

Development of Artificial Intelligence-Based Microcontroller Practice Learning Media

Anggi Puspita Sari^{1*}, Satria Gunawan², Yasser Abdul³
Universitas Negeri Makassar, Makassar, Indonesia



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ABSTRACT

This study aims to design learning media for Artificial Intelligence-based Microcontroller practicum and analyze the validity, practicality and effectiveness of learning media for Artificial Intelligence-based microcontroller practicum. The study uses a modified Research and Development (R&D) method from the Borg & Gall, 4-D, and ADDIE models. The product developed is an APSteach AI web that has digital jobsheet features with AI chatbot, automatic assistance, report upload, and AI-based quizzes. The validation results show that material experts give an average value of 90.27% and 91.66%, while media experts give a value of 93.75% to 100%, all of which are categorized as very feasible. The practicality test shows results of 93.75% (individual), 90% (small group), and 86.58% (large group). The effectiveness test shows a very feasible category with achievements of 95.41%, 87.5%, and 86.58%. The results of the Liliefors normality test show that all pretest and posttest data are normally distributed ($L \text{ count} \leq L \text{ table} = 0.161$). The homogeneity test shows that the data variance is homogeneous ($\text{sig. } 0.246 > 0.05$). The Independent Sample T-Test test shows a significance of $0.01 < 0.05$, so there is a significant difference in learning outcomes between the experimental class and the control class. Overall, AI-based learning media is proven to be valid, practical, and effective, and is suitable for use to improve student understanding and independence in learning Microcontroller practicum.

INTRODUCTION

In law number 20 of 2003, Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have spiritual religious strength, self-control, personality, intelligence, noble morals and skills needed by themselves, society, nation and state. To achieve this goal, the role of educators is needed, in this case lecturers in higher education who have the ability to teach, facilitate and direct learning through the application of media, learning tools, methods, creativity and role models.

Based on the results of interviews with lecturers, it was found that Based on interviews conducted with lecturers in charge of practicum courses, information was obtained that the learning media used in practicum activities is currently still less efficient. This is evident from the large amount of time taken up for assistance activities before the practicum begins. Lecturers said that the assistance process often takes quite a long time, so that the available practicum time (± 3 hours) is significantly reduced. This condition causes students to not have enough time to truly understand the practicum material in depth.

Furthermore, the lecturer revealed that during the assistance process, he was unable to optimally assess the students' initial knowledge levels. This was due to limited time available for assistance, while the number of students required was approximately 30. This situation resulted in a less than optimal identification of students' initial abilities. The lecturer also added that some students sometimes failed to clearly demonstrate their

understanding of the lab material, due to reluctance or unwillingness to ask questions. As a result, the lecturer had difficulty ensuring that students truly understood the lab material. The lecturer also stated that after the practicum was completed, he needed considerable time to assess the students. This assessment process was labor-intensive and time-consuming, adding to the lecturer's workload in managing the practicum activities as a whole.

The laboratory assistant echoed the remarks made by the lecturer in charge of the Microcontroller practicum. He also explained that the learning media used in the practicums were still conventional, making them less engaging. This situation resulted in students being passive and less creative during the practicums, as the existing learning media were unable to motivate and encourage them to be more active and innovative.

Further interviews with students also revealed similar complaints. Students expressed the hope that more engaging and easily accessible learning media would be available. They also admitted to often feeling embarrassed to ask lecturers or lab assistants when they encountered difficulties understanding the material. Furthermore, students felt that the current learning media hasn't kept up with current developments due to the minimal use of digital technology, making it less relevant to current learning needs.

Based on the results of the observations, a number of problems faced in the field were revealed. The observation process was carried out through interviews with lecturers and laboratory assistants, as well as students as the main users in the laboratory. According to Pratama (2023), identification of learning problems based on interviews with multiple informants provides a comprehensive picture for the development of targeted media. The initial findings are in line with the study (Saputra & Kurniawan, 2023) which emphasizes the importance of mapping user needs in designing learning media. In addition, an initial observation-based approach is also recommended by (Nugroho, 2022) to ensure that interactive media is appropriate to the real conditions of learning in vocational laboratories. Especially in the microcontroller practicum subject, these challenges are increasingly felt. Microcontroller practicum is a subject that places great emphasis on technical skills and an understanding of concepts in an applied manner.

With this background, researchers see the need to develop Artificial Intelligence-Based learning media as an appropriate solution to overcome these obstacles. This media allows for formal presentation of material and can be accessed flexibly by students. So by using Artificial Intelligence (AI), lecturers can be facilitated so that students can more easily understand what they do not know and lecturers can be helped in providing assistance and assessment to each student.

In a study by Sari & Avianty (2023), they confirmed that this media can provide interactive learning materials and support independent learning in the online Mathematics Learning Evaluation course. By utilizing several AI applications such as ChatGPT, Fliki, Toonme, and D-ID, this media produces engaging and easy-to-use audio and video content, significantly increasing student interaction and motivation. In the research of Sudrajat, D, et al. (2023), it was shown that the use of ChatGPT as artificial intelligence can help educators in compiling more effective, fast, and structured learning media content, thereby increasing the interest and credibility of educators in the teaching and learning process.

Although various studies have developed technology-based learning media, most still focus on the use of microcontroller simulators, which function as tools for circuit

visualization and programming. These simulators are generally static and unable to provide adaptive interaction, automated assistance, or real-time feedback on students' learning.

Based on these conditions, a significant research gap exists: the lack of learning media that integrates artificial intelligence (AI) as an intelligent learning system. Existing media are unable to replace the role of manual assistance in practicums and do not optimally support independent learning. Unlike conventional microcontroller simulators, the media developed in this study integrates AI in the form of an AI Agent (N8N)-based chatbot and the Gemini 2.5 Flash model that is capable of providing interactive responses, answer analysis, and automatic feedback on student work results. Thus, this media functions not only as a simulator, but as an adaptive learning system that is able to increase student effectiveness, independence, and engagement in microcontroller practicums.

RESEARCH METHODS

Types of research

This research is a Research and Development (R&D) study aimed at developing and testing the feasibility of Artificial Intelligence (AI)-based microcontroller practicum learning media. The development model used is a modification of the Borg & Gall, 4-D, and ADDIE models, adapted to the needs of developing web-based learning media. The results of modifications from various development models produce relevant and appropriate syntax for designing and developing learning media products. This syntax consists of, among others; (1) Media Needs Analysis (2) Media Design (3) Media Development (4) Evaluation (5) Dissemination & Implementation.

Test Subjects

The trial subjects in this study consisted of experts and media users. The expert subjects included two material experts and two media experts who had competence in the field of Microcontroller learning and learning media development. Validation by experts aimed to assess the feasibility of the content, appearance, and functionality of the developed learning media. The media user subjects were students of the Electronic Engineering Education Study Program and the Computer Engineering study program who took the Microcontroller Practicum course. User trials were conducted in stages, including individual trials, small group trials, and large group trials, to obtain input regarding the practicality and ease of use of the learning media. The effectiveness test of the learning media involved 60 students from the Department of Informatics and Computer Engineering, and the Department of Electronics, who were divided into two groups, namely 30 students as the experimental class and 30 students as the control class. The experimental class used Artificial Intelligence (AI)-based Microcontroller practicum learning media, while the control class used conventional learning media.

Data Collection Instruments

Interviews are a data collection technique used when researchers want to conduct a preliminary study to identify research problems, or when researchers want to learn more in-depth information and have a small number of respondents. Data collection methods, on the other hand, are procedures carried out to obtain data or information. Questionnaires are used as considerations for revising the learning model. The goal is to

determine the feasibility of this learning module and its suitability for use in the learning process.

Data Analysis Techniques

This study uses descriptive data analysis techniques. Descriptive data analysis is a statistic used to analyze data by describing or depicting the data as it is without the intention of making conclusions that apply to the public or generalizations (Sugiyono, 2016). Based on the validation questionnaire obtained, the formula used to process the data/responses of experts, content, and design experts with presentations is

$$P = \frac{X}{X_1} \times 100$$

Information:

P : Presentation

X : Respondent's answer in 1 item

X_1 : Total ideal score in 1 item

100% : Constant

Table 1. Gain Index Criteria

Gain Index	Interpretation
$g > 0.70$	Tall
$0.30 \leq g \leq 0.70$	Currently
$g < 0.30$	Low

Table 2. Criteria

Category	Qualification	Criteria
A	80-100%	Very Worthy
B	60-79%	Worthy
C	50-59%	Quite Decent
D	0-49%	Less than worthy

Practicality Analysis Uses the same percentage categories as the feasibility assessment. Effectiveness Analysis Effectiveness is measured using normalized gain (N-gain):

$$g \geq \frac{skor\ posttest - skor\ pretest}{skor\ maksimum - skor\ pretest}$$

Prerequisite Tests Normality test: Lilliefors Homogeneity test: F or Levene's test Hypothesis test: independent sample t test (Sig < 0.05 indicates a significant difference). Impact Analysis This analysis was conducted to test: improvement in conceptual understanding, independent learning, student engagement, and readiness to face Industry 4.0 automation competencies.

Research Design

The research design used in this study is "Pre-test-Post-test Control Group Design"

Table 1. Research Design

Group	Pre-test	Treatment	Post-test
E	T1	X	T2
K	T1	-	T2

Information:

E : Experimental Group

K : Control Group

- T1 : Pre-test
 T2 : Post-test
 X : Treatment, namely the application of learning modules
 *) The treatment was carried out four times.
 *) The sample for each class is 15 students.

RESULTS AND DISCUSSION

Research result

This research resulted in an Artificial Intelligence (AI)-based learning media for microcontroller practicums, developed as a web application. This learning media is equipped with digital jobsheet features, AI-based automated assistance, posttests, quizzes, and practicum report submission. The media is designed to support independent learning and improve the effectiveness of microcontroller practicums in vocational education.

The validation results show a very high level of feasibility with an average validation percentage of 92.14% and 92.78% for design experts, which shows that the media is very valid in terms of content, presentation, language, appearance and user friendliness.

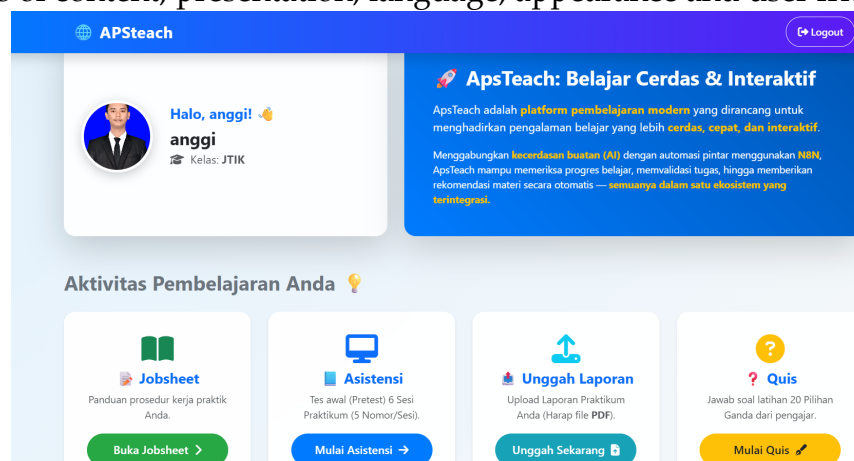


Figure 1. Media Display

The Practicality Test was conducted through individual, small group, and large group experiments. The Practicality Test results showed scores of 93.75%, 90%, and 85.58%, respectively, which are categorized as very feasible. These findings indicate that the media used is easy to use, has clear navigation, supports independent learning, and is able to increase student engagement in microcontroller practicum learning.

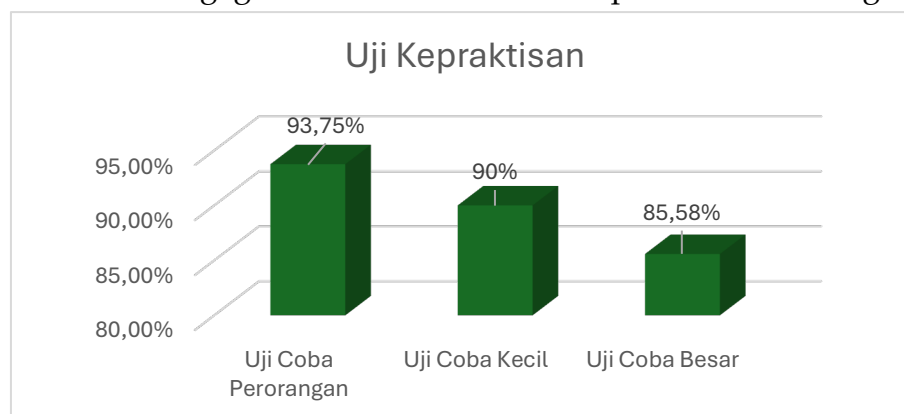


Figure 2. Percentage of Practicality Test Results

The effectiveness test was conducted through a student response questionnaire and analysis of learning outcomes using a pre-test and post-test. The questionnaire results showed the level of effectiveness in individual, small group, and large group experiments. The questionnaire results showed an effectiveness level of 95.41%, 87.50%, and 84.62%.

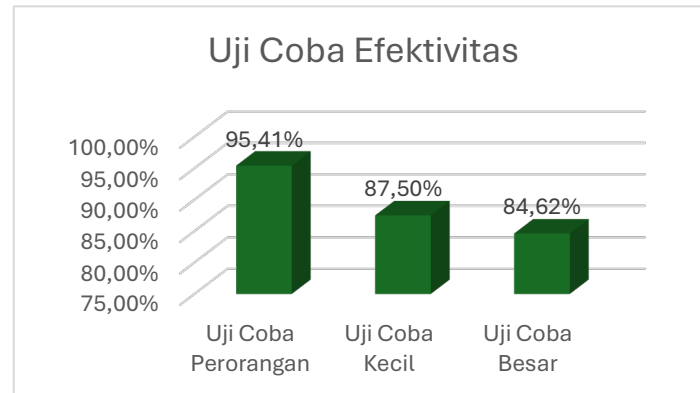


Figure 3. Percentage of Effectiveness Test Results

To obtain data on learning improvement, students were given a pretest as initial data and a posttest as final data. There were 30 students in the experimental class who were given AI-based learning media and a control class consisting of 30 students from a combination of mechatronics and vocational study programs and computer engineering who participated without using AI-based media. The results of the pretest and posttest for these two groups became the basis for analysis to measure the effectiveness of the microcontroller practicum learning media.

Table 3. Experimental value classes

Nu	Name	Pretest	Post Test	Gain Score
1	Tizya Anugrah Asdar	30	90	1
2	Ananda Puspitasari	40	80	0.66
3	Wulan Adinurmana	30	90	1
4	Diva Nur Maulidiyanti	40	90	0.71
5	Fahrian Dwi Ardhana	60	70	0.25
6	Suciana	30	100	1
7	Rezha Nabilah Mumtazah	50	70	0.4
8	Rismayanti	80	90	0.5
9	Muh Alif Generous	40	90	0.83
10	Patta Intang Pearl	20	90	0.87
11	Nurul Nabila	40	80	0.66
12	Ayu Wahyuni	80	100	1
13	Muhammad Faras	40	100	1
14	Qabliyah Ashari	20	90	0.87
15	Abd. Rahim	40	100	1
16	Andi Aidin Akbar	70	100	1
17	Annisa April	70	90	0.66
18	Early ferry	50	100	1
19	Joy Febrianto Hale	50	90	0.8
20	MUh ichwanul T	70	80	0.33
21	Muhammad Akhsan Awaluddin	50	80	0.6
22	Muhammad Alfarizi	60	90	0.75
23	Muhammad Rahyan Noorfauzan	40	70	0.5
24	Nayla Azzahra Karim	50	80	0.6
25	Nurul Hikmalia	70	80	0.33

Nu	Name	Pretest	Post Test	Gain Score
26	Rahmi Dwi Ramadhani	70	70	0
27	Rezky Suci Amalia	90	100	1
28	Sitti Nurhaliza	40	80	0.66
29	Sultan Budiluhur	50	90	0.8
30	Surya Radiramdhani S.	50	90	0.8
	Amount	1550	2620	
	Average	51.66	87.33	0.71933

Table 4. Control value classes

Nu	Name	Pretest	Post Test	Gain Score
1	Adhitya Saputra Alimuddin	60	60	0
2	Agustina Kondolele	60	60	0
3	Nuradelia	60	90	0.75
4	Andre Maulana	60	70	0.25
5	Hasnidar Ilyas	40	40	0
6	Holy Ramadan	50	50	0
7	Sri Angga	60	70	0.25
8	Asriadi	60	70	0.25
9	Sa'adah Ainun	70	80	0.33
10	Syarbina	60	60	0
11	Fidia Rahmadani	70	60	-0.33
12	Muzhirulhaq iftitah Amrullah	60	40	-0.5
13	Lisa	20	60	0.5
14	Lili Aprilya	50	70	0.4
15	Zulfikar	60	80	0.5
16	Askia Wali	60	40	-0.5
17	Graceful. S	50	70	0.4
18	Alif al an nur	70	40	-1
19	Charly Hardika	80	40	-2
20	Dinda Ayu Miriam Alamsyah	50	60	0.2
21	Elya Ikmal Tasidjawa	70	70	0.03
22	Fionagita Sabir	60	60	0
23	Fitri Afrianti	50	70	0.4
24	Kumaira	40	70	0.5
25	Muh bintang abywardhana	40	60	0.33
26	Muhammad Amar Amri Asnul	40	60	0.33
27	Naisya Nabila Pratiwi	40	70	0.5
28	Nur hikmah greetings	60	40	-0.5
29	Nur Fajriani Burhan	60	70	0.25
30	Sarah Triwahyuni	60	60	0
	Amount	1670	1840	
	Average	55.66	61.33	0.044666667

N-gain analysis, this study also calculated the standard deviation to determine the level of variation in student learning outcomes. Based on the gain data obtained, the average N-gain in the experimental class was 0.71 with a relatively low standard deviation (≈ 0.25), while in the control class the average N-gain was 0.04 with a higher standard deviation (≈ 0.46).

These results indicate that the improvement in learning outcomes in the experimental class was not only higher but also more consistent compared to the control class. In contrast, in the control class, there was quite a lot of variation, even with negative gain values, indicating that some students did not achieve improvement. Thus, the use of AI-

based learning media not only improves learning outcomes but also reduces the gap in understanding among students.

In addition, the results of the independent sample t-test showed a significance value of $0.001 < 0.05$, indicating a significant increase in learning outcomes in the experimental class compared to the control class. Thus, the artificial intelligence-based learning media was declared valid, practical, and effective for use in microcontroller practical learning in vocational and professional education.

Table 5. Results of Independent Sample T-Test

Variabel	Asumsi Varians	F	Sig. Levene	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI Lower	95% CI Upper
Hasil Belajar	Equal variances assumed	1.373	0.246	-8.610	58	<0.001	-26.000	3.020	-32.045	-19.955
	Equal variances not assumed	-	-	-8.610	53.285	<0.001	-26.000	3.020	-32.056	-19.944

Discussion

Development of learning media based on artificial intelligence This research is a Research and Development (R&D) study aimed at developing and testing the feasibility of Artificial Intelligence (AI)-based microcontroller practicum learning media. The development model used is a modification of the Borg & Gall, 4-D, and ADDIE models, adapted to the needs of developing web-based learning media. The results of modifications from various development models produce relevant and appropriate syntax for designing and developing learning media products. This syntax consists of, among others; (1) Media Needs Analysis (2) Media Design (3) Media Development (4) Evaluation (5) Dissemination & Implementation.

Expert Validation Results Validation results show a very high level of feasibility with an average validation percentage of 92.14% and 92.78% for design experts, which indicates that the media is very valid in terms of content, presentation, language, appearance and user friendliness. This score indicates that the media has met the feasibility standards in terms of content, presentation, language, appearance, and ease of use. Product validity testing in R&D research is useful for seeing the truth and appropriateness of a product or model that will be used in the learning process (Muhsinin & Fatmawati, 2020).

The Practicality Test showed that the media was easy to use and very well received by students. The Practicality Test was conducted through individual, small group, and large group trials. The results of the Practicality Test showed scores of 93.75%, 90%, and 85.58%, respectively, which were included in the very feasible category. The practicality referred to here is practicality in the field of education such as: learning tools, modules, instruments, or other products (Rahayu et al., 2019).

The effectiveness test shows that learning media has a significant positive impact on student learning outcomes. The questionnaire results show the level of effectiveness in individual, small group, and large group experiments. The questionnaire results show an effectiveness level of 95.41%, 87.50% and 84.62% which are included in the very feasible category. Erdina & Hariani, (2017) stated that "Effectiveness shows success in terms of whether or not the set targets have been achieved. The higher the results of the activity approach the target, the higher the effectiveness". Effectiveness can also be interpreted as a measurement of success in achieving predetermined goals (Putri, 2019).

Overall, the core confirms that the artificial intelligence-based microcontroller practical learning media that has been developed has met the criteria of being valid, practical, and effective, and is relevant for use in microcontroller practical learning.

CONCLUSION

1. Learning Media Design The learning media design is based on a needs analysis that shows that the practicum learning process still requires interactive, responsive media, and is able to provide automatic feedback. The media is designed with a clear navigation structure, a modern interface, and the arrangement of practicum materials according to the curriculum. The main features designed include: Welcome page, login, dashboard, jobsheet, assistance, upload reports, and quizzes (for students). Assistance management page, jobsheet management, practicum assignment management, grade management, and quiz management (for admins), AI integration on jobsheet chatbot, assistance answer checking, and quiz result analysis using AI Agent N8N and Gemini 2.5-flash model. The UI/UX design is made responsive, simple, and intuitive so that it is easy to use by both students and lecturers. This design ensures that each feature supports independent learning while facilitating digital-based assistance and evaluation.
2. The development of Learning Media is carried out through the stages of modifying the Borg & Gall, 4-D, and ADDIE models to produce the following steps: Needs Analysis, Design, Development, Evaluation, and Dissemination and implementation. The results of the development are in the form of APSteach AI web-based learning media that has complete features, including: Digital jobsheets with AI chatbot Automatic assistance, displaying essay questions per practicum and providing answer suggestions. Upload reports, with a structured collection format. Online quizzes, displaying automatic grades and detecting page changes. Admin dashboard, to manage all learning content. The media has been validated by material experts and media experts who stated that the product is in the very feasible category. Trials on 60 students showed that this media is very practical, easy to use, interactive, and effective in improving understanding and learning outcomes. The results of the Independent Sample t-test also showed a significant difference between the experimental and control classes after using the media. Overall, this media can be developed to meet the aspects of validity, practicality, and effectiveness so that it is suitable for use as a supporter of microcontroller practicum learning.

Implications:

1. Theoretical Implications

This research strengthens the theory that the use of AI-based learning media can improve the effectiveness of vocational learning. The integration of chatbots, automated analysis, and adaptive learning demonstrates AI's ability to function as an intelligent tutoring system in vocational education.

2. Practical Implications

- a. This media helps lecturers in managing practical classes more efficiently, reducing manual workload, and speeding up the evaluation process.
- b. Students gain a more modern, interactive learning experience that meets the demands of 21st century learning.

- c. The industrial world is helped because graduates who use this media have better digital skills, technical understanding, and learning independence.

3. Implications for Educational Institutions

This media can serve as an example of an AI-based learning media development model that can be applied to other practical courses. Sustainable implementation can support digital transformation programs in higher education.

Suggestion

For further development, this learning tool still has significant potential for improvement by integrating more sophisticated artificial intelligence models. Currently, the system uses the Google Gemini-based AI Agent, which has limitations in response coverage and analysis depth.

Therefore, further research is recommended to integrate other AI models, such as OpenAI, which has more contextual, adaptive, and responsive natural language processing capabilities. This multi-model AI integration is expected to improve the quality of interactions, expand reference sources, and provide more accurate and personalized feedback to students.

This development also has the potential to make learning media a more comprehensive intelligent tutoring system that is in line with learning needs in the digital era and industry 4.0.

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***Anggi Puspita Sari (Correspondent Author)**

Master's Degree Program, Technology and Vocational Education,
Makassar State University, Makassar, Indonesia.
E-mail: anggipuspitasari.S22024@student

Satria Gunawan

Educational and Vocational Technology, Faculty of Engineering, Makassar State University,
Makassar, Indonesia.
E-mail: sg.zain@unm.ac.id

Yasser A. Djawad

Educational Technology and Vocational Studies, Faculty of Engineering, Makassar State University,
Makassar, Indonesia.
Email: yasser.djawad@unm.ac.id
