factory to enhance student readiness for the workforce.

Method. The research method includes a literature review and a case study of SMKs that have integrated IoT into their Teaching Factory activities.

Results. The results indicate that IoT use increases efficiency and productivity in the learning process while enriching students' learning experiences through interactive and adaptive methods. IoT integration also helps students develop relevant skills for the workforce, thus reducing unemployment rates in Indonesia.

Conclusion. In conclusion, the incorporation of IoT into the Teaching Factory concept offers significant opportunities for SMK to better prepare students for the challenges of Industry 5.0. This article provides practical recommendations for SMK administrators to develop IoT-based curricula and learning infrastructure to align with industrial needs.

KEYWORDS

Industry 5.0, Internet of Things, Teaching Factory, Technology-Based Learning, Vocational Education

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INTRODUCTION

The Industrial Revolution 5.0 emphasizes the importance of collaboration between intelligent technology and humans,

where technologies such as the Internet of Things (IoT) are key elements in the industrial transformation process. Internet of Things, which allows devices to connect to each other and exchange data in real-time has been widely adopted in various industrial sectors to improve operational efficiency and production quality (Kishor & Chakraborty, 2022; Padmaja dkk., 2022). However, in the field of education, especially in Vocational High Schools (SMK) which aim to prepare graduates ready for work, the application of IoT technology is still not optimal.

One learning approach that is relevant to Industry 5.0 is the Teaching Factory (TEFA) concept, where vocational high school students can practice in an environment that resembles the real industrial world (Dvorak dkk., 2024; Irawan dkk., 2022). Teaching Factory not only provides students with technical skills but also an in-depth understanding of the production process (Maksum dkk., 2022; Prianto dkk., 2021; Saputro, 2024). However, the implementation of TEFA in many vocational high schools today has not fully utilized advanced technologies such as IoT (Diwangkoro & Soenarto, 2020; Kristanto dkk., 2023). With the potential of IoT to enhance industry-based learning through realistic simulations, optimizing IoT-based Teaching Factory is essential to meet the demands of Industry 5.0.

Several studies have highlighted the importance of implementing IoT in education. Research conducted by(Akbar dkk., 2024) shows that IoT can create more interactive and personalized learning, especially in the context of vocational education. (Setiawan dkk., 2023; Wahjusaputri dkk., 2021) also studied the impact of IoT use on improving students' technical skills in the manufacturing sector, but there are still limitations in exploring the application of IoT in production process simulations in vocational schools. Likewise, in another study conducted by (Oktavianto, 2021) identified the benefits of IoT in real-time data processing in the industrial world, but they did not discuss in depth how IoT can be integrated into the Teaching Factory.

Thus, there is still a research gap regarding how IoT can be implemented effectively in the Teaching Factory in vocational schools. This study aims to answer the main questions, namely: (1) How can the use of the Internet of Things (IoT) optimize the Teaching Factory in vocational schools; (2) What are the challenges faced by vocational schools in adopting IoT for the Teaching Factory (AlHelaibi & Al Mubarak, 2023); and (3) How can IoT improve the readiness of vocational school students to face the demands of Industry 5.0 (Heriyati & Abror, 2023).

The novelty of this study lies in its focus on integrating IoT into the Teaching Factory in SMK to present a more modern and sophisticated production simulation, in accordance with technological developments in Industry 5.0. Unlike previous studies that only highlighted the implementation of IoT in the industrial or education sectors in general, this study will specifically examine the application of IoT in the Teaching Factory model in SMK. (Suwastika dkk., 2023), for example, studied IoT in vocational education but focused more on general technical training without specifically touching on the Teaching Factory aspect. In addition, this study will also identify the technical and non-technical challenges faced by SMK in adopting IoT, an area that has not been widely discussed in the existing literature. This study offers an innovative solution in the form of an IoT integration model designed to support Teaching Factory practices, while also answering the need for skill sets needed by SMK graduates in facing Industry 5.0. Therefore, the objectives of this study are: (1) Identifying and analyzing the role of the Internet of Things (IoT) in optimizing the Teaching Factory process in SMK; (2) Explaining the challenges and obstacles faced in implementing IoT in SMK ; and (3) Provide recommendations for IoT implementation strategies to improve the efficiency and quality of learning in the Teaching Factory.

This research is expected to provide significant contributions to the development of vocational education in Indonesia, especially in terms of increasing the effectiveness of industry-

based learning through the adoption of IoT technology. With the implementation of IoT in the Teaching Factory, it is expected that vocational school students can gain a more relevant learning experience and be oriented towards modern industrial practices. Scientifically, this research is expected to enrich the literature on the application of advanced technology in vocational education, especially in the context of the Teaching Factory. In addition, this research is also expected to be a reference for educators and policy makers in developing a vocational education curriculum that is more adaptive to technological developments.

RESEARCH METHODOLOGY

Approach Study

Study This use approach qualitative and quantitative (mixed methods) for understand and analyze utilization Internet of Things (IoT) in optimization Teaching Factory in three vocational schools in East Java, namely SMK PGRI 1 Kediri, SMK Islam 1 Blitar , and SMK 3 Pancasila Ambulu (Febrinasari dkk., 2023) . The approach This chosen Because study focuses on technical data collection and understanding deep about IoT implementation in education vocation (Love dkk., 2023) .

Research Design

The research design used is studies case comparative , where the three vocational schools will made into location studies For compare implementation of IoT in Teaching Factory (Alizamir dkk., 2020; Shekhovtsov & Sałabun, 2020). This study aiming For identify difference level IoT adoption , challenges faced , and effectiveness its implementation in support learning based on industry.

Location and Subject Study

Study conducted in three vocational schools in East Java

Vocational School PGRI 1 Kediri

Islamic Vocational School 1 Blitar

Vocational School 3 Pancasila Ambulu

Subject study includes

Teachers and staff lecturers in relevant departments with Teaching Factory and IoT.

Students involved direct in the Teaching Factory program.

Party management schools that play a role in taking policy related development technology in schools.

Amount subject study is 5-7 teachers and 10-12 students from each vocational school, with a total of 45 subjects study.

Data Collection Techniques

Data in study This collected through a number of techniques, namely

Semi-structured interviews: Conducted towards teachers and other parties management school For get information deep about IoT implementation in Teaching Factory, the challenges faced, and perception they about impact the use of IoT in the learning process (Hwang dkk., 2023; Ibarra-Sáiz dkk., 2023).

Observation direct: Researcher do observation at the Teaching Factory in each vocational school for see in a way direct how IoT is implemented in production process simulation as well as interaction student with technology the (X. Chen dkk., 2021; Mohamadirizi dkk., 2020).

Questionnaire closed: Shared to student For measure understanding and skills they in use IoT technology in Teaching Factory. Questionnaires were also used For know perception student about readiness they face Industry 5.0 (Jaganathan dkk., 2020; M dkk., 2023).

Documentation: Collecting secondary data in the form of policy school, material learning used in the Teaching Factory, and internal reports related to the Teaching Factory program in each vocational school (Perla dkk., 2023; Zhang dkk., 2020).

Data Analysis Techniques

Qualitative data analysis: Data from interviews and observations analyzed use method analysis thematic, with steps coding, categorization, and retrieval conclusion (Kiger & Varpio, 2020). Approach This used For identify themes main related IoT adoption in Teaching Factory.

Quantitative data analysis: Data from questionnaire analyzed in a way descriptive statistics use device SPSS software or application similar (Liang, 2021). Analysis This used For evaluate level understanding students and perception they to application of IoT in the Teaching Factory.

Data Validity and Reliability

For ensure data validity, research This use technique triangulation data sources, namely compare information from interviews, observations, and documentation For to obtain consistent results. While For ensure reliability, researcher will do trials questionnaire on sample small before distribution full For measure reliability instrument.

Stages Study

Preparation

Collection literature related to IoT, Teaching Factory, and education vocational. Preparation instrument study like guide interviews, questionnaires, and sheets observation.

Data collection

Conducted in period time three month with visit to three vocational schools that became location study.

Data analysis

Data is analyzed after all over data collection is complete, with focus on comparison IoT implementation in each vocational school.

Reporting Results Research

Writing report research that includes findings main, discussion, and recommendations.

RESULT AND DISCUSSION

This study aims to examine the use of the Internet of Things (IoT) in optimizing the Teaching Factory (TEFA) in three vocational schools in East Java, namely SMK PGRI 1 Kediri, SMK Islam 1 Blitar, and SMK 3 Pancasila Ambulu. Data analysis was carried out by combining qualitative and quantitative approaches, where qualitative data was obtained through interviews and observations, while quantitative data came from questionnaires given to students in the three schools.

Implementation of IoT in Teaching Factory

SMK PGRI 1 Kediri

IoT is used in an integrated manufacturing laboratory, where students learn to program sensors and monitor machines in real time through the IoT dashboard. Students are also trained to use IoT technology to improve production efficiency.

SMK Islam 1 Blitar

The implementation of IoT focuses on energy management, with sensors that monitor electricity consumption. The use of IoT has not been fully implemented in the production process, but provides students with insight into optimizing energy resources.

SMK 3 Pancasila Ambulu

The application of IoT is still limited to the use of temperature and humidity sensors in food production simulations. IoT has not been fully integrated into the daily learning process, and the available infrastructure does not support maximum IoT utilization.

This finding is in line with research by Rukhiran dkk (2023) dan (Hussain dkk., 2020) which states that the level of adoption of IoT technology in education is highly dependent on the readiness of infrastructure, training, and school management policies.

Challenges of IoT Implementation at TEFA

Based on interviews with teachers and school management, several main challenges were found in IoT implementation, namely:

Budget Constraints

Schools have difficulty in obtaining sophisticated IoT devices due to limited funds. This limits the school's ability to carry out technology updates that are relevant to industry 5.0.

Teacher readiness: Many teachers have not received intensive training related to IoT. This results in a low level of adoption of IoT technology in learning.

Infrastructure Readiness

Only SMK PGRI 1 Kediri has adequate internet network infrastructure. SMK Islam 1 Blitar and SMK 3 Pancasila Ambulu still face obstacles related to internet speed and stability.

The results of this study are also supported by Li (Nidhom dkk., 2021; Sultana & Tamanna, 2022) which shows that infrastructure readiness and educator competence are two crucial elements in the successful adoption of IoT in the education system. (Al-Emran dkk., 2020; L. Chen & Lertamornsak, 2023) also emphasize that without proper infrastructure support, the use of IoT in education will be limited to minimal use of technology.

Questionnaire Results Student

Quantitative data from The questionnaires filled out by students at the three vocational schools describe perception student to IoT implementation in TEFA. Questionnaire consists of out of 10 questions with Likert scale (1 = very much disagree) agree, 5 = strongly agree). The following is average response result from 36 students:

Table 1. Students' Perceptions of IoT Implementation in TEFA.

Dimensions	SMK PGRI 1 Kediri	SMK Islam 1 Blitar	SMK 3 Pancasila Ambulu	Average
Understanding of the production process	4.8	4.1	3.9	4.26
Technical skills	4.7	4.2	4.0	4.30
Career advancement	4.9	4.3	3.8	4.33
Intensity of IoT usage	4.5	3.9	3.6	4.00
Ease of data collection for production systems	4.6	4.1	3.7	4.13
Confidence in using IoT	4.7	4.0	3.9	4.20
Improving learning efficiency	4.8	4.2	3.8	4.27
Interest and motivation to learn	5.0	4.5	4.2	4.57

IoT				
Increasing creativity and Innovation	4.7	4.1	3.9	4.23
Ready for work	4.8	4.3	3.7	4.27

Average perception student to the use of IoT in TEFA at SMK PGRI 1 Kediri is more tall compared to with two other vocational schools. This is show that more IoT implementations progress in school the impact on understanding student about technology and readiness they For enter to the world of work based on industry 5.0. (Kumar dkk., 2024; Siddiqui dkk., 2020) confirm that IoT adoption in education can increase students' digital skills and encourage they For more Ready face challenge modern industry. Research by (Awodoyin & Okiki, 2023; Pham dkk., 2020) also states that integration technology in education give profit significant in matter skills technical and innovation student.

Research result This show that IoT implementation in Teaching Factory provides significant impact in increase quality learning and skills students at SMK. SMK PGRI 1 Kediri own more IoT implementations forward and support understanding student regarding the production process IoT based, which in turn prepare they with more Good For challenges in the world of work.

However, the challenge related limitations infrastructure, resources power, and teacher training is still become obstacle main in implementation of IoT in SMK Islam 1 Blitar and SMK 3 Pancasila Ambulu. Challenges This slow down adoption technology smart in the environment education. (Ardhinar & Wibawa, 2022) also emphasized importance strong infrastructure and support policy For maximize benefits of IoT in learning based on industry.

Although so, enthusiasm student For Study more Lots about IoT and innovation technology seen clear from results questionnaire. The majority student feel IoT helps they understand the production process more good and prepare they for an increasingly working world depend on technology automatic and digital, as expressed by Al Mubarak (2023)

Study this also found that IoT is not only help increase efficiency learning, but also stimulating creativity and innovation students, who are in line with findings (Habibi dkk., 2023; Kayohana dkk., 2023) about benefit technology intelligent in education vocation.

Benefits of IoT for Student

In general general, results study This show that IoT is capable of give benefit significant for vocational high school students in matter improvement skills technical, understanding of production processes, and readiness enter the world of work. Putra et al. (2022) mention that IoT has the potential For increase experience Study students at school vocational, especially in matter adaptation to development technology industry.

In conclusion, the implementation of IoT in TEFA delivers contribution big in optimize learning based on industry in vocational schools, although challenge infrastructure and training Still need overcome so that the benefits can felt in a way evenly distributed across all school .

CONCLUSION

This study demonstrates that the implementation of Internet of Things (IoT) in Teaching Factory (TEFA) at vocational schools significantly enhances students' technical skills, understanding of production processes, and preparedness for Industry 5.0. While SMK PGRI 1 Kediri exhibits more advanced IoT integration, other schools face challenges such as limited infrastructure, funding, and teacher training. Overcoming these barriers is crucial for broader IoT adoption, ensuring equitable learning opportunities. This research highlights the relevance of IoT in

vocational education, building on prior studies, and underlining its potential to align educational outcomes with the demands of the modern workforce.

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AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.
Author 4: Formal analysis; Methodology; Writing - original draft.
Author 5: Supervision; Validation.

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