Implementation of IoT-Based Trainer as a Learning Media in Microprocessor System Courses

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Abstract. This study examines the implementation of Internet of Things (IoT)-based trainers in the Microprocessor System course. The trainer is designed using the ESP32 with integrated sensors and actuators, allowing for remote interaction via the web. The methodology includes trainer development, learning implementation, and evaluation using a mixed method. The results showed a significant increase in the understanding of microprocessor and IoT concepts, as well as students' learning motivation. Trainers are effective in bridging theory and practice, preparing students to face industry 4.0. This research contributes to the development of innovative learning strategies in engineering education.

Keywords: learning media, IoT trainer, microprocessor system.

1 Introduction

The rapid development of technology in the era of the Industrial Revolution 4.0 has brought significant changes in various aspects of life, including education. One of the technologies that is a major focus is the Internet of Things (IoT), which has changed the way we interact with the devices and systems around us. In the context of engineering education, especially in learning microprocessor systems, the integration of IoT technology is becoming increasingly important to prepare students to face the demands of modern industry [1].

Microprocessor systems are a fundamental component in many modern electronic devices and are the basis of various IoT applications. A solid understanding of microprocessor systems is essential for electrical and computer engineering students. However, learning microprocessor systems is often considered complex and abstract, requiring innovative and practical learning approaches.

The Internet of Things (IoT) is defined as a network of physical devices connected through the internet, enabling the collection and exchange of data [2]. IoT technology has revolutionized a wide range of industries, including manufacturing, healthcare, and smart cities. In the context of education, IoT offers great potential to enhance the learning experience through real-time interactivity and remote access to learning devices [3].

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The use of trainers or practical learning media in engineering education has been proven to be effective in improving students' conceptual understanding and practical skills [4]. IoT-based trainers combine the advantages of hands-on learning with the flexibility and accessibility of IoT technology, creating a learning environment that is dynamic and relevant to industry needs [5].

Several previous studies have shown the effectiveness of the use of trainers in learning microprocessor systems. For example, Putra et al. [6] reported a significant improvement in students' concept understanding and learning motivation after using the microprocessor trainer. Meanwhile, Nur et al. [7] developed an Arduino trainer for microprocessor learning and found the improvement of students' practical skills.

In the context of IoT, research by Alhasan et al. [8] demonstrated the effectiveness of using IoT platforms in improving students' understanding of network concepts and data communication. Furthermore, Gómez et al. [9] integrate IoT technology in the electrical engineering curriculum and report an increase in student interest in the latest technology applications.

Although these studies show the potential use of trainers and IoT technology in learning, there is still a gap in the integration of the two, especially in the context of microprocessor system learning. Therefore, this study aims to develop and evaluate the effectiveness of IoT-based trainers as an innovative learning medium in the Microprocessor System course.

The IoT-based trainer developed in this study uses the ESP32 microcontroller as the main component. The ESP32 was chosen for its ability to support Wi-Fi and Bluetooth connectivity, as well as its high performance at an affordable price [10]. The trainer is equipped with a variety of sensors and actuators commonly used in IoT applications, such as temperature and humidity sensors, light sensors, servo motors, and RGB LEDs.

One of the main advantages of IoT-based trainers is their ability to be accessed and controlled remotely via a web interface. This allows students to interact with devices not only during lecture hours, but also outside of the classroom, increasing flexibility and learning opportunities [11]. Additionally, the ability to collect and visualize data in real-time provides a richer and more contextual learning experience.

The implementation of IoT-based trainers in microprocessor system learning is expected to provide several benefits. First, to increase students' conceptual understanding of microprocessor systems and their applications in the context of IoT [12]. Second, develop practical skills in microcontroller programming and sensor/actuator integration [13]. Third, introduce students to IoT concepts and practices that are relevant to the demands of modern industry [14].

This research is also in line with the education 4.0 paradigm, which emphasizes the use of digital technology and the internet in the learning process [15]. Through the use of IoT-based trainers, students not only learn about technology, but also experience firsthand how the technology can be implemented in real situations.

The research methodology used in this study includes the design and development of trainers, implementation in learning, and evaluation using a mixture of quantitative and qualitative methods. This approach allows for a comprehensive assessment of the effectiveness of trainers, both in terms of improving students' conceptual understanding and practical skills [16].

The expected result of this study is a significant increase in students' understanding of microprocessor systems and their applications in IoT, as well as an increase in learning motivation. Furthermore, this research is expected to contribute to the development of innovative learning strategies in engineering education, especially in integrating IoT technology into the curriculum.

In a broader context, this research is also relevant to efforts to prepare engineering graduates who are ready to face the challenges of the Industrial Revolution 4.0. By equipping students with practical knowledge and skills in microprocessor systems and IoT, it is expected to increase the competitiveness of graduates in the global job market [17].

In conclusion, this study aims to explore and evaluate the potential of IoT-based trainers as an innovative learning medium in the Microprocessor System course. Through the integration of IoT technology in learning, it is hoped that it can bridge the gap between theory and practice, as well as prepare students to face the demands of the industry in the digital era.

2 Method

This study uses a mixed-method approach, combining quantitative and qualitative methods to obtain a comprehensive understanding of the effectiveness of IoT-based trainers. The research design adopts a quasi-experimental model with pre-test and post-test to measure the improvement of student understanding. IoT trainer development is a complex and iterative process, involving several key stages:

a. Needs Analysis:

1) Conducted a survey of 20 students and 2 lecturers of the Microprocessor System course.
2) Held a focus group discussion (FGD) with 2 IoT industry practitioners to understand industry trends and needs.
3) Analyze course learning outcomes to identify areas that can be improved with IoT integration.
4) Results: A prioritized list of features and capabilities that IoT trainers must have.

b. Design:

1) Create a trainer architecture blueprint that includes:
    a) Main microprocessor unit (e.g. Arduino Mega or Raspberry Pi 4)
    b) Sensor module (temperature, humidity, motion, light)
    c) Actuator module (servo motor, RGB LED, buzzer)
    d) Communication module (WiFi, Bluetooth, LoRa)
    e) OLED display for data visualization

2) Designing electronic network schematics using CAD software such as Autodesk Eagle.
    a) Design a user interface for trainer companion software.
    b) Result: Comprehensive design document and network schematic.

c. Implementation:
  1) Assemble a prototype trainer based on the design that has been made.
    a) Develop firmware for microprocessors using the Arduino IDE or an appropriate development platform.
    b) Create web-based companion applications using frameworks such as Flask or Django for IoT visualization and control.
    c) Implement IoT communication protocols such as MQTT for data exchange.
    d) Results: Prototype of a functional IoT trainer and supporting software.

d. Testing:
  1) Perform functional testing for each trainer component (sensors, actuators, communications).
  2) Carry out stress tests to evaluate the performance and stability of the system under various conditions.
  3) Perform security testing to ensure data integrity and protection against unauthorized access.
  4) Testing compatibility with a wide range of devices and operating systems.
  5) Involve student groups in beta testing to get early feedback.
  6) Results: Comprehensive test reports and a list of necessary improvements.

e. Evaluation and Improvement:
  1) Analyze test results and feedback from beta testing.
  2) Make improvements to hardware and software based on findings.
  3) Optimize system performance, including energy efficiency and response speed.
  4) Improve user documentation and supporting materials.
  5) Perform final testing after repair.
  6) Results: Final version of IoT trainers ready to be implemented in the curriculum.

The entire development process is carried out in an iterative cycle, with at least three main iterations to ensure the quality and suitability of the trainer to the learning needs. Each iteration allows for refinements based on new feedback and findings.

The development of the trainer also considers the scalability aspect, allowing for the addition of modules or features in the future without the need to change the underlying architecture. This is important to ensure the relevance of trainers in the long term along with the development of IoT technology.

3 Results and Discussion

3.1 Result

3.1.1. Learning Effectiveness

The following table shows the comparison of pre-test and post-test scores between the experimental group using the IoT trainer and the control group:

Table 1. Comparison of Pre-test and Post-test Scores

Group	Pre-test (Mean)	Post-test (Mean)	Increased
Experiments	65.3	86.5	32.5%
Control	64.8	76.9	18.7%

Table 1 above shows that the experimental group showed an increase in the average score of 32.5%, while the control group only increased by 18.7%. The paired t-test showed that this difference was statistically significant ($p < 0.001$, $t = 7.82$, $df = 58$). The effect size (Cohen's d) was calculated at 1.45, indicating a large effect of the IoT trainer intervention.

The significant increase in the experimental group indicates the effectiveness of IoT trainers in improving students' conceptual understanding of microprocessor systems. Some factors that may contribute to this result include:

a) Visualization of abstract concepts: IoT trainers allow students to see firsthand how microprocessors interact with sensors and actuators, aiding in understanding abstract concepts such as interrupts and I/O.
b) Contextual learning: The use of IoT applications provides real context for students, helping them connect theory with practice.
c) Increased engagement: The interactive aspect of IoT trainers increases student interest and engagement, which is positively correlated with learning outcomes.

3.1.2 Practical Skills

Evaluation of the students' final project showed differences in practical skills between the two groups.

Table 2. Final Project Evaluation

Aspects	Experiments	Control
Self-implementation capabilities	85%	62%
Average complexity score (/10)	8.3	6.7

Table 2 above shows that 85% of the students in the experimental group were able to implement IoT projects independently, compared to only 62% in the control group. The experimental group's projects were on average 24% more complex (8.3 vs 6.7 out of 10). The qualitative analysis of the project showed that the experimental group was more likely to integrate multiple sensors and actuators, as well as implement more sophisticated control algorithms.

The improvement in practical skills in the experimental group can be attributed to several factors:

a) Hands-on experience: IoT trainers provide more opportunities for practical experiments, increasing students' confidence in handling hardware.
b) System understanding: Exposure to a complete IoT system helps students understand the interactions between components, allowing them to design more complex systems.
c) Intrinsic motivation: The ability to create functional projects that are relevant to the real world increases students' motivation to explore further.

3.1.3 Student Motivation and Engagement

The survey results showed differences in student motivation and engagement between the two groups:

Table 3. Motivation Survey Results

Aspects	Experiments	Control
Increased interest in courses	92%	73%
Increase in practicum attendance	15%	2%

Table 3 shows that 92% of students in the experimental group reported increased interest, compared to 73% in the control group. Practicum attendance increased by 15% in the experimental group, while the control group only experienced a 2% increase. Correlation analysis showed a strong positive relationship ($r = 0.78$) between the use of IoT trainers and the level of student engagement in class discussions.

Increased motivation and engagement in the experimental group can be explained through several perspectives:

1. Relevance and applicability: Students see a direct connection between the course material and real-world applications, improving their perception of course value.
2. Engaging learning experience: The interactivity of IoT trainers makes practicum sessions more engaging, encouraging higher attendance and participation.
3. Self-efficacy: Success in completing practical tasks increases students' confidence, encouraging them to be more engaged in learning.

3.1.4 Student Perception

The analysis of semi-structured interviews revealed several key themes related to student perceptions.

Table 4. Main themes of the interview

Theme	Positive Response Percentage
Relevance to the real world	88%
Improved understanding	78%
Technical challenges	35% (having difficulties)

The results of the thematic analysis of the interviews identified three main themes: relevance, understanding, and technical challenges. 88% of students feel that IoT trainers provide relevant real-world context. 78% reported an increase in understanding of microprocessor concepts. 35% experience technical challenges, especially in the early phases of adoption.

Students' positive perception of IoT trainers can be attributed to several factors:

a) Contextualize learning: IoT trainers help students see practical applications of the concepts learned, increasing the perception of relevance.
b) Visualization and interaction: The ability to see and interact directly with a microprocessor system aids in the understanding of abstract concepts.

Development of problem-solving skills: The technical challenges faced, although initially frustrating, contribute to the development of valuable troubleshooting skills.

3.2 Discussion

3.2.1 Learning Effectiveness

The results showed that the experimental group using IoT trainers experienced a significant increase in understanding the concept of microprocessors compared to the control group. This increase can be explained through the theory of constructivism, put forward by Piaget [18] and Vygotsky [19], which states that effective learning occurs when students are actively involved in the learning process and build their own understanding through hands-on experience.

The visualization of abstract concepts offered by IoT trainers supports constructivist principles, where students are able to build a deeper understanding when they can see firsthand the interaction between sensors and actuators with microprocessors. As stated by Bruner [20], active learning with the help of visualization tools can improve students' understanding of difficult and abstract concepts. In this case, the IoT trainer serves as a visual aid that facilitates a deeper understanding of the concept.

3.2.3 Practical Skills

This study also showed that students in the experimental group were able to implement IoT projects that were more complex and independent than the control group. These findings are in line with the experiential learning theory put forward by Kolb [21], where optimal learning occurs when students actively participate in a learning cycle involving concrete experiences, reflection, abstract conceptualization, and active experiments.

IoT trainers provide more hands-on experience to students, which Kolb says is a key element in building practical skills. Students in the experimental group are more confident in handling IoT hardware and systems as a whole because they are involved in a complete learning cycle, from designing to implementing their own projects.

3.2.3 Motivasi dan Keterlibatan Mahasiswa

The significant increase in motivation and engagement in the experimental group showed that the use of IoT trainers created a more engaging and meaningful learning experience for students. Based on the intrinsic motivation theory of Ryan and Deci [22], the use of IoT allows students to feel the relevance of learning materials to the real world, which is an important factor in increasing intrinsic motivation.

According to this theory, when students feel that the tasks they are doing are relevant to real life, they tend to be more motivated to learn. IoT trainers provide real context that helps students relate theory to practice, improving the perception of value from their lecture materials. This is in line with research by Malone and Lepper [23], which stated that fun and relevant tasks can increase intrinsic motivation.

3.2.4 Student Perception

This study also found that most students have a positive perception of the use of IoT trainers. They feel that these tools are relevant to the real world and help them understand the concept of microprocessors better, although some experience technical challenges. According to the situational learning theory of Lave and Wenger [24], learning that occurs in an authentic context and is relevant to real situations is more likely to be understood and applied by students.

The perception that IoT trainers help improve their understanding is in line with the visualization theory of Mayer [25], which states that visualization tools can help students in processing and understanding complex information better, especially if the information is abstract or technical.

From the above analysis, it can be concluded that the use of IoT trainers is not only effective in improving students' conceptual learning outcomes and practical skills, but also in motivating them to be more involved in learning. This is supported by learning theories that prioritize hands-on experience, contextualization, and visualization as effective ways to increase student understanding and engagement.

4 Conclusion

Based on the results of the research and analysis that has been carried out, it can be concluded that the implementation of IoT-based trainers as a learning medium in the Microprocessor System course has a significant positive impact on the learning process and outcomes. The use of IoT trainers has been shown to be effective in improving students' conceptual understanding, with an average score increase of 32.5% in the experimental group compared to 18.7% in the control group. This shows that the hands-on learning approach with IoT technology helps students understand the abstract concepts of microprocessor systems better.

In addition to improving conceptual understanding, this study also shows a substantial development in students' practical skills. As many as 85% of the students in the experimental group were able to implement IoT projects independently, with a higher level of complexity than the control group. This indicates that hands-on experience with IoT technology enhances students' ability to apply theoretical knowledge into practical applications.

The aspects of student motivation and engagement also showed a significant improvement. Most students (92%) reported an increase in interest in the course, which was reflected in the increase in practicum attendance by 15%. Students' positive perception of the relevance of learning to real-world applications (88%) shows that this approach successfully bridges the gap between academic theory and industry practice.

The implementation of IoT-based trainers in microprocessor system learning has proven to be very effective in improving the quality of learning, developing relevant practical skills, and increasing student motivation. This research emphasizes the importance of integrating the latest technology in higher education to prepare students to face the demands of the industry that continues to grow in the era of the Industrial Revolution 4.0. With these positive results in mind, it is recommended that higher education institutions consider adopting a similar approach in their engineering curriculum, while continuing to evaluate and refine them to ensure continued relevance and effectiveness.

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