

Development of a Microcontroller Training Kit to Increase Student Learning Motivation

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Received: 6 January 2025 | Revised: 2 February 2025 | Accepted: 14 February 2025

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ABSTRACT

This research aims to develop a microcontroller training kit to increase students' learning motivation in microcontroller education practices. The research follows a modified ADDIE model (Analysis, Design, Coding, Testing and Validation, Implementation, and Evaluation) involving two experts in the field of educational media, microcontrollers, and 33 vocational education students. The validity test results show that this training device is well suited for curriculum integration, with high scores in technical features, durability, reliability, safety, and design. The average validity score was 0.83. In addition, the motivation assessment showed a significant increase in students' interest, active participation, persistence, learning satisfaction, engagement, and self-confidence. Thus, the development of the microcontroller training kit was proven to be effective in increasing students' motivation to learn. These findings suggest that such innovative and accessible tools can significantly increase engagement and participation in research and contribute to the advancement of educational technology by providing practical solutions that improve students' learning experience and motivation in technical disciplines.

Keywords-microcontroller; training kit; learning motivation; engineering education

I. INTRODUCTION

Education in the digital era requires innovation in the delivery of learning materials, especially in technical disciplines such as microcontrollers. Learning microcontrollers requires a deep understanding of theoretical concepts and hands-on practical experience to ensure optimal comprehension [1]. However, the lack of innovative and engaging learning facilities can hinder students' motivation to actively participate in microcontroller practice [2]. This is a challenge that teachers and students face when integrating microcontroller learning.

Conventional learning is often less engaging, leading to a decrease in student interest and affecting the quality of conceptual understanding. Therefore, it is necessary to develop learning facilities that can increase students' motivation and optimize the learning process of microcontroller practice.

Learning motivation is a key factor that determines a student's success in understanding the subject matter [3-5]. The motivation theory proposed by the authors in [6], emphasizes the importance of the need for autonomy, competence, and social relationships in increasing intrinsic motivation. The research of the authors in [7] showed that motivated students

tend to be more active and have better learning outcomes. However, in microcontroller learning, students' motivation is often underemphasized, hindering their active involvement in learning practices. The results of several studies highlight the importance of instructional design that can motivate learning. Authors in [8] showed that learning motivation plays a crucial role in improving students' learning outcomes, especially in disciplines that require active participation such as microcontrollers. The results of the study emphasize that motivated students tend to have a better comprehension, perseverance, and creativity in solving problems, which are very relevant in the context of microcontroller learning.

Various microcontroller training kits have been developed to enhance students' motivation and understanding of technical disciplines. For instance, microcontroller training kits, such as those studied by the authors in [9], have been widely used to provide hands-on experience in microcontroller programming and circuit design. These kits balance theoretical knowledge with practical application, enabling students to interact directly with hardware components. However, existing microcontroller trainers often lack features that actively engage students or adapt to different learning levels, limiting their effectiveness in maintaining student interest. Another example is the development of modular microcontroller systems, as explored by the authors in [10], that allow for customizable learning experiences. While these systems provide flexibility, they can be complex and expensive, making them less accessible for widespread educational use. In addition, the research by the authors in [11] highlights the effectiveness of low-cost microcontroller platforms, such as Arduino-based trainers, in improving student engagement and learning outcomes. These platforms are praised for their affordability and ease of use, but they often lack advanced features and scalability that are critical for more complex microcontroller applications.

Therefore, this study will complement previous findings by exploring alternative solutions that are more affordable and practical, such as the development of microcontroller trainers. Not only can such trainers be a more accessible solution for students, but they can also be more efficiently integrated into the learning environment without being hampered by device compatibility limitations or high costs. The research gap filled by this study is the lack of attention to student learning motivation in the context of microcontroller practice. The proposed microcontroller trainer aims to provide an authentic hands-on experience and stimulate students' interest and motivation in understanding the concept of microcontroller. Thus, this research fills the gap in the literature by focusing on the student motivation aspect and makes an important contribution to the development of more holistic and effective microcontroller learning facilities. It aims to produce a valid microcontroller trainer to increase students' motivation to learn microcontrollers and open new opportunities for further development in educational technology.

II. METHODOLOGY

The research method applied in this study involves a series of systematic steps modified from the ADDIE development model [12]. These steps are tailored to the research needs to ensure the successful development and implementation of the

microcontroller trainer and to evaluate its impact on student learning motivation. The research procedure is illustrated in Figure 1.

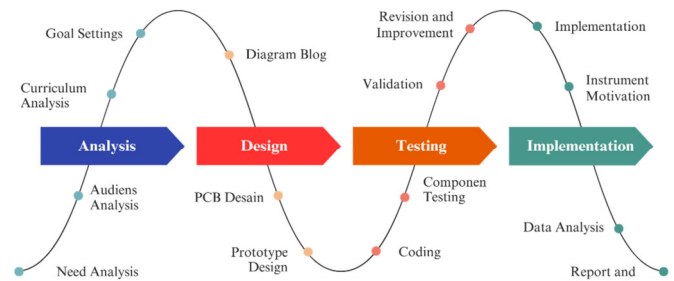


Fig. 1. Research procedure.

This research begins with a needs analysis stage where specific needs in learning microcontroller practices are identified. This stage includes evaluation of the needs analysis, discussion with teachers, and curriculum review to determine crucial aspects that need to be covered by the microcontroller trainer. The research continued with the design stage, namely the initial concept design, by creating a blog diagram in the form of a concise image. Based on the blog diagram, a PCB design was created using Corel Draw software to create an overview of the PCB board, and a 3D display design was continued using Sketchup software. The next stage is the coding stage, which is the application of the design concept to a functioning microcontroller trainer. The coding process using the C programming language is done using the Arduino IDE software. The testing stage is the next critical stage in this study. The built microcontroller trainer must be evaluated and validated by experts to see if it meets the learning needs. The instrument used is a validation questionnaire with a Likert scale. The test results are used to correct any deficiencies that may arise. Furthermore, the microcontroller trainer is implemented in a real learning environment as part of the implementation stage. Students involved in the microcontroller practice use the trainer and the learning process is monitored to observe changes in their learning motivation. After the implementation, an evaluation was conducted to determine whether using the microcontroller trainer could improve students' learning motivation. The students involved in using the microcontroller trainer were given an instrument in the form of a motivation questionnaire to be filled out according to the learning experience provided.

A. Research Subject

This research involves the collaboration of two experts with extensive expertise in learning media and microcontrollers to test the validity of the developed microcontroller trainer. The experts were selected based on specific criteria, including academic qualifications, professional experience, and relevance to the study. Both experts have Ph.D. degrees and are professors of educational technology and electronics engineering, with more than 15 years of professional experience in their respective fields. The first expert is a professor in educational technology with more than 15 years of experience in the design and validation of innovative learning

media. His research focuses on the integration of technology in vocational education, making him highly relevant to the development and validation of the microcontroller trainer. The second expert is a senior lecturer with a Ph.D. and extensive experience in microcontroller programming and hardware design. He has been involved in numerous projects developing hands-on training tools for technical education and thus provides valuable insights into the technical aspects of the microcontroller trainer. In addition to the validity test, this study also evaluated the effectiveness of the microcontroller trainer in increasing student learning motivation. After using the trainer, a motivation questionnaire was developed and administered to 33 students from Painan Vocational High School 5 to measure changes in their interest, perseverance, and creativity in understanding microcontroller concepts. The collaboration between these experts ensures a comprehensive evaluation of the microcontroller trainer and contributes to the development of a more effective tool for improving student learning outcomes.

B. Instruments and Data Analysis

This study employs two instruments: a validation questionnaire and a motivational questionnaire. The validation instrument is used to assess the validity of the microcontroller trainer, whereas the motivational instrument evaluates its impact on students' learning motivation. The validation process involves two experts in microcontroller technology and educational media. These experts were provided with the prototype of the microcontroller trainer and a detailed validation questionnaire, structured based on indicators from previous studies [13-20]. The questionnaire assesses five key aspects, which are presented in Table I.

TABLE I. VALIDITY INSTRUMENT INDICATORS

Indicator	Item no.
Curriculum coherence	1,2,3
Technical functionality	4,5,6,7
Durability & reliability	8,9,10,11,12
Security	13,14,15,16
Design	17,18,19,20

Each expert independently evaluated the prototype by testing its functionality, examining its design, and assessing its alignment with educational standards. The evaluation process included hands-on testing of the trainer's hardware and software components and a review of its instructional materials. The experts recorded their ratings using a Likert scale (1 = strongly disagree to 5 = strongly agree) for each item in the questionnaire. The validity of the microcontroller trainer was then calculated using Aiken's validity coefficient formula, as shown in (1).

$$V = \sum S / [n(c - 1)] \quad (1)$$

where $\sum S$ is the number of scores from experts, n is the number of experts, and c is the rating scale. A validity coefficient V greater than 0.6 indicates that the trainer meets the validity criteria presented in Table II.

Furthermore, a motivational instrument was used to evaluate the impact of microcontroller trainers on students'

learning motivation. This motivation questionnaire was designed considering several factors that have also been used in several previous studies [21-28]. The indicators used are presented in Table III.

TABLE II. VALIDITY CRITERIA

Criteria	Decision
>0.6	Valid
<0.6	Invalid

TABLE III. LEARNING MOTIVATION INSTRUMENT INDICATORS

Aspects	Indicator
Interest and enthusiasm	1,2,3,4
Active participation	5,6,7
Determination and perseverance	8,9,10,11
Satisfaction with learning	12,13,14
Engaging learning	15,16,17
Confidence	18,19,20

Students were given a hands-on task using the microcontroller trainer, followed by a debriefing session to ensure they understood its functionality. They then completed the questionnaire, rating their experience on a Likert scale (1 = strongly disagree to 5 = strongly agree). The data collected were analyzed using the formula shown in (2).

$$NA = \frac{S}{S} \times 100\% \quad (2)$$

where S is the total score received by the student and M is the maximum possible score. The NA value is used to categorize the student's level of motivation based on the criteria determined in Table IV.

TABLE IV. CATEGORIES OF LEARNING MOTIVATION LEVEL

Motivation level	Category
85-100	Very effective
75-84	Effective
60-74	Quite effective
55-59	Less effective
0-54	Ineffective

The evaluation tools and techniques included the microcontroller trainer prototype, validation and motivation questionnaires, and a testing environment equipped with the necessary hardware and software. This comprehensive validation process ensures that the microcontroller trainer is technically sound, educationally effective, and provides valuable insights for further development and implementation.

III. RESULTS

A. Design

The first step involves the creation of a blog for the microcontroller trainer, which serves as the fundamental guide for its workflow. The diagram blocks created for this purpose are shown in Figure 2. This diagram outlines the architecture and main components used in the microcontroller trainer, illustrating the relationship between the various components, input devices, and outputs connected to the Arduino UNO

microcontroller. It shows how each element connects to the Arduino UNO and works together to create an interactive and practical learning environment. The combination of input and output devices allows students to understand and apply the concept of microcontrollers in various practical scenarios.

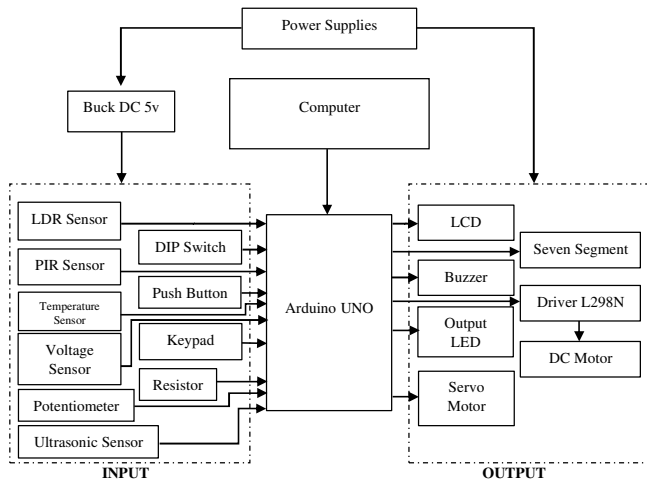


Fig. 2. Microcontroller trainer block diagram.

Based on the block diagram, the following PCB board design was initially created to connect the entire electronic assembly of the microcontroller trainer. This design was created to allow students to directly access and manipulate a variety of sensors and actuators so that they can learn and experiment with microcontroller concepts in a safe and structured environment. These boards are designed to support hands-on learning by providing all the necessary components in one easy-to-use unit. The design of the microcontroller trainer PCB board is shown in Figure 3.



Fig. 3. PCB board top layer design.

From the block diagram, the equipment used, and the design of the top layer of the PCB board, a 3D drawing was created. The design was created using SketchUp software and the entire process was carried out by detailing each functional element to achieve the learning objectives. Each element and feature was

adjusted to the block diagram to obtain the design results, as shown in Figure 4.

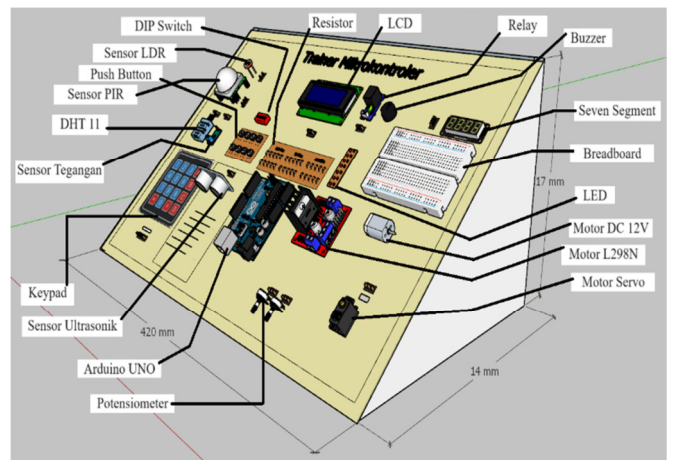


Fig. 4. Microcontroller trainer design.

B. Coding

In the coding phase, the microcontroller trainer is assembled to run as required, according to the design. The code used to test the temperature and humidity sensor is as follows.

```
#include "DHT.h"
#define DHTPIN 2
#define DHTTYPE DHT11 // DHT 11
#define DHTTYPE DHT11 // DHT 22 (ALM2302), ALM2321

DHT dht(DHTPIN, DHTTYPE);
void setup() {
  Serial.begin(9600);
  Serial.println("DHTxx test!");
  dht.begin();
}

void loop() {
  delay(500);
  float h = dht.readHumidity();
  float t = dht.readTemperature();
  float f = dht.readTemperature(true);
  if (isnan(h) || isnan(t) || isnan(f)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }
  float hif = dht.computeHeatIndex(f, h);
  float hic = dht.computeHeatIndex(t, h, false);
  Serial.print("Humidity: ");
  Serial.print(h);
  Serial.print(" %\t");
  Serial.print("Temperature: ");
  Serial.print(t);
  Serial.print(" *C ");
  Serial.print(f);
```

```
Serial.print(" *F\t");
Serial.print("Heat index: ");
Serial.print(hic);
Serial.print(" *C ");
Serial.print(hif);
Serial.println(" *F");
}
```

C. Testing

Once the coding is complete, the next step is to test various sensors used in the microcontroller trainer, one of which is the temperature and humidity sensor, by applying a temperature rise stimulus. The test is shown in Figure 5.

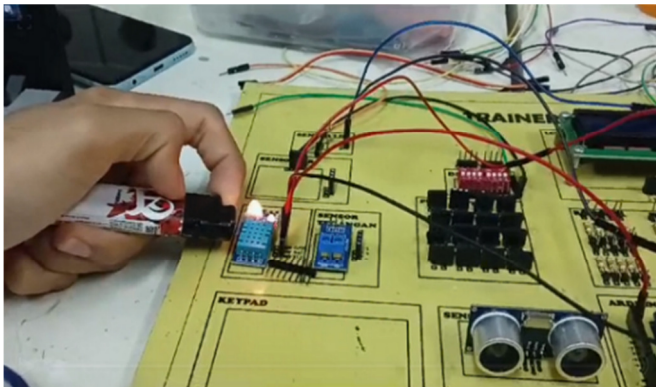


Fig. 5. Temperature sensor testing.

When the temperature rise stimulus is applied, the monitor shows a gradual temperature increase corresponding to the temperature of the stimulus applied. The display of the test results is shown in Figure 6.

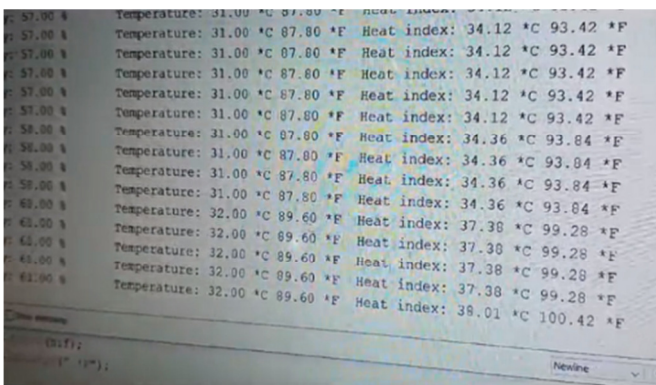


Fig. 6. Temperature sensor test results.

After confirming that the sensors were working well, the trainer underwent a validity test by two experts in the field of microcontrollers and educational media, respectively. The purpose of this test is to ensure the quality and relevance of this learning tool in the context of microcontroller learning. The evaluation results for each aspect provided by the validator were analyzed using Aiken's V statistical formula. The results of the validation process are presented in Table V.

TABLE V. VALIDITY TEST SUMMARY

Indicator	Validator		Average
	1	2	
Curriculum coherence	0.78	0.82	0.80
Technical functionality	0.88	0.85	0.87
Durability & reliability	0.80	0.84	0.82
Security	0.77	0.79	0.78
Design	0.90	0.86	0.88
Result			0.83

Several key indicators were assessed by the validators. Curriculum coherence has an average score of 0.80, indicating that the microcontroller trainer is aligned with the respective curriculum and can support the learning objectives. Technical functionality received the highest average score of 0.87, indicating that the trainer works correctly and meets the expected technical specifications. Durability & reliability received an average score of 0.82, indicating that the trainer is durable and reliable enough for long-term use. For safety, the trainer received an average score of 0.78, indicating that the trainer is safe enough to use, but that there is room for improvement. The design indicator received an average score of 0.88, indicating that the trainer's design is excellent and appealing to users. Overall, the average score of all indicators is 0.83, indicating that this microcontroller trainer is valid and suitable for learning purposes. These results show that the trainer meets the technical and curriculum requirements, has an attractive design, and is relatively safe to use. However, further improvements in the safety aspect can improve the quality of the trainer even more. The final appearance of the trainer is shown in Figure 7.

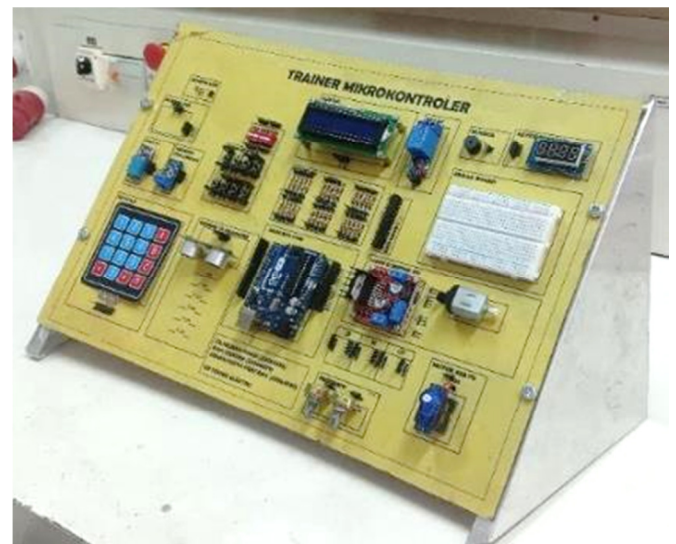


Fig. 7. Microcontroller trainer.

D. Implementation

A valid microcontroller trainer was implemented in a microcontroller learning session to evaluate its effectiveness in increasing student motivation. This study involved 33 students from Painan 5 Vocational High School, whose demographic details are presented in Table VI. The participants consisted of

18 male and 15 female students, aged 16-18 years, all enrolled in an electrical engineering program. After completing the learning session using the microcontroller trainer, the students

were given a motivation instrument to assess the impact of the trainer on their learning motivation. A summary of the results is presented in Table VII.

TABLE VI. PARTICIPANT DEMOGRAPHICS

Category	Details	No. of students	Percentage (%)
Total participants		33	100
Gender	Male	18	54.5
	Female	15	45.5
Age	16	10	30.3
	17	15	45.5
	18	8	24.2
Educational background	Electronics engineering program	33	100

TABLE VII. LEARNING MOTIVATION DATA

Aspects	Item no.	Questionnaire item	Avg. score (S)	Max. score (M)	NA (%)	Category
Interest and enthusiasm	1	I find learning with the microcontroller trainer enjoyable.	138	165	83.6	Effective
	2	I am excited to participate in microcontroller learning sessions.	142	165	86.1	Very effective
	3	I look forward to using the microcontroller trainer in future lessons.	135	165	81.8	Effective
	4	I feel more interested in learning microcontrollers after using the trainer.	140	165	84.8	Effective
Average for interest and enthusiasm					84.1%	Effective
Active participation	5	I actively engage in tasks during microcontroller learning.	148	165	89.7	Very effective
	6	I contribute ideas during group activities.	145	165	87.9	Very effective
	7	I ask questions when I don't understand something.	138	165	83.6	Effective
The average for Active Participation					87.1%	Very effective
Determination and perseverance	8	I persist in solving problems even when they are challenging.	128	165	77.6	Effective
	9	I complete tasks thoroughly and on time.	132	165	80.0	Effective
	10	I stay focused during learning sessions.	125	165	75.8	Effective
	11	I am determined to master microcontroller concepts.	130	165	78.8	Effective
Average for determination and perseverance					78.1%	Effective
Satisfaction with learning	12	I am satisfied with the learning methods used in the microcontroller trainer.	138	165	81.8	Effective
	13	I feel that the microcontroller trainer helps me understand the material better.	142	165	83.6	Effective
	14	I would recommend this trainer to other students.	145	165	86.1	Very effective
Average satisfaction with learning					83.8%	Effective
Interesting learning	15	I find the tasks and activities with the microcontroller trainer engaging.	142	165	87.9	Very effective
	16	The trainer makes learning more fun and interactive.	148	165	86.1	Very effective
	17	I enjoy the hands-on experience provided by the trainer.	122	165	89.7	Very effective
Average for engaging learning					87.9%	Very effective
Self-confidence	18	I feel confident in my ability to use microcontrollers after using the trainer.	125	165	73.9	Quite effective
	19	I believe I can solve microcontroller-related problems on my own.	120	165	75.8	Effective
	20	I feel prepared to tackle more advanced microcontroller tasks.	138	165	72.7	Quite effective
Average for confidence					74.1%	Quite effective

The results of the motivation questionnaire analysis showed that using the microcontroller trainer significantly increased students' learning motivation in various aspects. In the interest and enthusiasm aspect, the average NA value was 84.1% with the effective category, indicating that students felt more interested and enthusiastic in learning microcontrollers after using this trainer. Items such as "I find learning with the microcontroller trainer enjoyable" and "I am excited to participate in microcontroller learning sessions" received high scores of 83.6% and 86.1%, respectively, reflecting students' increased interest.

The active participation aspect had the highest average NA, 87.1%, with the very effective category. This indicates that students are more actively involved in learning, as evidenced by the item "I actively engage in tasks during microcontroller learning," which scored 89.7%. In addition, the engaging learning aspect also achieved an average NA of 87.9% with the very effective category, with the item "I enjoy the hands-on experience provided by the trainer" scoring the highest (89.7%). This indicates that students enjoy the interactive and hands-on learning experience the trainer provides.

In the determination and perseverance aspect, the average *NA* of 78.1% with the effective category reflects that students show perseverance and determination in completing tasks. Items such as "I persist in solving problems even when they are challenging" scored 77.6%, indicating that students can face challenges well. Meanwhile, the satisfaction with learning aspect achieved an average *NA* of 83.8% with the effective category, with the item "I would recommend this trainer to other students" scoring 86.1%. This indicates that students are satisfied with the learning method used.

However, the confidence aspect had the lowest average *NA*, 74.1%, in the quite effective category. Although the item "I believe I can solve microcontroller-related problems on my own" scored 75.8% in the effective category, other items such as "I feel confident in my ability to use microcontrollers after using the trainer" scored only 73.9%. This shows that although the trainer was successful in increasing students' confidence, there is still room for improvement.

Overall, these results indicate that the microcontroller trainer effectively increases students' learning motivation, especially in terms of interest, active participation, and engagement in learning. However, further efforts are needed to improve students' confidence in mastering more complex microcontroller concepts.

IV. DISCUSSION

The results of the microcontroller trainer validity test show that this tool is of good quality and suitable for use in the learning process. Indicators such as curriculum suitability, technical functionality, durability and reliability, safety, and design all received quite high scores. The overall average validity score is 0.83, which indicates that this trainer not only meets the needs of the curriculum, but also has a good design and optimal functionality. However, the safety aspect with a score of 0.78 indicates that although it is quite safe, there is still room for further improvement in ensuring user safety while using this trainer.

The results of the learning motivation test demonstrated that the microcontroller trainer significantly increased student motivation by making microcontroller learning more engaging, interactive, and fun. Students showed increased interest and enthusiasm, actively participated in tasks, and demonstrated determination and perseverance in overcoming challenges, reflecting the trainer's ability to foster a dynamic and collaborative learning environment. The high level of satisfaction and the fun, hands-on nature of the trainer further underscored his effectiveness in meeting students' learning needs. However, while the trainer excelled at increasing engagement and practical skills, it revealed an area for improvement in building students' confidence to tackle more advanced tasks. Overall, the trainer proved valuable in increasing motivation and creating a positive learning experience. However, future development should focus on strengthening students' confidence in handling complex challenges.

The results of this study are consistent with the findings of several previous studies that have developed training kits to

increase student motivation to learn. Like the research of the authors in [29] who developed a trainer kit for learning digital circuits, the results of the study show that the use of training can increase students' motivation to learn and affect students' performance. In line with the study, the results of the research conducted by the authors in [30], revealed that trainer kits can improve students' abilities, individual inventive behavior, and skills, so that they can be considered as learning media used in the era of the Industrial Revolution 4.0. Thus, the results of the research conducted by the authors in [31], reveal that trainer kits can be an effective learning medium to improve students' learning performance at a more economical cost than the use of the latest technologies, so that the use of trainer kits reaches different economic levels of students.

Although the results indicate that microcontroller trainers are effective in increasing students' learning motivation, several limitations need to be considered. First, the security aspect still needs to be improved to ensure optimal safety for users. Second, the study is limited to a specific sample of students and may not reflect the broader student population. Therefore, further studies are needed to test the effectiveness of these trainers in various educational contexts and with a more diverse sample. In addition, further research can explore the integration of other advanced technologies and see their impact on student motivation and learning outcomes. Thus, it is hoped that future research can strengthen these findings and provide a more holistic and inclusive solution to microcontroller learning.

V. CONCLUSION

This study demonstrates that the development of microcontroller trainers effectively increases student motivation to learn microcontrollers. With high validity in the aspects of curriculum coherence, technical functionality, durability and reliability, security, and design, as well as a positive impact on various aspects of students' learning motivation such as interest, active participation, determination, satisfaction, and confidence, this microcontroller trainer can be considered an innovative and practical learning tool. The implications of these findings suggest that the use of this type of trainer can be an effective solution for overcoming the challenges of student motivation and engagement in disciplines that require hands-on practical involvement, making an important contribution to the development of more interactive and effective learning methods in the digital era.

ACKNOWLEDGEMENT

We would like to thank the Center for Higher Education Funding and Assessment Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, Education Fund Management Agency (LPDP) and, Indonesian Education Scholarship (BPI).

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