Online-Journals.org

iJOE International Journal of Online and Biomedical Engineering

iJOE | eISSN: 2626-8493 | Vol. 21 No. 11 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijoe.v21i11.56391

PAPER

Mobile Robotics Training Kit: Enhancing Learning Achievement, Practical Skills, and Problem-Solving Skills of Industrial Electrical Engineering Students

Herlin Setyawan[1],
Sukardi[1] (✉),
Risfendra[1],
Tee Tze Kiong[2],
Krismadinata[1], **M. Giatman**[1]

[1]Universitas Negeri Padang, Padang, Indonesia

[2]Universiti Tun Hussein Onn Malaysia, Johor, Malaysia

sukardiunp@ft.unp.ac.id

ABSTRACT

The complexity of microcontroller learning that must combine theoretical concepts and real practices makes it difficult for many students to master the competencies of microcontroller control systems. In addition, it is difficult to achieve practical skills that students must master without a training kit that can interpret the application of microcontroller control systems. Thus, the purpose of this study is to examine the effectiveness of mobile robotic training kits to improve student learning achievement, practical skills, and problem-solving skills. This study used a mixed method with a sequential explanatory design, combining true-experimental research with semi-structured interviews. It involved 76 participants, divided into 38 experimental groups and 38 control groups selected at random. The results of this study show that the mobile robotic training kit is significantly effective in improving students' learning achievement, practical skills, and problem-solving skills in the field of microcontroller control systems. This study provides empirical evidence of the importance of implementing a mobile robotics training kit in the learning process to improve students' competencies and prepare them with competencies relevant to the needs of the world of work.

KEYWORDS

training kit, learning achievement, practical skills, problem solving skills, vocational education, quality education

1 INTRODUCTION

Industrial electrical engineering education faces significant challenges in preparing students with competencies relevant to the needs of industries that increasingly use highly complex technology. Since the Industrial Revolution 4.0, industries have increasingly used automation and robotics-based technology to carry out

Setyawan, H., Sukardi, Risfendra, Kiong, T. T., Krismadinata, Giatman, M. (2025). Mobile Robotics Training Kit: Enhancing Learning Achievement, Practical Skills, and Problem-Solving Skills of Industrial Electrical Engineering Students. *International Journal of Online and Biomedical Engineering (iJOE)*, 21(11), pp. 4–27. https://doi.org/10.3991/ijoe.v21i11.56391

Article submitted 2025-06-02. Revision uploaded 2025-07-02. Final acceptance 2025-07-02.

the production process. Both of these control systems use microcontrollers as the core of the controller (the brain in a machine) [1], [2]. Thus, to produce graduates ready to face these challenges, they must master the microcontroller control system. To master this control system, students must master the knowledge and skills of both system design (electrical and electronic systems), microcontroller programming, and manufacturing microcontroller-based systems according to their functions [3], [4]. Therefore, the learning must also be contextualized according to industry needs to produce competent graduates. From the results of the teaching, students not only master knowledge and skills but can indeed create a system that is to industry needs [5]. In this context, microcontroller learning must combine theory and structured practice so that students feel the direct impact of applying the concepts they learn.

In addition to the knowledge and practical skills that vocational students must possess to build a microcontroller control system, problem-solving skills are also one of the skills that students must master to overcome complex problems in the system. In the era of Industrial Revolution 4.0, students are not only required to master knowledge and practical skills, but they must also be able to identify and solve problems that arise in a complex system [6], [7]. Through problem-solving skills, students can identify maladies, generate solutions to problems, and perform and evaluate the problems they have overcome [8]. To master these skills, the learning process cannot be theoretical. However, it must actively involve students and put them in hands-on learning situations that require them to think critically, creatively, and analytically when dealing with real problems [9]. Through this learning process, students can hone their knowledge and practical skills and train themselves to think systematically and develop essential problem-solving skills [8]. With these skills, students will be better prepared to face the challenges of the dynamic industrial world and adapt to the ever-evolving technological demands in the era of the Industrial Revolution 4.0 [10].

However, in the learning process, students often have difficulty understanding microcontroller learning materials that are very complex, ranging from circuits, programming, and direct testing [11]. The basic theory of control systems, input/output processes, programming, and signal management is very complex and not easily understood with a theoretical approach in the classroom. Without concrete applications, students often have difficulty understanding theoretical concepts, which results in low student achievement [12]–[14]. In this learning, students not only master knowledge but also have to master practical skills in assembling circuits, programming microcontrollers, and operating and integrating various electronic components [15]. To master skills, educational institutions often experience difficulties, such as the unsuitability of the practicum equipment used. Often, the practicum tools used can only train programming but cannot train electronic circuits because the nature of the practicum tools used is finished, and students can only program them. This will result in low practical skills obtained by students who initially had to master the electronic circuit of input and output integration, programming, and system testing; however, with learning tools (training kits), these skills cannot be learned by students as a whole [5], [11].

This problem is crucial because the training kit used is too simplified by educators, making students not get concrete learning, which lowers students' technical skills and problem-solving skills. After all, it does not get students used to analyzing problems from scratch [16], [17]. As [18] described, an effective microcontroller training kit for learning should include practical, hands-on experiences that allow students to interact directly with hardware and software components. Training kits should allow students to explore and experiment with real-world applications and scenarios [19], [20]. To overcome this problem, a more applicable microcontroller training kit is designed to involve students directly in the learning process and can directly apply microcontroller control systems in real applications. This study is urgently needed considering the rapid development of technology and the need for a competent workforce in microcontroller control systems that understand knowledge, practical skills, and problem-solving skills. Microcontrollers are core components in automation systems, robotics, and other intelligent controls widely used in various industries [1], [2]. Industrial electrical engineering students must master microcontroller control system competence to compete in an increasingly competitive job market.

Based on this background, this study offers an innovative solution: designing a mobile robotics training kit that can be used in the microcontroller learning process. This training kit can be applied to a microcontroller control system as a robotics system. Three types of robots can be applied: line followers, wall tracers, and robots that can be controlled from a smartphone via Bluetooth. In addition, this training kit can be used for basic microcontroller learning by students. With this concept, this training kit can make students more active and explore the real application of microcontrollers. Thus, there are three specific objectives in this study: (1) testing the effectiveness of the mobile robotics training kit to improve student learning achievement, (2) testing the effectiveness of the mobile robotics training kit to improve student practical skills, and (3) testing the effectiveness of the mobile robotics training kit to improve the problem-solving skills of industrial electrical engineering students in the field of microcontroller control systems.

2 LITERATURE REVIEW

Some previous researchers have developed various training kits that can be used in learning microcontrollers or embedded systems to improve learning quality, as shown in Table 1. From the literature study results, there are generally three types of learning tools (training kits) used in the microcontroller learning process: simulation applications, portable training kits, and robotics training kits. First, using simulation applications has been proven to improve student programming skills, but learning can only be done virtually by using simulation applications (tinkercad). So, the limitations of this learning practical skills that students must master are not well mastered by students [11]. Second, some researchers use portable training kits, where this training kit can be used for learning the basic concepts of microcontroller-based control systems, such as the operation of inputs and system outputs. The development of portable training kits has been carried out in various fields of control systems that are growing rapidly at this time, namely the Internet of Things (IoT) control system [12], [13], [21], and artificial intelligence (AI) [14]. From the results of the development that has been carried out, this training kit has also proven to be well used in the learning process and tested valid, practical, and effective for increasing student knowledge, satisfaction, and confidence.

Table 1. Summary of previous relevant research

Technology Applied	Research Results
Mobile robotics training kit (wall follower) [22]	Positive impact on students' intellectual ability and learning satisfaction
Simulation application (Tinkercad application) [11]	Improve students' programming skills
Lego Mindstorm robot training kit [23]	Cultivate logical thinking and improve students' understanding of technical operations
Portable training kit (IoT system) [12]	Increase student satisfaction and confidence
Mobile robotics training kit (wall follower and wall follower) [24]	Improve student engagement in robotics and technical literacy
Mobile robotics training kit (ROS-based omnidirectional) [25]	An open-source robotic device that can be used in university learning
Lego Mindstorm robot training kit [26]	Improve students' practical skills, motivation, and self-directed learning
Mobile robotics training kit (wall follower) [27]	Positive impact on student engagement, motivation and satisfaction
Mobile robotics training kit (wall follower) [28]	Improve students' logical thinking, problem-solving skills, and communication skills
Portable training kit (IoT system) [13]	The training kit is categorized as valid and practical for use in the learning process and effective for increasing student knowledge
Portable training kit (IoT system) [21]	Improve student knowledge
Portable training kit (Artificial Intelligence System) [14]	The results of laboratory tests (training kits can work according to their functions) also categorize training kits as valid, very practical for use in the learning process, and effective for improving student knowledge
Mobile robotics training kit (wall follower) [5]	Improve student knowledge

Third, several researchers have developed microcontroller training kits or embedded systems for mobile robotics applications. Currently, some researchers use mobile robotics from Lego Mindstorm, which is already in the form of modules of robotics components [23], [26]. Lego Mindstorm robots have also been shown to improve students' practical skills, motivation, and independent learning and foster logical thinking. However, at the university level, using this tool has the disadvantage that the components are already provided as finished packaging (modules). Students only combine one module with another. At the university level, students must directly understand the design, components, assembly, programming, and testing [29], [30]. To overcome this gap, researchers have developed training kits in the form of line-follower robots that work to follow lines and wall-follower robots that work to follow walls. Students can assemble robotic systems, including mechanical and electronic circuits and robotic programming, using this robot. The results also show that this training kit can improve students' knowledge, engagement, motivation, technical skills, technical literacy, problem-solving skills, logical thinking, and communication [5], [22], [24], [27], [28].

In addition to line follower and wall follower robots, there is also a study that develops a robotic mobile training kit based on the Robot Operating System (ROS), where this robot can move by mapping the conditions of the room around it [25]. The study results show that the robot developed is open source in that anyone can make it by following the guidelines in the paper [25], and it has been tested to be used in learning processes at the university level. Based on the results of the literature study, it is known that the robotic mobile training kit developed at the university level must be able to work autonomously using line guides, walls, and even the most sophisticated ones swarm by mapping the room directly. From the results of various studies that have been conducted, there are still various limitations, namely that the training kit developed can be used by students who already have basic competencies in the field of microcontrollers or embedded systems so that students starting from the basics cannot use it [24], [25]. Based on the reviewed studies, there are limitations, such as only assessing practical skills in the programming element, but the mechanical and electronic circuit elements are not assessed [11], [26]. In addition, problem-solving skills that students need to solve complex problems systematically in the field of microcontroller control systems are still few researchers who study them [28].

Based on previous studies, the novelty offered in this study is a mobile robotic training kit that can interpret the microcontroller control system from the basics to the application of the system. So, basic learning of microcontrollers, namely understanding microcontroller input and output devices for real applications in robotics systems, can be done. So that students who do not have the initial skills and knowledge and students who already have good competence can use this training kit in the learning process. Three types of robots can be applied: line follower robots, wall followers, and robots controlled from smartphones via Bluetooth. Thus, this training kit has a high flexibility in practicum projects and basic understanding. So that using this training kit can cover all the learning material that students will study during one semester, not only focusing on one learning topic. In addition to focusing on the training kit applied, novelty is also raised in the topic of study, namely examining the impact of using a mobile robotic training kit to improve learning achievement (knowledge), practical skills of microcontrollers as a whole, and problem-solving skills of students in the field of microcontroller control systems.

3 RESEARCH METHODS

3.1 Research design

This study uses a mixed-methods approach with a sequential explanatory design that combines quantitative and qualitative data in a single study [31]. The study was conducted in two stages. The first stage involved collecting quantitative data to gather numerical data on students' knowledge, practical skills, and problem-solving abilities. The second stage involved qualitative data collection, which aimed to explore and deepen the findings from the quantitative data through semi-structured interviews with students. In the first stage, the researcher used a true-experimental pretest-posttest control group design, where two groups were used in the study: the experimental group (receiving treatment) and the control group (not receiving treatment). A simplified version of the study design used is shown in Figure 1. This study method demonstrates a cause-and-effect relationship between independent and dependent variables through strict control of external factors. By randomly allocating participants into experimental and control groups, the effects of independent variables can be isolated while minimizing research bias [32].

3.2 Research participation

This study involved four diploma students (Bachelor's degree) majoring in industrial electrical engineering at the faculty of engineering at the Universitas Negeri Padang in Indonesia, as well as 76 students, consisting of 24 (31.58%) female and 52 (68.42%) male students. To determine the number of test subjects in true-experiment research, there is no minimum size that must be met, but several previous studies suggest a minimum of 15 test subjects in both the experimental and control classes [32], [33]. The process of dividing the experimental and control groups is randomized so that all students have an equal opportunity to enter the research group, which can reduce selection bias and allow for more reliable causal inference about the effects of the intervention group [34].

The process of randomizing the sample was done by giving a sequential number to all students ranging from 1 to 76, and the purpose of this study was to blind students to reduce the effects of bias. Students who get odd numbers are included in the experimental group (N = 38), and students who get even numbers will be included in the control group (N = 38). All students in the study did not yet have knowledge and skills about microcontroller-based control systems. They only know the introduction and basic electronic control systems learned in previous courses in the first and second semesters. The researcher determined that the students were majoring in industrial electrical engineering. They had obtained research approval from the dean or chairman of the Faculty of Engineering, Universitas Negeri Padang, with letter number 1961/UN35.2.1/LT/2024. All students have agreed to participate in the research for one whole semester. The lecturer assigned to teach in the experimental class has agreed to participate in the study and use the mobile robotics training kit developed in the learning process. Likewise, the lecturer assigned to teach in the control class has also agreed to participate in the research.

3.3 Research procedure

This study was conducted for one semester, consisting of 16 meetings in a formal classroom environment. There was one meeting per week for 210 min per meeting. The study was conducted in a formal learning process as usual, without opening a special class for research, in both the experimental and control groups. In week 1, the study was carried out by dividing the group into two groups: experimental and control groups. Week 2 assessed the student's learning achievement, practical skills, and problem-solving skills before the study. Pre-test research was conducted to determine the initial skills and knowledge possessed by students, thus allowing the study to measure the impact of the treatment by comparing the initial and post-assessments [35].

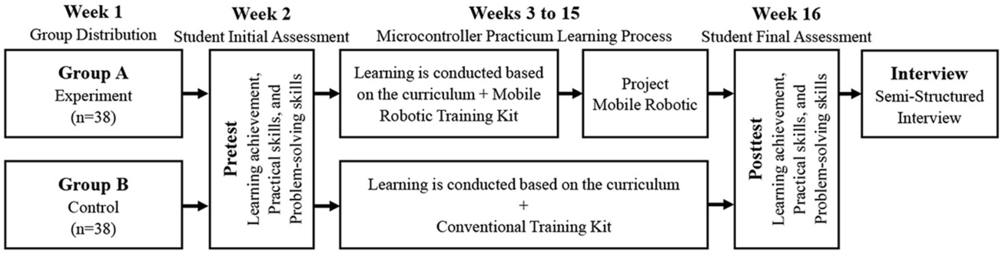

Fig. 1. Research implementation procedure

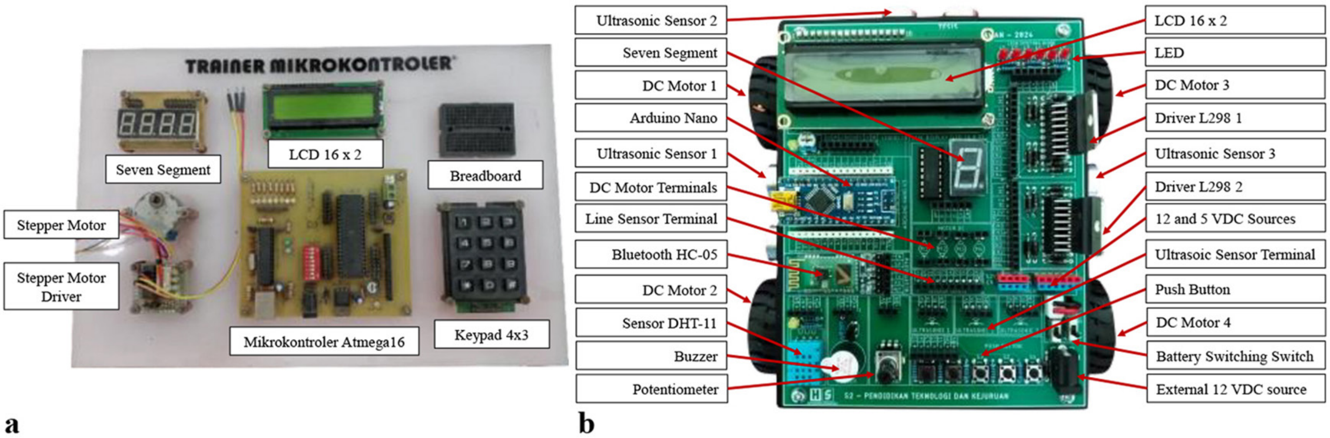

Fig. 2. a. conventional training kit, b. mobile robotic training kit

The microcontroller practicum learning process was carried out from weeks 3 to 15 using the same learning topics in the experimental and control groups, but they received different treatments. The control group used a conventional training kit previously used in the microcontroller practicum learning process, as shown in Figure 2a. Based on the results of previous research, such training kits can significantly increase student knowledge [13], [21]. However, the experimental class uses a mobile robotic training kit with an Arduino nano microcontroller, as shown in Figure 2b. The researcher developed this training kit to be applied in the process of learning a microcontroller practicum with an applicative concept. The developed training kit can be used in various applications. First, this training kit was used by students to learn the basic concepts of microcontroller programming with various integrated input and output devices. In addition, through this training kit, students conduct a practicum by applying microcontroller control systems in robotic systems such as line follower robots, wall tracers, and mobile robots that can be controlled via smartphones. With this concept, the application of microcontroller control systems can be explored directly by students so that learning will be centered on students and student competence can be improved [36].

For 13 weeks, the learning topics that students will study consist of six main topics. In week 3, students will learn the basics of the microcontroller control systems and the components used. In weeks 4 to 5, students will learn programming and the installation of microcontroller digital input and output components. Here, students will learn how to control digital inputs and outputs connected to the microcontroller. Week 6 to 7 students will learn the basics of programming and installation of analog inputs and programming and installation of outputs that use PWM (pulse width modulation). Weeks 8 through 10, students learn serial microcontroller communication using a universal asynchronous receiver/transmitter (UART), I2C (inter-integrated circuit), and serial peripheral interface (SPI). In weeks 11 to 12, students learn the programming algorithm of branching microcontrollers to be used as an integrated control system.

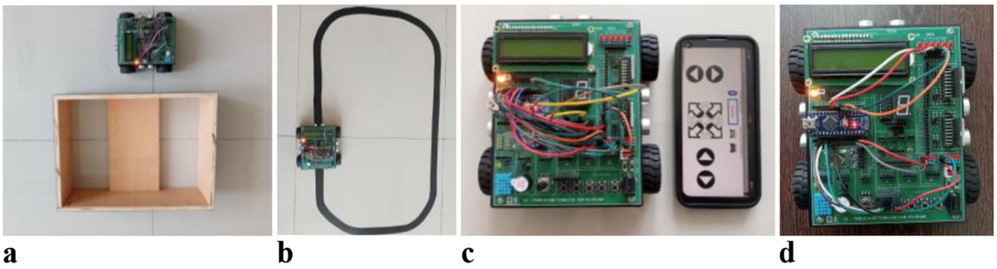

Fig. 3. Application of mobile robotic training kit: a. used as a wall tracer robot, b. used as a line follower robot, c. used as a robot controlled by a smartphone, d. used in basic microcontroller practicum

From the 13th to the 15th week, students create a project to implement a microcontroller control system in an industry using the learning they have done before. This aims to monitor the maturity of knowledge and skills owned by students and can be applied in real applications. Here, there are differences in application between the experimental control group. The experimental group of tools used in the learning process can already be used directly to apply microcontroller control systems to a robotics system, while the control group of tools used can only simulate the system made by students. Robots that can be used with mobile robotics training kits include line-following robots, wall-following robots, and robots that can be controlled using smartphones, as shown in Figure 3. After completing the learning process, in week 16, a posttest will be conducted to determine learning achievements, practical skills, and problem-solving skills in microcontroller control systems that students have mastered. At the end of the study, semi-structured interviews were conducted with students in the experimental group to evaluate their learning experiences while using the mobile robotics training kit.

Meanwhile, in the control group, learning was conducted based on the material outlined in the applicable curriculum, namely (1) basic concepts of microcontroller control systems and the components used, (2) programming and installation of digital input and output components of microcontrollers, (3) programming and installation of analog inputs and programming and installation of outputs using PWM, (4) serial communication of microcontrollers using UART, I2C, and SPI, and (5) microcontroller branching programming algorithms. In the control group, this learning material was taught for a whole semester using an already available conventional training kit, as shown in Figure 2a. Learning is conducted without creating a direct microcontroller control system application project due to the limitations of the training kit, which can only be used for learning the proof of concept of microcontroller control. Therefore, the control group was not trained to develop knowledge and skills in applying microcontroller control systems, including design, construction, programming, and direct testing for real-world applications. This is a significant difference from the experimental group.

3.4 Research instruments

Learning achievement assessment instrument. Assessment of student learning achievement using test instruments, namely multiple-choice questions for student pretest and posttest assessments. The preparation of the test instrument includes all learning materials studied by students from the 3rd to the 15th meeting and the literature review that has been done. Thus, the test instrument is arranged based on six elements of assessment, namely understanding the concept of microcontroller, understanding the concept of microcontroller input and output, microcontroller input and output circuit, microcontroller control system design [21], and microcontroller input and output components and microcontroller programming [5], [37]. The test instrument developed consists of 30 questions, each with four alternative answers. The assessment scores obtained by students will be converted into values ranging from 0 to 100. The difficulty level of the test instruments is based on the student's knowledge level according to the latest revision of Bloom's taxonomy, ranging from level C2 (understanding) to level C5 (evaluation), with test questions as shown in Table 2 [38].

The instrument used is tested for validity and reliability first to determine the accuracy and consistency of the measurements taken [39]. Instrument testing was carried out by 36 students who were studying in semester 5. All of these students carried out microcontroller practicum learning in the previous semester 3, then analyzed the validity of the test instrument using the point biserial correlation analysis technique and reliability using the Kuder-Richardson analysis technique known as KR-20. From the results of the validity analysis, the r-value ranged from 0.372 to 0.677. The results obtained are greater than the r-table value (>0.2709), so it can be assumed that 30 valid question items are used to measure student learning achievement. Furthermore, the reliability test results show that the KR-20 value is 0.906, greater than the minimum limit (>0.70), so the test instrument is reliable for measuring student learning achievement. These results show that the test instrument developed can measure student learning achievement accurately and show high measurement consistency [40], [41].

Table 2. Multiple-choice test instrument grid

Main Topic	Subtopics	Number of Questions			
		C2	C3	C4	C5
Microcontroller Concepts	Functions and parts of a microcontroller	1	2		
	Configuration of input, output, and communication pins of a microcontroller				
Programming Languages	Functions of C language programming instructions	4	4	2	4
	Translating flowcharts into C language programs				
Microcontroller Inputs	Types of digital/analog inputs according to their functions	1	3	4	
	Sensor output criteria				
Microcontroller Outputs	Types of microcontroller outputs	3		2	
	Types of drivers for operating microcontroller outputs				

Practical skills assessment instrument. Students' practical skills are assessed using a practical skills assessment rubric. The instrument developed contains nine assessment criteria: (1) Preparation of microcontroller components, (2) Making a microcontroller input device circuit, (3) Making a microcontroller output device circuit, (4) Using programming applications, (5) Writing microcontroller programs, (6) Using microcontroller communication protocols, (7) Designing microcontroller control systems, (8) Testing microcontroller control systems, (9) Using debugging tools in programming applications. The assessment framework also refers to previous research to increase the instruments' validity [29], [30]. Each criterion is scored from 1 (lowest) to 4 (highest) with different rubrics. The scores obtained by students will be converted into scores from 0 to 100. The instrument developed also went through the validity and reliability test stages with the same respondents during the learning achievement instrument trial. The validity analysis uses the product moment equation, and reliability is measured using the Cronbach alpha equation. The validity test results obtained R-values ranging from 0.605 to 0.663, where these results are greater than the r-table value (>0.2709), so it can be interpreted that the nine criteria proposed are valid to measure students' practical skills. The reliability test results also show a Cronbach alpha value of 0.807, where this result is greater than the minimum limit (>0.70), so the rubric developed can assess students' practical skills. Thus, it can be concluded that the developed rubric can accurately measure students' practical skills and be assessed with high consistency [39], [42].

Problem-solving skills assessment instrument. Assessed students' problem-solving skills using a questionnaire adapted from expert opinions [43], [44]. To master problem-solving skills, there are four steps of problem-solving that students must master: (1) problem definition and formulation, (2) generation of alternative solutions, (3) decision-making, and (4) solution implementation and verification. These four steps were developed into dimensions of student problem-solving assessment. Thus, the instrument developed consists of four assessment dimensions with 24 items arranged as a questionnaire. The scoring system for each assessment item uses a Likert scale with five answer options. The scores obtained by the students were converted into values from 0 to 100. This problem-solving assessment questionnaire was tested beforehand with the same respondents as the test question. Testing was carried out to test the validity and reliability of the questionnaire, with data analysis of the validity test using product moment analysis and reliability using Cronbach's alpha analysis. From the results of the validity test, the r-value obtained ranged from 0.435 to 0.671, and the results obtained were greater than the r-table value (>0.2709). The reliability test results get a value of 0.886, which is also greater than the minimum of Cronbach's alpha (>0.70). The results of these two tests show that the instrument used can measure student problem-solving skills with good accuracy and consistency [39], [42].

Semi-structured interview instrument. Semi-structured interviews were conducted after the learning process was carried out for one semester to explore experiences, perceptions, and the impact of using mobile robotics training kits. The researcher developed four questions to explore the impact of mobile robotics training kits in the microcontroller learning process, supported by previous research [42], [45]. The interviews were conducted with 15 students (1 female and 14 males) selected randomly from the experimental group. The interviews lasted 15 to 20 minutes and were conducted via the Zoom Meet application, with audio recording. The interviews were conducted in the student's native language (Indonesian). The list of questions posed to the students is as follows:

Q1. In your opinion, how does the use of the Mobile Robotics Training Kit affect your understanding of the microcontroller control system theory that you learned in class? Explain and give examples.

Q2. In your opinion, can using the Mobile Robotics Training Kit in the learning process improve your practical microcontroller skills? Explain and give examples.

Q3. Have you ever encountered technical challenges while learning to use the Mobile Robotics Training Kit? How did you overcome them? Explain and give examples.

Q4. Are there any specific experiences or stories from using this tool that you think are important to share? Please explain in detail.

3.5 Data analysis technique

The study data will be analyzed using SPSS V25.0. Descriptive statistics in the form of mean values (M) and standard deviations (SD) of each dependent variable measured will be presented. Before conducting statistical analysis, normality (Kolmogorov-Smirnov) and homogeneity (Levene) tests will be performed with a p-value > 0.05. If the assumptions are not met, nonparametric tests will be used. The first analysis will use a paired sample t-test to determine the difference in pretest and post-test scores between the experimental and control groups. Next, an independent t-test was used to examine the differences in pretest scores between the two groups and the differences in problem-solving skills in each assessment dimension. The third analysis used a one-way ANCOVA with pretest scores as a covariate to compare post-test results between the experimental and control groups. Finally, effect size analysis (partial eta squared and Cohen's d) was conducted to measure the magnitude of the treatment effect on each variable and dimension assessed [39], [42]. This analysis aims to demonstrate the effectiveness of using the Mobile Robotics Training Kit in improving the learning achievement, practical skills, and problem-solving abilities of industrial electrical engineering students in microcontroller control systems.

Meanwhile, qualitative data were analyzed using thematic analysis [46], following six steps of analysis, namely, familiarization, coding, theme generation, theme review, theme definition and naming, and writing. To further improve the quality of the data obtained, the theme definition and naming stages were carried out jointly by all researchers. Translation software (https://evernote.com) was used to transcribe the audio interview data. The qualitative analysis results are directly supported by student quotes (ST), so each student is assigned a code from ST00 to ST14 to distinguish them from one another.

4 RESULTS

4.1 Preliminary data analysis

Preliminary analysis was conducted to test the data assumptions that must be met to conduct paired sample t-test, independent t-test, and ANCOVA analysis. First, the data normality test was carried out using Kolmogorov-Smirnov analysis, and the results are shown in Table 3. From the results, it is known that the learning achievement variable data is usually distributed with a p-value of the pre-test experimental group ($p = 0.200 > 0.05$) and control ($p = 0.127 > 0.05$) and the post-test data experimental group ($p = 0.064 > 0.05$) and control ($p = 0.200 > 0.05$). Data on practical skills variables are also normally distributed with a p-value of the pre-test experimental group ($p = 0.200 > 0.05$) and control ($p = 0.200 > 0.05$) and post-test data for the experimental group ($p = 0.109 > 0.05$) and control ($p = 0.200 > 0.05$). Data on problem-solving skills variables are also normally distributed with a p-value of pre-test experimental group (p = 0.117 > 0.05) and control (p = 0.195 > 0.05), and post-test data for the experimental group (p = 0.067 > 0.05) and control (p = 0.200 > 0.05). Thus, from the results of this test, it is known that the variable data on learning achievement, practical skills, and problem-solving skills meet the data normality assumption test requirements.

Table 3. The results of testing the normality and homogeneity of the data

Variables	Values	Group	K – S		Levene	
			Statistic	p-Value	Statistic	p-Value
Learning Achievement	Pre-test	Exp	0.114	0.200	0.138	0.712
		Con	0.127	0.127		
	Post-test	Exp	0.139	0.064	0.390	0.534
		Con	0.116	0.200		
Practical Skills	Pre-test	Exp	0.115	0.200	0.036	0.849
		Con	0.118	0.200		
	Post-test	Exp	0.129	0.109	2.337	0.131
		Con	0.116	0.200		
Problem-Solving	Pre-test	Exp	0.128	0.117	0.090	0.765
		Con	0.119	0.195		
	Post-test	Exp	0.138	0.067	0.242	0.624
		Con	0.094	0.200		

Note: K – S = Kolmogorov Smirnov, Exp = experiment group, Con = control group.

The second test was a data homogeneity test, the results of which are shown in Table 3. Based on the results obtained, it is known that the pre-test and post-test data of learning achievement variables between the experimental and control groups are homogeneous, with the p-value of pre-test data (p = 0.712 > 0.05) and post-test (p = 0.534 > 0.05). The pre-test and post-test data of student practical skills variables between the experimental and control groups were also homogeneous, with the p-value of pre-test (p = 0.849 > 0.05) and post-test (p = 0.131 > 0.05) data. The pre-test and post-test data of the problem-solving skills variable between the experimental and control groups were also homogeneous, with the p-value of the pre-test (p = 0.765 > 0.05) and post-test data (p = 0.624 > 0.05). From the results of this test, it is known that the data on learning achievement variables, practical skills, and problem-solving skills fulfill the assumption test of data homogeneity.

4.2 Analysis of the effectiveness of the mobile robotic training kit

The first test uses paired sample t-test analysis to determine the difference in student learning outcomes before and after learning is done. The results of the test obtained are shown in Table 4. From the test results, it is known that the variable learning achievement of the experimental group and the control group has a significant difference in learning achievement and a large impact on the p-value and effect size of the experimental group (p = 0.000 and g = 2.98) and control (p = 0.000 and g = 1.33). The practical skills variable also significantly affects the p-value and effect size obtained by the experimental (p = 0.000 and g = 3.83) and control (p = 0.000 and g = 2.79) groups. The problem-solving skills variable also significantly affects the p-value and effect size obtained by the experimental group (p = 0.000 and g = 3.41) and the control (p = 0.000 and g = 2.56). Based on the results obtained, it is known that the experimental class using the mobile robotics training kit has a significant impact on improving student learning achievement, practical skills, and problem-solving skills. However, the control group that did not receive treatment like the experimental group also greatly improved student learning achievement, practical skills, and problem-solving skills. So, to find out which group is superior, further analysis is carried out using ANCOVA analysis.

Table 4. Results of paired sample t-test and independent t-test of pretest data

Variables	Group	Paired Sample T-test			Independent T-test (Pre-test)			
		t	p	g	M	SD	t	p
Learning Achievement	Exp	9.387	0.000	2.98	71.53	8.29	0.351	0.726
	Con	4.190	0.000	1.33	72.21	8.68		
Practical Skills	Exp	12.045	0.000	3.83	66.18	8.99	0.241	0.810
	Con	8.793	0.000	2.79	65.68	9.09		
Problem-Solving	Exp	10.720	0.000	3.41	68.79	5.61	0.904	0.369
	Con	8.056	0.000	2.56	67.66	5.29		

Note: t = t-value, p = p-value, g = effect size hedges, M = mean, SD = standard deviation.

Before the ANCOVA analysis, the second analysis, the independent t-test, was conducted to determine the differences in learning achievement, practical skills, and problem-solving skills of experimental and control group students before learning. The results of the tests conducted are shown in Table 4. Testing the learning achievement variable proved that there was no significant difference with a p-value (p = 0.726 > 0.05); this result was also seen from the average value of the experimental group (M = 71.53 and SD = 8.29) and the control (M = 72.21 and SD = 8.68). Testing the student practical skills variable also shows no significant difference with the p-value (p = 0.810 > 0.05); this result is also seen from the average value of the experimental (M = 66.18 and SD = 8.99) and control (M = 65.68 and SD = 9.09) groups. The assessment of the problem-solving skill variable also did not experience a significant difference with a p-value (p = 0.369 > 0.05); this result was also seen from the mean value of the experimental (M = 68.79 and SD = 5.61) and control (M = 67.66 and SD = 5.29) groups. From these results, experimental and control groups of students have the same learning achievement, practical skills, and problem-solving skills. So that there is no inequality of knowledge between groups, and the validity of the study results obtained can be increased [47].

The third test, using ANCOVA analysis, aims to determine the differences in learning achievement, practical skills, and problem-solving skills between experimental and control classes after the learning process. The results of this test are shown in Table 5. The test results revealed that there was a significant difference in student learning achievement with a p-value (p = 0.000 > 0.05), with an average value of experimental (M = 85.184 and SD = 6.371) and control (M = 79.26 and SD = 7.047). Testing the practical skills variable also shows there is a significant difference with a p-value (p = 0.000 > 0.05) between the average value of the experimental

(M = 82.42 and SD = 9.565) and control (M = 76.26 and SD = 7.333) groups. Testing the problem-solving skills variable, there is also a significant difference with a p-value ($p = 0.000 > 0.05$), with the average value of the experimental group (M = 84.89 and SD = 7.333) and the experimental control (M = 78.84 and SD = 6.756). Thus, it is known that the experimental group using the robotic mobile training kit can improve student learning achievement, practical skills, and problem-solving skills better than the control group.

Table 5. ANCOVA test results of posttest and pretest scores as covariates

Variables	Group	M	SD	F	p-value	η^2
Learning Achievement	Exp	85.184	6.371	15.731	0.000	0.177
	Con	79.26	7.047			
Practical Skills	Exp	82.42	9.565	13.830	0.000	0.159
	Con	76.26	7.388			
Problem-Solving	Exp	84.89	7.333	13.662	0.000	0.158
	Con	78.84	6.756			

Note: η^2 = partial eta squared.

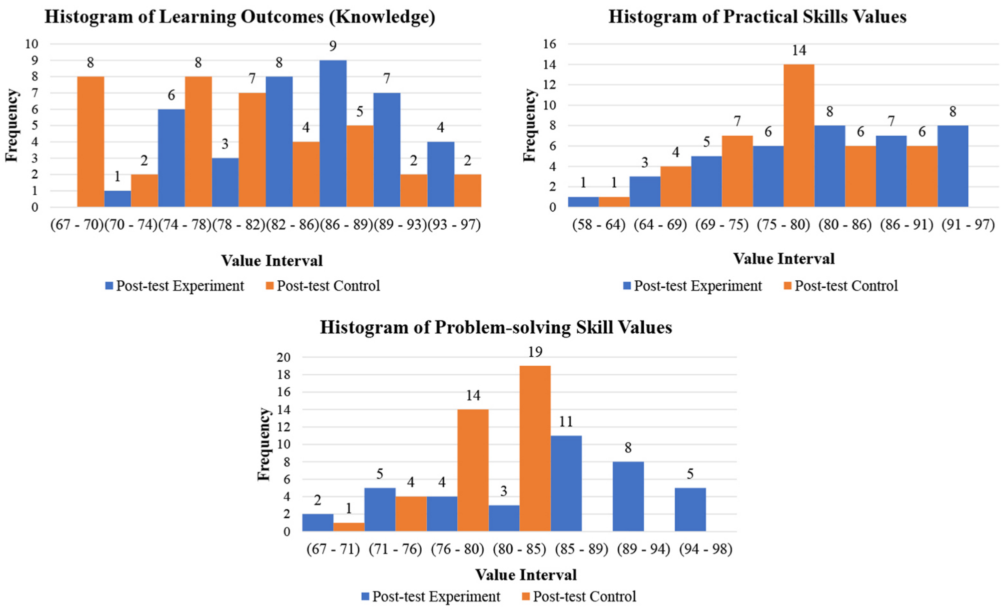

Fig. 4. Histogram of research data distribution

In addition to analyzing differences in ANCOVA analysis, it also analyzes the impact of mobile robotic training kits in the learning process through partial eta-squared analysis. The results obtained are categorized into three categories, namely 0.01 (small effect), 0.06 (medium effect), and 0.14 (big effect) [48]. The results of testing the learning achievement variable received a value of $\eta^2 = 0.177$ (large effect), practical skills $\eta^2 = 0.159$ (big effect), and problem-solving skills $\eta^2 = 0.158$ (big effect). So, the ANCOVA test results show that the mobile robotics training kit significantly impacts student learning achievement, practical skills, and problem-solving skills. However, to find out the distribution of post-test scores obtained by students in all assessment variables (see Figure 4). These results show that the value intervals obtained by all students are visible from the differences in student learning achievement, practical skills, and problem-solving skills.

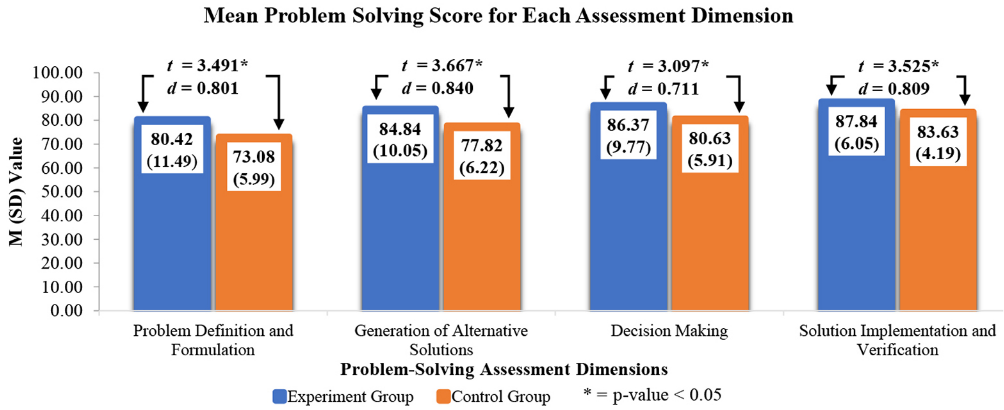

Fig. 5. The difference between the average value of problem-solving skills of the experimental group and the control group on the post-test value

Suppose analyzed in depth for each dimension of problem-solving skills using the independent t-test. In that case, there is a significant difference between the experimental and control groups, as shown in Figure 5. This result is based on the t-value and p-value obtained in the dimensions of problem definition and formulation ($t = 3.491$ and $= 0.001 < 0.05$), generation of alternative solutions ($t = 3.667$ and $= 0.000 < 0.05$), decision-making ($t = 3.097$ and $= 0.03 < 0.05$), solution implementation and verification ($t = 3.525$ and $= 0.01 < 0.05$). In addition, an analysis of the impact on each element was also carried out using Cohen's d analysis, which was categorized into three categories, namely, 0.2 (small effect), 0.5 (medium effect), and 0.8 (large effect) [49]. Thus, it is known that the mobile robotics training kit has a significant impact on improving problem definition and formulation ($d = 0.812$), generation of alternative solutions ($d = 0.839$), and solution implementation and verification ($d = 0.846$), while having a moderate impact on improving decision-making ($d = 0.705$) of students.

4.3 Results of qualitative analysis of semi-structured interviews

Semi-structured interviews were conducted to examine the impact of the mobile robotic training kit, which has been quantitatively proven to improve students' knowledge, practical skills, and problem-solving skills. The results of the interviews showed that all students stated that contextual-based learning (hands-on learning) could improve their understanding of the microcontroller learning process (ST00). Therefore, using this training kit makes learning more student-centered, and 3/15 students stated that it makes it easier for students to conduct practical work (ease of use), significantly improving their practical skills (ST03). These results also confirm that 6/15 students demonstrated good literacy skills in seeking information to solve problems (ST10). In-depth, three out of 15 students developed self-confidence (ST11), and three out of 15 students developed strong motivation to learn (ST09). As a result, 5/15 students developed self-directed learning, where they automatically carried out the learning process without any instructions from the lecturer (ST05). Thus, the contextual approach improved cognitive understanding and shaped independent, adaptive, and reflective learning characteristics.

ST00: "*However, my understanding of this theory became more concrete and easier to understand when I implemented it directly using the training kit*."
ST03: "*Then, because there is a module that has been created, it becomes more focused, making it easier for us to conduct trials and carry out the programming*."
ST10: "*We initially read the robot's report, the datasheet of the robot driver, the location of the pins, and how to assemble it*."
ST11: "*Well, because of that, sir, I have become more confident in undertaking projects related to microcontrollers*."
ST09: "*... When we finished fixing the program ... the robot worked as we had hoped, we were very happy. This increased my motivation to learn more about programming ...*"
ST05: "*... I can also make my own robot and invite my friends to make their own robots too ...*"

In addition to the data above, our interviews also found that this training kit impacts 21st-century skills that are essential today. A total of 12 students demonstrated good critical thinking skills by analyzing technical problems, applying logical solutions, identifying wiring errors, or designing robot control logic (ST06). Furthermore, nine out of 15 students demonstrated good collaboration skills through group projects, task division, discussions, and providing feedback when technical challenges arose (ST12). Additionally, creativity skills were evident, with seven out of 15 students attempting to innovate in the innovation practical process regarding robot design or developing functions in programming (ST02). Furthermore, four out of 15 students demonstrated good communication skills through the importance of team communication in completing tasks together (ST00). These results indicate that the training kit not only impacts knowledge, practical skills, and problem-solving abilities but also has the potential to influence the development of soft skills, which are crucial for addressing the challenges of the industrial world.

ST06: "*Technically, the error is usually caused by incorrect pin input. This also happens frequently, or it is usually caused by the placement of the sensor, the line follower sensor.*"
ST12: "*The main thing, sir, is that after several attempts and discussions with the team, I managed to develop a more suitable algorithm, sir.*"
ST02: "*At that time, the solution was to add a filter program and adjust the average sensor value to reduce noise and recalibrate the sensor threshold.*"
ST00: "*However, through many discussions and experiments, we repeatedly discovered various pieces of information ...*"

5 DISCUSSION

The first finding of the mobile robotic training kit applied in the microcontroller learning process is significant and has a major impact on improving students' microcontroller control system learning achievement. This is also consistent with previous research where using well-designed mobile robotic training devices in the microcontroller learning process can effectively improve student academic learning outcomes [50], [51]. Training kits have shown significant results in improving microcontrollers' conceptual knowledge and cognitive schema construction, as they provide hands-on experience and practical application of theoretical concepts learned [26], [52]. The use of mobile robotics training kits is also supported by Edgar Dale's cone of experience theory, which emphasizes that students understand and retain information better when they are directly involved with the material through various sensory modalities, such as being directly involved in working on robotics projects [53], [54]. The results obtained can be explained by using a mobile robotic training kit containing material relevant to learning needs and technological developments so that the concepts of microcontroller learning can be conveyed well to students. However, it should be noted that the use of training kits and project-based learning in the learning process, if not preceded by a good explanation of the concept of the material, can also affect the mastery of understanding and can even have no effect on student learning achievement [55].

The second finding revealed that the mobile robotic training kit significantly improves students' practical skills with microcontroller control systems, which is consistent with previous research [28]. Previous research confirms that mobile robotic training kits can improve three domains of students' much-needed practical skills, namely programming, electronic circuits, and mechanical skills [26], [30]. Using training kits in the learning process allows students to do interactive, hands-on learning and get feedback so that students can see the results of applying the concepts they learn. Direct engagement with the training kit allows students better to understand technical concepts through real-life experiences [27]. This type of learning can improve technical skills and provide valuable learning experiences for students to face the real challenges they will face [26]. The good results are due to the role of using training kits and the learning model applied by emphasizing student-centered learning through project-based learning so that the learning experience is more memorable to students and impacts their practical skills [22], [23].

The findings of the mobile robotics training kit significantly impact improving students' problem-solving skills, which are needed especially in vocational education because they are often faced with complex system problems that require in-depth analysis and creative solutions [3]. Previous research has also revealed that learning by using an applicable training kit can systematically improve students' problem-solving skills, thus helping them design effective and efficient solutions [8], [23]. This theory of constructivism emphasizes that knowledge and skills can be built through direct experience and interaction with the surrounding world, not just passively received [56]. Thus, using training kits supports experiential learning, where students actively build their knowledge and skills through real practice, and significantly impacts students' problem-solving skills. Using the training kit, they recognize the theory and apply the concepts learned to solve the problems encountered [57].

Through problem-solving skills, students are trained not only to make improvements but students will be trained starting from how to identify problems, make solutions to the problems they face, make decisions on solutions to be carried out, work on these problems, and test the results of the improvements they do [56]. Students using robotic mobile training kits in the learning process can better apply the solutions generated to overcome the problems, characterized by increased student problem-solving skills. Apart from using robotic mobile training kits, learning achievement also influences problem-solving skills. Students can identify and understand a problem by mastering strong theoretical concepts. Students with exemplary learning achievements can think logically and systematically to formulate effective solutions [58], [59]. In addition, students' practical skills also affect problem-solving skills. Mastery of theory and good practical skills will strengthen them in implementing solutions in the real field. Through practical skills, students can operate tools, analyze technical data, and apply relevant methods; they will be better prepared to face real challenges that require holistic problem-solving [60]. Through this study, both learning achievement and practical skills also significantly improve students' problem-solving skills.

The good learning outcomes obtained by students are supported by the learning model used in the microcontroller practicum learning process. In addition to using a mobile robotic training kit that applies to the learning process, the study also uses a project-based learning (PBL) model. This learning model provides opportunities for students to identify and formulate problems directly through robotics projects. In this learning model, they can also generate alternative solutions, make decisions based on the results of real experiments, implement solutions, and verify the solutions they choose [23], [60]. Integrating PBL learning steps can deepen the four dimensions of problem-solving skills measured. In addition, this complex hands-on work can also improve the practical skills and knowledge of microcontroller control systems learned by students [50]. Applying the mobile robotics training kit integrated with the PBL model will enrich students' learning experience by providing relevant practical skills, improving their understanding of technical concepts, and preparing them to make more informed and data-driven decisions professionally.

5.1 Implications

This study shows that the use of Mobile Robotics Training Kits significantly improves learning outcomes, practical skills, and problem-solving abilities among Industrial Electrical Engineering students [52]. Vocational education institutions can adopt mobile robotics training kits as interactive learning tools for microcontroller practicals. Through the PBL approach, students not only learn theory but also implement real-world solutions in robotics projects while also developing teamwork skills—a key competency required by industry. However, these implications cannot yet be generalized comprehensively, as this study was limited to testing at the Universitas Negeri Padang. Therefore, for broader generalization, further studies need to be conducted at other institutions with different student characteristics, learning environments, and facilities, as these three factors significantly influence study outcomes [47].

5.2 Research limitations

The positive impact of the mobile robotics training kit in the microcontroller practicum learning process is inseparable from the limitations of the study conducted. The first limitation is that the study was conducted with a limited sample, namely, at one of the Indonesian universities in Sumatera Barat Province (Universitas Negeri Padang, Faculty of Engineering, Department of Industrial Electrical Engineering), so the results of this study cannot be generalized to a broader population and other disciplines. However, the researcher has tried to minimize bias in the study process by randomizing the test subjects included in the experimental and control groups, and from the test results, it has also been confirmed that the two groups have the same knowledge and skills. The second limitation is that the data taken are still one, namely quantitative data, while qualitative data are not taken. This data is beneficial for understanding students' in-depth condition after the learning process. By combining these two data sets, the phenomena that occur in the study can be identified holistically.

5.3 Future research directions

Future research is expected to develop a robotic mobile training kit built into mechanical and electronic circuits and programmed from scratch. This is a shortcoming of this study, where this robotic mobile training kit cannot be changed mechanically. However, in terms of electronic circuits and programming, it can be made according to the projects that students work on. In addition to testing the effectiveness of the robotic mobile training kit, further research can examine how students' level of acceptance of this technology can be measured through the technology acceptance model (TAM). Most importantly, the study results contained cognitive (learning achievement and problem-solving) and psychomotor (practical skills) domains. Thus, the study can also examine the effect of this training kit on students' affective domain, that is, attitude, motivation, and interest in carrying out the learning process. The robotic car training kit's effect can be determined comprehensively based on future research recommendations.

6 CONCLUSION

The results of this study have provided empirical evidence of the effectiveness of mobile robotic training kits in improving the quality of microcontroller practicum learning in the Department of Industrial Electrical Engineering. Based on the results of the paired sample t-test, both the experimental and control groups experienced significant differences in pretest and posttest results. Both groups experienced increased learning achievement variables and practical and problem-solving skills. An ANCOVA test was conducted with pretest data as the covariate to determine the difference between the two classes. From the test results, it was found that there were significant differences in both learning achievement variables, practical skills, and problem-solving skills measured. The experimental group that used the robotic mobile training kit was superior to the control group. Thus, this study confirms that integrating mobile robotic training kits in the microcontroller practicum learning process can improve learning achievement and the skills and problem-solving skills of industrial electrical engineering students.

Based on these results, vocational colleges need to develop practicum equipment that is flexible and applicable in the application process to make students actively participate in the learning process instead of being passive in receiving learning from lecturers. Although the conventional training kit used in the control group also makes students active, students cannot apply microcontroller system learning to real applications using this training kit. A robotic mobile training kit can be used in robotic applications. Thus, using a mobile robotics training kit helps students understand knowledge, practical skills, and problem-solving more effectively, allowing them to face the challenges of real work in the industry.

7 ACKNOWLEDGMENTS

This study is supported by the Directorate General of Higher Education of the Ministry of Education and Culture of the Republic of Indonesia with contract number 088/C3/DT.05.00/PL/2025. This study is part of the Program Pendidikan Magister menuju Doktor untuk Sarjana Unggul (PMDSU). All authors have approved this study included in this paper.

8 REFERENCES

[1] N. Slob and W. Hurst, "Digital twins and industry 4.0 technologies for agricultural greenhouses," *Smart Cities*, vol. 5, no. 3, pp. 1179–1192, 2022. https://doi.org/10.3390/smartcities5030059

[2] N. Kashpruk, C. Piskor-Ignatowicz, and J. Baranowski, "Time series prediction in industry 4.0: A comprehensive review and prospects for future advancements," *Appl. Sci.*, vol. 13, no. 22, p. 12374, 2023. https://doi.org/10.3390/app132212374

[3] S. Sukardi *et al.*, "Soft skills and hard skills needed in industry 4.0 for electrical engineering students," *J. Appl. Eng. Technol. Sci. (JAES)*, vol. 5, no. 1, pp. 142–149, 2023. https://doi.org/10.37385/jaets.v5i1.2174

[4] I. H. Sarker, "Machine learning: Algorithms, real-world applications and research directions," *SN Comput. Sci.*, vol. 2, 2021. https://doi.org/10.1007/s42979-021-00592-x

[5] F. Vrbančič and S. Kocijančič, "Strategy for learning microcontroller programming—a graphical or a textual start?" *Educ. Inf. Technol.*, vol. 29, pp. 5115–5137, 2024. https://doi.org/10.1007/s10639-023-12024-9

[6] A. Jaedun, M. Nurtanto, F. Mutohhari, I. N. Saputro, and N. Kholifah, "Perceptions of vocational school students and teachers on the development of interpersonal skills towards Industry 5.0," *Cogent Educ.*, vol. 11, no. 1, 2024. https://doi.org/10.1080/2331186X.2024.2375184

[7] M. Poláková, J. H. Suleimanová, P. Madzík, L. Copuš, I. Molnárová, and J. Polednová, "Soft skills and their importance in the labour market under the conditions of Industry 5.0," *Heliyon*, vol. 9, no. 8, 2023. https://doi.org/10.1016/j.heliyon.2023.e18670

[8] M. Çınar and H. Tüzün, "Comparison of object-oriented and robot programming activities: The effects of programming modality on student achievement, abstraction, problem solving, and motivation," *J. Comput. Assist. Learn.*, vol. 37, no. 2, pp. 370–386, 2021. https://doi.org/10.1111/jcal.12495

[9] M. Veber, I. Pesek, and B. Aberšek, "Implementation of the modern immersive learning model CPLM," *Appl. Sci.*, vol. 12, no. 6, p. 3090, 2022. https://doi.org/10.3390/app12063090

[10] M. M. Magagula and O. A. Awodiji, "The implications of the fourth industrial revolution on technical and vocational education and training in South Africa," *Soc. Sci. Humanit. Open*, vol. 10, p. 100896, 2024. https://doi.org/10.1016/j.ssaho.2024.100896

[11] M. Tupac-Yupanqui, C. Vidal-Silva, L. Pavesi-Farriol, A. Sanchez Ortiz, J. Cardenas-Cobo, and F. Pereira, "Exploiting arduino features to develop programming competencies," *IEEE Access*, vol. 10, pp. 20602–20615, 2022. https://doi.org/10.1109/ACCESS.2022.3150101

[12] A. W. Nugroho, F. A. K. Yudha, T. Suwanda, A. Kurniawan, and N. Ardiyansyah, "Improving the IT competence of vocational high school teachers with internet of things training based on ESP 8266," in *Proceeding Int. Conf. Community Serv.*, vol. 1, no. 2, 2023, pp. 613–618. https://doi.org/10.18196/iccs.v1i2.110

[13] W. Mustakim, H. Effendi, Aswardi, M. Giatman, Hariyadi, and W. Dwi Pratiwi, "Development of internet of things trainer kit as a learning media for digital circuit subjects in higher education," *Int. J. Online Biomed. Eng. (iJOE)*, vol. 20, no. 9, pp. 4–16, 2024. https://doi.org/10.3991/ijoe.v20i09.48349

[14] W. R. Gusti, "Embedded system training kit for artificial intelligence," *Int. J. Inf. Educ. Technol.*, vol. 14, no. 1, pp. 72–80, 2024. https://doi.org/10.18178/ijiet.2024.14.1.2026

[15] T. P. Nugraha, R. Pratama, D. Wahyudin, and Y. Somantri, "Development of Integrated IoT Trainer (LRioT) for practical work in electrical engineering education program amid pandemic," in *Proceedings of the 6th UPI International Conference on TVET 2020 (TVET 2020)*, 2021, pp. 244–247. https://doi.org/10.2991/assehr.k.210203.126

[16] H. Seifi, M. Chun, C. Gallacher, O. Schneider, and K. E. MacLean, "How do novice hapticians design? A case study in creating haptic learning environments," *IEEE Trans. Haptics*, vol. 13, no. 4, pp. 791–805, 2020. https://doi.org/10.1109/TOH.2020.2968903

[17] E. Twyford and B. A. Dean, "Inviting students to talk the talk: Developing employability skills in accounting education through industry-led experiences," *Account. Educ.*, vol. 33, no. 3, pp. 296–318, 2024. https://doi.org/10.1080/09639284.2023.2191288

[18] I. E. Efe, E. Çinkaya, L. D. Kuhrt, M. M. T. Bruesseler, and A. Mührer-Osmanagic, "Neurosurgical education using cadaver-free brain models and augmented reality: First experiences from a hands-on simulation course for medical students," *Medicina (B. Aires).*, vol. 59, no. 10, p. 1791, 2023. https://doi.org/10.3390/medicina59101791

[19] P. Abichandani, V. Sivakumar, D. Lobo, C. Iaboni, and P. Shekhar, "Internet-of-Things curriculum, pedagogy, and assessment for STEM education: A review of literature," *IEEE Access*, vol. 10, pp. 38351–38369, 2022. https://doi.org/10.1109/ACCESS.2022.3164709

[20] N. Fijačko *et al.*, "Evaluating quality, usability, evidence-based content, and gamification features in mobile learning apps designed to teach children basic life support: Systematic search in app stores and content analysis," *JMIR mHealth uHealth*, vol. 9, no. 7, 2021. https://doi.org/10.2196/25437

[21] M. Wildan Habibi and I. G. P. Asto Buditjahjanto, "Impact of training kit-based internet of things to learn microcontroller viewed in cognitive domain," *TEM J.*, vol. 13, no. 2, pp. 1157–1166, 2024. https://doi.org/10.18421/TEM132-30

[22] H.-J. Lee and H. Yi, "Development of an onboard robotic platform for embedded programming education," *Sensors*, vol. 21, no. 11, p. 3916, 2021. https://doi.org/10.3390/s21113916

[23] R. C. Hsu and T.-H. Tsai, "Assessing the impact of a project-based learning robotics course with integrating of STEM education using content analysis method," *Eur. J. STEM Educ.*, vol. 7, no. 1, 2022. https://doi.org/10.20897/ejsteme/12633

[24] C. Pantos, J. Doornbos, G. Mier, and J. Valente, "The ReFiBot makers guide: Fostering academic open science and circularity with a robotic educational kit," *HardwareX*, vol. 16, p. e00484, 2023. https://doi.org/10.1016/j.ohx.2023.e00484

[25] R. Raudmäe *et al.*, "ROBOTONT – Open-source and ROS-supported omnidirectional mobile robot for education and research," *HardwareX*, vol. 14, p. e00436, 2023. https://doi.org/10.1016/j.ohx.2023.e00436

[26] B. Díaz-Lauzurica and D. Moreno-Salinas, "Applying design thinking to enhance programming education in vocational and compulsory secondary schools," *Appl. Sci.*, vol. 13, no. 23, p. 12792, 2023. https://doi.org/10.3390/app132312792

[27] A. Suarez, D. García-Costa, J. Perez, E. López-Iñesta, F. Grimaldo, and J. Torres, "Hands-on Learning: Assessing the impact of a mobile robot platform in engineering learning environments," *Sustainability*, vol. 15, no. 18, p. 13717, 2023. https://doi.org/10.3390/su151813717

[28] K. S. Praveena, . M., B. S. Gowda, K. Bhargavi, and C. M. Patil, "An effective Build Your Own Robot (BYOR) skill development course for first year engineering students to promote interdisciplinary learning environment," *J. Eng. Educ. Transform.*, vol. 36, pp. 207–213, 2023. https://doi.org/10.16920/jeet/2023/v36is2/23029

[29] A. Yousef and A. Ayyoub, "Rubric development and validation for assessing educational robotics skills," *Front. Educ.*, vol. 9, pp. 1–12, 2024. https://doi.org/10.3389/feduc.2024.1496242

[30] C. Boya-Lara, D. Saavedra, A. Fehrenbach, and A. Marquez-Araque, "Development of a course based on BEAM robots to enhance STEM learning in electrical, electronic, and mechanical domains," *Int. J. Educ. Technol. High. Educ.*, vol. 19, no. 1, 2022. https://doi.org/10.1186/s41239-021-00311-9

[31] J. W. Creswell and V. L. P. Clark, *Designing and Conducting Mixed Methods Research* (3rd ed.). Thousand Oaks, CA: SAGE Publications, Inc., 2017.

[32] A. Yusuf and N. M. Noor, "Modeling students' algorithmic thinking growth trajectories in different programming environments: An experimental test of the Matthew and compensatory hypothesis," *Smart Learn. Environ.*, vol. 11, 2024. https://doi.org/10.1186/s40561-024-00324-7

[33] R. C. R. Davison and P. M. Smith, "Quantitative data analyses," in Stephen R. Bird, Ed., *Research Methods in Physical Activity and Health* (1st ed.). London: Routledge, 2018, pp. 168–183. https://doi.org/10.4324/9781315158501

[34] J. G. Young, M. J. Stensrud, E. J. Tchetgen Tchetgen, and M. A. Hernán, "A causal framework for classical statistical estimands in failure-time settings with competing events," *Stat. Med.*, vol. 39, no. 8, pp. 1199–1236, 2020. https://doi.org/10.1002/sim.8471

[35] P. O. Okougbo, E. N. Okike, and A. Alao, "Accounting ethics education and the ethical awareness of undergraduates: An experimental study," *Account. Educ.*, vol. 30, no. 3, pp. 258–276, 2021. https://doi.org/10.1080/09639284.2021.1888135

[36] H. Luginbuehl, S. Nabecker, R. Greif, S. Zuber, I. Koenig, and S. Rogan, "Transforming traditional physiotherapy hands-on skills teaching into video-based learning," *BMC Med. Educ.*, vol. 23, 2023. https://doi.org/10.1186/s12909-023-04556-y

[37] B. Zhong and L. Xia, "Effects of new coopetition designs on learning performance in robotics education," *J. Comput. Assist. Learn.*, vol. 38, no. 1, pp. 223–236, 2022. https://doi.org/10.1111/jcal.12606

[38] T. M. Larsen, B. H. Endo, A. T. Yee, T. Do, and S. M. Lo, "Probing internal assumptions of the revised bloom's taxonomy," *CBE—Life Sci. Educ.*, vol. 21, no. 4, pp. 1–12, 2022. https://doi.org/10.1187/cbe.20-08-0170

[39] D. T. P. Yanto *et al.*, "Android-based courseware as an educational technology innovation for electrical circuit course: An effectiveness study," *Int. J. Inf. Educ. Technol. (IJIET)*, vol. 13, no. 12, pp. 1835–1843, 2023. https://doi.org/10.18178/ijiet.2023.13.12.1996

[40] M. Terra, M. Baklola, E. A. Hasabo, D. G. Shaheen, and A. H. El-Gilany, "Translation, validation and cultural adaptation of the Arabic version of the HIV knowledge questionnaire (HIV-Kq-18)," *PLoS One*, vol. 18, no. 4, 2023. https://doi.org/10.1371/journal.pone.0284542

[41] M. Moghadam and F. Nasirzadeh, "The application of Kunnan's test fairness framework (TFF) on a reading comprehension test," *Lang. Test. Asia*, vol. 10, 2020. https://doi.org/10.1186/s40468-020-00105-2

[42] M. Fidan and M. Fidan, "The effects of video-driven discussions integrated into the flipped classroom model on learning achievement, practical performance, and higher-order thinking skills in dental education," *J. Comput. Assist. Learn.*, vol. 40, no. 1, pp. 158–175, 2024. https://doi.org/10.1111/jcal.12869

[43] T. J. D'Zurilla and M. R. Goldfried, "Problem solving and behavior modification," *J. Abnorm. Psychol.*, vol. 78, no. 1, pp. 107–126, 1971. https://doi.org/10.1037/h0031360

[44] T. J. D'Zurilla and A. Maydeu-Olivares, "Conceptual and methodological issues in social problem-solving assessment," *Behav. Ther.*, vol. 26, no. 3, pp. 409–432, 1995. https://doi.org/10.1016/S0005-7894(05)80091-7

[45] X. Ren, Z. Guo, A. Huang, Y. Li, X. Xu, and X. Zhang, "Effects of social robotics in promoting physical activity in the shared workspace," *Sustainability*, vol. 14, no. 7, p. 4006, 2022. https://doi.org/10.3390/su14074006

[46] V. Clarke and V. Braun, "Thematic analysis," in *Encyclopedia of Critical Psychology*. New York, NY: Springer, 2014, pp. 1947–1952. https://doi.org/10.1007/978-1-4614-5583-7_311

[47] C. Ma-Kellams, "Using true experiments to study culture: Manipulations, measurement issues, and the question of appropriate control groups," *Methods Psychol.*, vol. 4, p. 100046, 2021. https://doi.org/10.1016/j.metip.2021.100046

[48] J. Sung, J. Y. Lee, and H. Y. Chun, "Short-term effects of a classroom-based STEAM program using robotic kits on children in South Korea," *Int. J. STEM Educ.*, vol. 10, pp. 1–18, 2023. https://doi.org/10.1186/s40594-023-00417-8

[49] J. Cohen, *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.

[50] J. Acker, I. Rogers, D. Guerra-Zubiaga, M. H. Tanveer, and A. A. A. Moghadam, "Low-cost digital twin approach and tools to support industry and academia: A case study connecting high-schools with high degree education," *Machines*, vol. 11, no. 9, p. 860, 2023. https://doi.org/10.3390/machines11090860

[51] M. Donnermann, P. Schaper, and B. Lugrin, "Social robots in applied settings: A long-term study on adaptive robotic tutors in higher education," *Front. Robot. AI*, vol. 9, pp. 1–12, 2022. https://doi.org/10.3389/frobt.2022.831633

[52] N. Pellas and K. Tzafilkou, "The influence of absorption and need for cognition on students' learning outcomes in educational robot-supported projects," *Educ. Sci.*, vol. 13, no. 4, p. 379, 2023. https://doi.org/10.3390/educsci13040379

[53] B. Davis and M. Summers, "Applying dale's cone of experience to increase learning and retention: A study of student learning in a foundational leadership course," in *Engineering Leaders Conference 2014 on Engineering Education*, vol. 2015, 2015. https://doi.org/10.5339/qproc.2015.elc2014.6

[54] E. Chaidi, C. Kefalis, Y. Papagerasimou, and A. Drigas, "Educational robotics in primary education. A case in Greece," *Res. Soc. Dev.*, vol. 10, no. 9, p. e17110916371, 2021. https://doi.org/10.33448/rsd-v10i9.16371

[55] A. Drigas, E. Mitsea, and C. Skianis, "Virtual reality and metacognition training techniques for learning disabilities," *Sustainability*, vol. 14, no. 16, p. 10170, 2022. https://doi.org/10.3390/su141610170

[56] R. Fadli *et al.*, "Effectiveness of mobile virtual laboratory based on project-based learning to build constructivism thinking," *Int. J. Interact. Mob. Technol. (iJIM)*, vol. 18, no. 6, pp. 40–55, 2024. https://doi.org/10.3991/ijim.v18i06.47643

[57] E. Demertzi, N. Voukelatos, Y. Papagerasimou, and A. S. Drigas, "Online learning facilities to support coding and robotics courses for youth," *Int. J. Eng. Pedagog. (iJEP)*, vol. 8, no. 3, pp. 69–80, 2018. https://doi.org/10.3991/ijep.v8i3.8044

[58] B. Sinaga, J. Sitorus, and T. Situmeang, "The influence of students' problem-solving understanding and results of students' mathematics learning," *Front. Educ.*, vol. 8, pp. 1–9, 2023. https://doi.org/10.3389/feduc.2023.1088556

[59] P. Pimdee, A. Sukkamart, C. Nantha, T. Kantathanawat, and P. Leekitchwatana, "Enhancing Thai student-teacher problem-solving skills and academic achievement through a blended problem-based learning approach in online flipped classrooms," *Heliyon*, vol. 10, no. 7, p. e29172, 2024. https://doi.org/10.1016/j.heliyon.2024.e29172

[60] H. Setyawan, Sukardi, Risfendra, D. Tri Putra Yanto, and T. Tze Kiong, "The impact of robotic technology in vocational education towards the development of industry 5.0: A systematic literature review," *Int. J. Online Biomed. Eng. (iJOE)*, vol. 21, no. 6, pp. 36–55, 2025. https://doi.org/10.3991/ijoe.v21i06.53681

9 AUTHORS

Herlin Setyawan is a doctoral student of Technology and Vocational Education, Graduate School, Universitas Negeri Padang. His research focuses on technology and vocational education in the fields of educational technology, artificial intelligence in learning, robotics in learning, industrial automation, development of STEM Learning, 4C, and Computational Thinking students (E-mail: herlinsetyawan@student.unp.ac.id).

Sukardi is a Lecturer at the Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang. His research interests include Electrical Engineering Vocational Education and Training (TVET) (E-mail: sukardiunp@ft.unp.ac.id).

Risfendra is a Lecturer at the Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang. He is currently teaching and will conduct research in the field of industrial control systems, robotics, artificial intelligence, and educational technology in vocational education (E-mail: risfendra@ft.unp.ac.id).

Tee Tze Kiong is a Lecturer at the Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat, Johor. His specializations lie in the areas of modular approach in teaching and learning, high-order thinking skills, buzan mind mapping, and inventive problem-solving skills (E-mail: tktee@uthm.edu.my).

Krismadinata is a Lecturer at the Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang. Currently serving as rector of Universitas Negeri Padang. His research interests are power electronics control and renewable energy (E-mail: krisma@ft.unp.ac.id).

M. Giatman is a Lecturer at the Department of Civil Engineering, Faculty of Engineering, Universitas Negeri Padang. His specialization involves project management (E-mail: giatman@ft.unp.ac.id).