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Development of Artificial Intelligence Based E-Learning Modules to Improve Students' Critical Thinking and Communication Skills

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Abstract: The increasingly rapid development of digital technology requires the world of education to adapt to various innovations, one of which is the use of artificial intelligence (AI) in learning. However, in reality, many schools still use conventional, less interactive teaching materials, thus not optimally improving 21st-century skills, particularly critical thinking and communication skills. This research aims to produce a suitable and effective artificial intelligence-based e-learning module for improving students' critical thinking and communication skills. The research employed a mixed methods approach with an embedded experimental model design, consisting of several stages: introduction, design, development, and interpretation. The research subjects were 60 students of class X of SMA Negeri 5 Sigi. The research instruments included expert validation sheets, cognitive assessment tests (functioning as pretest and posttest), observation sheets on student communication skills and observation sheets on student activities during the learning process, and interview guidelines after the learning process. This study concludes that the development of e-learning modules containing artificial intelligence is effective and feasible for use in improving students' critical thinking and communication skills.

Keywords: Artificial intelligence; Communication skills; Critical thinking skills; E-teaching module

Introduction

The development of technology and science in the 21st century has had a significant impact on almost all aspects of life, one of which is education. The development of science and technology has led to a shift in the learning paradigm, marked by changes in curriculum, media, and technology (Nuzulia et al., 2023).

The current learning system focuses on 21st-century skills, particularly critical thinking and communication skills. Critical thinking and communication skills are crucial for students. Critical thinking skills enable students to analyze information in depth, make rational decisions, and and answer the problems well (Susilawati et al., 2020). Laksanawati et al. (2020) argues that students' critical thinking skills are still relatively low. This low level of critical thinking skills can be seen from their tendency to simply accept information without questioning or analyzing it further (Sarkity & Sundari, 2021).

Apart from critical thinking skills, communication skills are also very important because with communication skills students can convey ideas or information clearly. Arsil et al. (2020), argues that communication skills can provide students with the means to convey messages, express themselves, and influence others in the learning process. Communication

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skills can also help students express ideas and understand the information conveyed by teachers in the material lesson (Marfuah, 2017). Treasures (2021) also stated that students' communication skills are still relatively low. This low level of communication skills can be seen from their inability to explain their thoughts clearly and systematically.(Nugroho & Oktaviani, 2015).

Critical thinking and communication skills can be improved in various ways, through the application of various effective methods. One way to improve these skills is by implementing learning modules integrated with technology(Kristanto & Nesri, 2020). Through AI-enabled electronic learning modules. This is because the learning modules in the Merdeka curriculum include a set of tools or media facilities, methods, and guides designed to meet student needs (Setiawan et al., 2022).

Learning modules integrated with technology are known as electronic learning modules. The integration of digital technology allows students to collaborate, discuss, and explore topics in depth, encouraging active and critical participation (Sakti, 2023).

According to Dewi et al. (2023) by utilizing technology in the learning process, learning objectives can be achieved optimally, because animations and images can attract students' attention during the learning process. This is in line with the opinion of Zaeni et al. (2018), technology can assist and facilitate teachers in conveying and providing information during the teaching and learning process. Furthermore, the integration of technology into physics learning modules, particularly renewable energy, is an effort to support environmental conservation by shifting from printed learning modules to electronic-based learning modules (Izzania et al., 2024).

In general, the teaching modules currently used are printed (conventional) teaching modules. Printed modules can only be used physically and are limited to the number of copies printed. In addition, printed teaching modules do not support interactivity like electronic modules that can include multimedia elements such as videos, animations, and interactive quizzes, which can increase student understanding and engagement. Another drawback of current teaching modules is that the learning process does not utilize artificial intelligence (AI) technology, especially chat GPT, deepseek, Gemini, Perlexity, and blackbox.

The application of AI in the world of education has had a significant impact, as evidenced by the increased efficiency of the educational process (Montenegro-Rueda et al., 2023). AI technology itself can help students access information faster, get feedback, and increase the effectiveness of learning through various AI-based platforms (Holmes et al., 2019). Furthermore, with access to a wide variety of information sources, AI can also help students see a problem from multiple perspectives, providing intellectual challenges through open-ended questions, problem-based scenarios, and discussions that encourage analysis and argumentation. Furthermore, AI has great potential to transform the learning process by providing a more adaptive and interactive learning experience (Zawacki-Richter et al., 2019). Agustinasari et al. (2025) argues that artificial intelligence (AI) technology can help students develop critical thinking skills when used appropriately. Therefore, AI technology can be utilized for various educational purposes. One such use is in the development of AI-based e-learning modules. The weaknesses of AI are clearly evident when it produces information or answers that are not necessarily accurate (Wan & Chen, 2024).

Based on the above problems, it is necessary to develop an AI-based renewable energy teaching e-module. This is because the teaching e-module to be developed provides a more innovative, flexible, easy-to-understand learning experience, provides opportunities to deliver material in a more engaging way, increases environmental awareness and encourages students to develop critical thinking and communication skills. In addition, previous studies have examined the linguistic quality and scientific accuracy of chatgpt, the transformation of the learning process with AI, analyzed the role and effectiveness of AI use, analyzed and compared chatgpt and gemini responses, evaluated the creation of modules using chatgpt, analyzed the advantages and disadvantages of using chatgpt and textbooks. In contrast to previous research, This research aims to produce a teaching e-module containing artificial intelligence that is feasible and effective for use in improving students' critical thinking skills and communication skills, which specifically includes AI, especially chatGPT, deepseek, Gemini, Perlexity and blackbox, as a learning tool. The integration of AI in this e-module is designed to encourage students to develop critical thinking and communication skills through discussion. The significance of this research lies in its contribution to addressing the challenges of 21st-century education, where students are required not only to understand material concepts but also to possess digital literacy, critical thinking, and communication skills, as well as the ability to utilize artificial intelligence technology wisely. Thus, this research provides a novel contribution to digital learning innovation in developing essential 21st-century skills.

Method

Research Methods

The method used in this research is a mixed method (mixed methods) with designembedded experimental model mixed research is a research method that

combines qualitative research with quantitative research (Azhari et al., 2023). Designembedded experimentalThe model is a mixed research design that involves the collection and analysis of qualitative data in an experimental design.. The process of developing this e-teaching module goes through several stages, namely the preliminary stage, design stage, development stage, and interpretation of research results.

Time and Location of Research

This research was conducted at SMA Negeri 5 Sigi. The subjects were 60 10th-grade students. The research and development took place during the even semester of the 2024/2025 academic year.

Data Collection Technique

Data collection techniques are questionnaire techniques through validation sheets filled out by the validator team, response questionnaires filled out by teachers and students to measure the practicality of the e-module, test techniques through pretest and posttest essay questions filled out by students to measure critical thinking skills, observation techniques through observation sheets to measure communication skills and student activities during the learning process, as well as interview techniques to explore the experiences and perceptions of students or respondents regarding the learning process they have participated in.

Data Analysis Techniques

The data obtained was analyzed using the average score formula to see the feasibility of the e-module and the practicality of the teaching e-module, the effectiveness test of the teaching e-module using the formula *effect size Cohen's d*using the SPSS application, while the data on critical thinking skills and communication skills used hypothesis testing, paired T-tests and N-gain tests.

The following is Table 1 for the assessment scales used in the expert validation questionnaire, educator responses, and student response questionnaire.

Table 1. E-Module Eligibility Categories (Ramadhani & Putra, 2021)

Mark	Category
81-100	Very good
61-80	Good
41-60	Enough
21-40	Not enough
0-20	Very less

Testing the effectiveness of e-learning modules using the formulaeffect size. Hypothesis testing was used to determine whether there were differences in critical thinking and communication skills between the experimental class using an artificial intelligence-based e-learning module and those using a conventional learning module. The hypothesis testing used in this study was the Independent Samples Test.

Table 2. Interpretation Effect Size (Rahmah et al., 2022)

Effect Size Value	Interpretation
< 0.2	Small
0.2 < d < 0.8	Currently
> 0.8	Big

The basis for decision making for calculating the Independent Samples Test hypothesis test is: (1) A significance value of ≤ 0.05 means there is a difference in students' critical thinking and communication skills between classes using e-learning modules containing artificial intelligence and classes using conventional learning modules. (2) A significance value of ≥ 0.05 indicates that there is no difference in students' critical thinking and communication skills between classes using e-learning modules containing artificial intelligence and classes using conventional learning modules.

Test of improvement of students' critical thinking skills and communication skills based on the n-gain level criteria in Table 3.

Table 3. Level Criteria N-gain (Wahab et al., 2021)

N-gain rate (%)	Criteria
$\langle g \rangle \geq 70$ %	Tall
$30 \leq \langle g \rangle < 70$ %	Currently
$\langle g \rangle < 30$ %	Low

Result and Discussion

The results of the research and development of e-learning modules containing Artificial Intelligence to improve students' critical thinking and communication skills were conducted on grade X students of SMA Negeri 5 Sigi. The method used in this study is a mixed method with an embedded experimental model design, which consists of 4 stages, including the preliminary stage, design, development, and interpretation of research results. The stages carried out in this study will be explained as follows.

This preliminary stage collected data based on literature studies, student analysis, teacher needs analysis, and curriculum analysis. The results of the literature study found that the use of artificial intelligence (AI) in the learning process through e-learning modules has a positive impact on improving the quality of learning and student learning outcomes. Various studies have shown that AI integration can provide a more personalized, interactive, and responsive learning experience to individual student

needs. The literature study also emphasized that the use of AI needs to be balanced with the teacher's role as a facilitator to maintain pedagogical aspects and humanistic values in learning. These findings provide an important basis for designing AI-containing learning modules that are not only innovative but also effective in supporting 21st-century learning. Based on the results of the student needs analysis conducted by distributing questionnaires to 20 students from SMA Negeri 5 Sigi. It was found that from several descriptions of the questions asked to students, it can be seen that almost all students agree with learning that utilizes artificial intelligence. Based on the results of observations at SMA Negeri 5 Sigi, the results showed that students tend to be passive during the learning process, this has an impact on low critical thinking skills. The low critical thinking skills of students can be seen from the results of the educational report on the critical reasoning indicator, which reached 54.92% in the moderate category. This indicates that students have difficulty answering analytical questions in identifying given problems. In addition to low critical thinking skills, students are also less active in group discussions, rarely provide responses in discussion forums, and the inability of students to explain their thoughts clearly and systematically. This can be seen from the results of the educational report on the literacy indicator, which reached 51.11% in the moderate category. Based on this analysis, students need interactive teaching materials. Therefore, it can be said that there is a need to develop e-learning modules containing artificial intelligence. The teacher needs analysis was conducted by administering a questionnaire to physics teachers from SMA Negeri 5 Sigi. From the results of the teacher needs analysis, it can be seen that teachers agree with learning that uses e-learning modules containing artificial intelligence. Therefore, it can be said that it is necessary to develop e-learning modules because of their relevance to education in the digital era. The curriculum analysis was conducted through interviews with the Vice Principal for curriculum at SMA Negeri 5 Sigi. The interview results showed that the school is starting to be open to the use of AI in learning to improve the quality and personalization of teaching materials. Although there is no formal policy yet, the initiative to use AI is still individual teachers.Schools support this with digital literacy training and adequate facilities such as internet access and computer labs. The main challenge is the gap in teachers' digital competency and understanding of AI. Evaluation of the AI e-module is still informal, but the school plans to conduct a more systematic review. The resource person hopes the government and universities will support the development of the AI e-module more seriously. Therefore, the development of AI-based teaching e-modules is considered crucial because it aligns with the demands of digital-era education and supports the transformation of learning to be more contextual, interactive, and technologically relevant. This is supported by previous research conducted by Seplianti (2025) The results of interviews with teachers and questionnaires distributed to students revealed that their teachers needed more attractive learning media and were able to provide automatic feedback to students. 87% of teachers stated that the conventional e-modules currently used were still too simple. rigid and less responsive to learning needs. Several teachers also highlighted the importance of personalized features, such as material recommendations tailored to students' abilities and AI-based automatic evaluation. Teachers hope for integration between interactive content, learning videos, and practice questions accompanied by analysis of learning outcomes. Furthermore, based on the results of the questionnaire, 91% of students prefer interactive learning media that is easily accessible through digital devices. They hope that e-modules will be equipped with interactive quizzes, video explanations, and automatic guidance when answering questions incorrectly. Students also admitted to having difficulty understanding material presented monotonously in printed modules. According to them, the use of AI technology, such as chatbots to explain material or automatic evaluation systems, will be very helpful in improving understanding and fostering interest in learning.

The design stage of the researcher's design for an e-module for renewable energy teaching containing Artificial Intelligence. The initial design for the e-module for renewable energy teaching containing Artificial Intelligence. The intelligence is an initial product draft that will be developed through storyboarding. At this stage, the initial design is a renewable energy teaching e-module containing artificial intelligence integrated with a website using Google Sites.

The e-learning module development phase refers to the design phase. Therefore, the e-learning module was designed using the Google Sites website to improve students' critical thinking and communication skills. The e-learning module comprises a complete version consisting of three parts.

General information: This general information section consists of school identity, initial competencies, Pancasila learning profile, facilities and infrastructure, and student targets, and the learning model used. This e-learning module is structured starting from general information consisting of the name of the compiler, educational unit, class/semester, material, sub-material and time allocation. Initial competencies consist of the Pancasila profile (noble character, mutual cooperation, independent, creative, critical reasoning), facilities and infrastructure consist of laptops, LCD/Projectors, and

smartphones, media consist of teaching modules, teaching materials, PPT, LKPD, energy videos. targets (students), learning models, consist of learning methods (PBL) and methods (discussion, group work, lectures). Core competencies: These core competencies consist of learning outcomes, elements of physics understanding, elements of process skills, learning objectives, meaningful understanding, and trigger questions, learning activities, assessments, reflections, glossaries and bibliographies. Attachment Components: The attachment section consists of LKPD, teaching materials, learning videos, artificial intelligence features, power points, and assessments.

Developed e-learning modules, then validated by material expert validators and media experts with the aim of finding out how the validator assessed the renewable energy teaching e-module containing artificial intelligence before being tested. Expert validation analysis, obtained scores and summarized in Table 4.

Table 4. Expert Validation Results

Description	Percentage (%)	Interpretation
Subject matter expert validation	77.75	Good
Media expert validation	80	Good
Critical thinking skills instrument	85	Very good
Communication skills instruments	82.85	Very good
Teacher response questionnaire	85	Very good
Student response questionnaire	83.75	Very good
Observation sheet instrument during treatment	86.65	Very good
Post-treatment interview guide instrument	80	Good

Based on the results of product validation by material experts, an average score of 77.75 was obtained with a good assessment category. Then, based on the results of product validation by media experts, an average score of 80 was obtained with a good assessment category. Based on the results of the judgment of critical thinking skills experts, an average score of 85 was obtained with a very good assessment category. Based on the results of the judgment of communication skills experts, an average score of 82.85 was obtained with a very good assessment category. Based on the results of the judgment of teachers' practicality questionnaires for e-learning modules, an average score of 85 was obtained with a very good assessment category. Based on the results of the judgment of students' practicality questionnaires for e-learning modules, an average score of 83.75 was obtained with a very good assessment category. Based on the results of the judgment of observation sheet experts during the treatment, an average score of 86.65 was obtained with a very good assessment category. Based on the results of the judgment of interview guide experts, an average score of 80 was obtained with a good assessment category. So, the renewable energy teaching e-module containing artificial intelligence is suitable for use and testing. This is supported by previous research conducted by Kurniawan (2024) regarding the validation of Android-based e-module experts using AI (artificial intelligence) technology which obtained a percentage score of 95.5%. Similarly, research conducted by Rengkung et al. (2025) Regarding the development of e-module teaching materials based on PBL using generative-AI, the percentage score obtained for material expert validation was 96% and media expert validation was 94% with a very valid category.

After the e-learning module was validated and revised based on suggestions and input from experts, a limited trial was conducted to analyze the practicality and effectiveness of the artificial intelligence-based e-learning module. The limited trial sample used to assess the practicality of the e-learning module included 10 students and 1 teacher. The results of the analysis of teacher responses to the learning module yielded scores summarized in Table 5.

Table 5. Results of Teacher Responses to the Practicality of E-Teaching Modules

Assessment Aspects	Average Assessment Results
Content quality	90
Language	90
Presentation	84
Learning Activities	80
Average	86
Interpretation	Very good

Based on the results of the level of practicality by the teacher, a score of 86 was obtained with a very good category. The results of the analysis of practical responses to the e-learning module containing artificial intelligence by students obtained values summarized in Table 6.

Table 6. Results of Student Responses to the Practicality of E-Learning Modules

Assessment Aspects	Average Assessment Results
Content quality	86.7
Material	81.6
Language	87.3
Average	85.2
Interpretation	Very good

The trial yielded a practicality rating of 85.2 for students, categorized as very good. Based on teacher and

student assessments, it can be concluded that the e-learning module containing artificial intelligence is practical to use. This is in line with previous research conducted by Ulya et al. (2025). Based on the results of the questionnaire distribution, students stated that the use of AI-based discovery learning e-modules was very practical, especially in terms of the AI features, ease of use, and visual appearance. This finding aligns with the concept of user experience (UX) in educational technology development, which emphasizes that learning media designed in an intuitive and interactive manner can encourage increased learning motivation (Ali et al., 2024).

To measure the extent to which the artificial intelligence-based e-learning module impacted students' critical thinking and communication skills, quantitative data analysis was conducted using the Paired Samples Effect Sizes test. The results of the analysis of the effectiveness of the artificial intelligence-based e-learning module on students' critical thinking skills yielded values summarized in Table 7.

Table 7. Results of Calculation of the Effectiveness of E-Teaching Modules on Students' Critical Thinking Skills

Information	Control Class	Experimental Class
Pre-Test	31.4	28.6
Post Test	74.7	82.1
Standard deviation	8,651	7,167
Cohen's d effect		1,284
Interpretation		Big

The results of the analysis of the calculation of the effectiveness of the e-learning module containing artificial intelligence on students' communication skills obtained values summarized in Table 8.

Table 8. Results of Calculation of the Effectiveness of E-Teaching Modules on Students' Communication Skills

Information	Control Class	Experimental Class
Pre-Test	51	49.3
Post Test	79.3	88.7
Standard deviation	28,333	10,148
Cohen's d effect		1,114
Interpretation		Big

The results of the effect size test on students' critical thinking skills obtained a Cohen's d Effect Size value of 1.284, categorized as large. The results of the effect size test on students' communication skills obtained a Cohen's d Effect Size value of 1.114, categorized as large. These results indicate that the effectiveness value of the e-learning module containing Artificial Intelligence has a high level of effectiveness in improving students' critical thinking and communication skills. This is in line with the opinion Holmes et al. (2019), artificial intelligence can help students access information more quickly, receive immediate feedback, and improve learning effectiveness through various AI-based platforms. Furthermore, the availability of easily accessible materials through AI-powered platforms allows them to learn individually and tailored to their individual needs.

To measure the extent of differences and improvements in students' critical thinking skills and communication skills when using the developed e-learning module, testing was conducted using quantitative and qualitative approaches. This product testing used 60 students divided into 30 control class students and 30 experimental class students, whose data consisted of quantitative data obtained from the initial test (pretest), final test (posttest) to measure the improvement of students' critical thinking skills and observations on the learning process were carried out to assess the improvement of students' communication skills. To see the improvement of students' critical thinking skills and communication skills, an analysis was carried out using hypothesis testing, paired T-tests and N-gain tests.

The results of the pretest hypothesis testing for the experimental class and control class can be seen in Table 9.

Table 9. Results of the Pretest Hypothesis Calculation for the Experimental Class and Control Class on Students' Critical Thinking Skills

Information	Control Class	Experimental Class
Pre-Test	31.1	32.6
Post Test	74.9	80
Standard deviation	9,245	10.70
Sig. (2-tailed)		0.402

Results of the pretest hypothesis test for the experimental class and control class obtained sig value. (2-tailed) namely 0.402. This value is more than 0.05, which means there is no difference between the experimental class and the control class, so it can be said that the initial abilities of students between the experimental class and the control class are the same.

The results of the posttest hypothesis testing for the experimental class and control class can be seen in Table 10.

Table 10. Results of the Posttest Hypothesis Calculation for the Experimental Class and Control Class on Students' Critical Thinking Skills

Information	Control Class	Experimental Class
Pre-Test	31.1	32.6
Post Test	74.9	80
Standard deviation	9,245	10.70
Sig. (2-tailed)		0.013

Test results posttest hypothesis of experimental class and control class obtainedsig value. (2-tailed) namely 0.013. This value is less than 0.05, which means there is a difference between the experimental class, which in the learning process uses e-learning modules containing artificial intelligence, and the control class, which in the learning process uses conventional learning modules.

The results of the paired T-test in the experimental class can be seen in Table 11.

Table 11. Results of the Paired t-Test of the Experimental Class on Students' Critical Thinking Skills

Information	Control Class	Experimental Class
Pre-Test	31.1	32.6
Post Test	74.9	80
Standard deviation	9,245	10.70
Sig. (2-tailed)		0.002

The results of the paired T-test in the experimental class obtained a significance value (2-tailed) of 0.002. This value is smaller than 0.05, which means there is a significant difference between students' critical thinking skills in the pretest data before treatment and the posttest data after treatment.

The results of the paired T-test on the control class can be seen in Table 12.

Table 12. Results of the Paired t-Test of the Control Class on Students' Critical Thinking Skills

Information	Control Class	Experimental Class
Pre-Test	31.1	32.6
Post Test	74.9	80
Standard deviation	9,245	10.70
Sig. (2-tailed)		0.006

The results of the paired T-test in the control class obtained a significance value (2-tailed) of 0.006. This value is smaller than 0.05, which means there is a significant difference between students' critical thinking skills in the pretest and posttest data.

To see the improvement in students' critical thinking skills, an N-gain test was conducted. The results of the N-gain test can be seen in Table 13.

Table 13. Results of N-gain Analysis on Students' Critical Thinking Skills

Description	Sample	Average	Gain (%)	Category
Pre-test experiment	30	32.6	70.1	Tall
Post test experiment	30	80		
Pre-test control	30	31.1	63.2	Currently
Post test control	30	74.9		

The results of the N-gain analysis showed an increase in critical thinking scores in both classes, but the increase in the experimental class was more significant. The average pretest score in the experimental class was 32.6 and increased to 80 in the posttest, resulting in an N-Gain of 70.1% with a high category. Meanwhile, the control class experienced an increase in the pretest average from 31.1 to 74.9 in the posttest, with an N-Gain of 63.2% with a medium category. Based on the results of the hypothesis test, paired T-test and N-gain test conducted, it can be said that the renewable energy teaching e-module containing artificial intelligence can improve students' critical thinking skills. This is reinforced by previous research conducted by Holmes et al. (2016) that the use of AI technology in learning can improve students' critical thinking skills. Furthermore, AI can also help students think more deeply.(Chiu et al., 2023).

In terms of communication skills, the results of the pretest hypothesis testing of the experimental class and control class can be seen in Table 14.

Table 14. Results of the Pretest Hypothesis Calculation for the Experimental Class and Control Class on Students' Communication Skills

Information	Control Class	Experimental Class
Pre-Test	50.8	50
Post Test	79.3	88.3
Standard deviation	28.50	11,214
Sig. (2-tailed)		0.329

Quantitative analysis shows that the results of the pretest hypothesis test in the experimental and control classes obtained a sig. (2-tailed) value in both the experimental and control classes, namely 0.329. This value is greater than 0.05, which means there is no difference between the experimental and control classes.

The results of the post-test hypothesis testing for the experimental class and control class can be seen in Table 15.

Table 15. Results of Posttest Hypothesis Calculations for the Experimental Class and Control Class on Students' Communication Skills

Information	Control Class	Experimental Class
Pre-Test	50.8	50
Post Test	79.3	88.3
Standard deviation	28.50	11,214
Sig. (2-tailed)		0.001

The results of the posttest hypothesis test in the experimental and control classes obtained a sig. (2-tailed) value of 0.001. This value is less than 0.05, which means there is a difference between the experimental class, which uses an e-learning module containing artificial intelligence, and the control class, which uses a conventional learning module. The results of the paired T-test in the experimental class can be seen in Table 16.

Table 16. Results of the Paired t-Test of the Experimental Class on Students' Communication Skills

Information	Control Class	Experimental Class
Pre-Test	50.8	50
Post Test	79.3	88.3
Standard deviation	28.50	11,214
Sig. (2-tailed)		0.001

The results of the paired T-test in the experimental class obtained a significance value (2-tailed) of 0.001. This value is smaller than 0.05, which means there is a significant difference between students' communication skills in the pretest data before treatment and the posttest data after treatment.

The results of the paired T-test on the control class can be seen in Table 17.

Table 17. Results of the Paired t-Test of the Control Class on Students' Communication Skills

Information	Control Class	Experimental Class
Pre-Test	50.8	50
Post Test	79.3	88.3
Standard deviation	28.50	11,214
Sig. (2-tailed)		0.012

The results of the paired T-test in the control class obtained a significance value (2-tailed) of 0.012. This value is smaller than 0.05, which means there is a significant difference between students' communication skills in the pretest and posttest data.

To see the improvement in students' communication skills, an N-gain test was conducted. The results of the N-gain test can be seen in Table 18.

Table 18. Results of N-gain Analysis on Students' Communication Skills

Class	Meeting	Sample	Average	Ideal Score	Gain (%)	Category
Experiment	1	30	58	100	72.7	Tall
Experiment	2	30	71.8	100		
Experiment	3	30	88.3	100		
Control	1	30	50.8	100	58.1	Currently
Control	2	30	62.7	100		
Control	3	30	79.3	100		

Based on the N-gain test, the average score of the experimental group increased from 58 to 88.3 with an N-Gain of 72.7% in the high category. Meanwhile, the control group only increased from 50.8 to 79.3 with an N-Gain of 58.1% in the medium category. Based on the results of the hypothesis test, paired T-test and N-gain test, it can be said that the e-learning module containing artificial intelligence can not only improve critical thinking skills but also support in improving students' communication skills. This is in line with previous research conducted by Cotton et al. (2024) AI can be a platform for asynchronous communication. Furthermore, integrating AI into the learning process can support a more interactive learning experience and facilitate the improvement of students' communication skills (Vázquez-Cano et al., 2021). These results are also supported by qualitative data obtained through observations and interviews. The observation results can be seen in Table 19.

Table 19. Observation Results during Treatment

Observed Aspects	Indicator	Meeting	Notes/Findings (Descriptive)
Student interest	Enthusiasm when opening the e-module	1	Most of the students looked enthusiastic when opening the e-module and were enthusiastic about asking questions.
	Facial expressions during exploration	2	Interest remains high, students begin to explore more deeply
		3	Consistent enthusiasm, some students began exploring additional features without teacher instruction
Interaction with AI features	Trying out AI features actively Ask if you have any difficulties	1	Students seemed curious and tried the AI question and answer feature to ask questions.
		2	Most students started actively using AI to answer questions.
		3	Already accustomed, students use AI as a primary tool when they are struggling.
Learning Independence	Don't rely too much on teachers Completing independent activities	1	Some students are still waiting for teacher instructions and are not yet fully independent.
		2	Independence increases, students are more confident in completing assignments
		3	The majority of students appeared independent and only occasionally asked questions.
Understanding of the material	Response when answering questions	1	Student answers are still limited, discussions have not developed
		2	The majority of students appear independent and only occasionally ask questions.

Observed Aspects	Indicator	Meeting	Notes/Findings (Descriptive)
	Discussion with friends regarding content	3	Understanding increases; discussions are more critical and relevant to the content of renewable energy materials.
Technical/Non-Technical constraints	Technical barriers when using e-modules	1	There are connection issues and some AI features are not directly accessible.
	Difficulty understanding the features or language of the e-module	2	Technical issues have reduced but some students have complained that the technical language is difficult to understand.
		3	Minimal technical challenges, students are more fluent in using features and understanding instructions.
Cooperation and collaboration (if in a group)	Discussion and exchange of opinions	1	Collaboration is still limited, some students tend to work alone
	Help each other using AI features	2	Starting to see cooperation, especially when working on questions
		3	Intense collaboration, students exchange ideas and help each other using AI features
Emotional responses and learning attitudes	Students show curiosity	1	The high curiosity of some students seemed amazed by the AI features.
	Positive/negative attitude towards learning	2	Students' consistent positive attitudes make them appear active and interested in learning.
		3	enthusiasm for learning increases, students show a positive attitude towards technology in learning

To explore students' perspectives on the learning process using an artificial intelligence-based e-module, researchers interviewed three students who had participated in the learning process using the e-module. This interview technique was used to directly explore students' responses to various aspects of the e-module's use, including initial impressions, ease of accessing and utilizing the AI features, level of understanding of the material, independence in learning, and input for future e-module development.

Through a qualitative approach, the data obtained allowed researchers to identify student responses that not only reflect perceptions of the e-module's effectiveness but also reveal student obstacles, needs, and adaptations within the context of technology-based learning. The following interview findings provide a more comprehensive picture of student experiences and serve as an evaluative basis for assessing the quality and potential for further development of the artificial intelligence-based e-module. The interview results can be seen in Table 20.

Table 20. Interview Results

Indicator	Question	Respondents	Respondents' Answers
Experience using e-modules	What was your first impression when using this renewable energy E-module?	Respondent 1	I think the module is cool. Unlike a regular book, it's visually appealing and includes chatbot-like features. When I first opened it, I was immediately intrigued, as it's rare to find a module that allows you to "chat."
		Respondent 2	At first, I was curious. When I saw the interface, I was immediately excited. The features made me want to try them all. The modules are like modern learning apps.
		Respondent 3	I was a bit surprised at first, as I'd never used a module like this before. But after trying it, it turned out to be quite fun.
	Do you feel more independent when studying with this module compared to regular learning?	Respondent 1	Yes, I prefer to take the initiative and find out for myself. Learning is more relaxed because I can repeat things whenever I want.
		Respondent 2	Yes. It allows me to study without having to wait for my turn to ask questions to the teacher. Especially if I study at night, I can ask the AI directly.
		Respondent 3	Yes, because I can learn by myself, try to answer the questions first, and if I'm confused, then ask the AI or the teacher.
	Have you ever experienced any technical difficulties while using this module?	Respondent 1	At first, I was confused about how to use the AI feature. But after they explained it, I understood. Sometimes the internet is also slow, which is a bit annoying.
		Respondent 2	Only the first time I used it, I didn't know what to type into the AI. But after trying it a few times, I got used to it.
		Respondent 3	I have. When the network is bad, the module is difficult to open. Then the AI feature crashes or responds slowly.

Indicator	Question	Respondents	Respondents' Answers
	What is the role of the teacher while you are using this module?	Respondent 1	Teachers are still needed, especially to confirm answers from AI and provide additional understanding if there is still confusion.
		Respondent 2	It's still important. The teacher is the one who helps provide guidance and re-explains any unclear AI answers.
		Respondent 3	Teachers are still needed, especially to confirm answers from AI and provide additional understanding if there is still confusion.
Perceptions about Al Features	Do you find the AI feature in this module helpful?	Respondent 1	Very helpful. Usually, if I don't understand something, I have to wait for the teacher. But with AI, I can ask questions directly, and the answers are quick and clear. It makes self-study much easier.
		Respondent 2	Not bad. Sometimes the answers are formal, so I still like to ask the teacher. But overall, it's quite helpful.
		Respondent 1	Very helpful. Usually, if I don't understand something, I have to wait for the teacher. But with AI, I can ask questions directly, and the answers are quick and clear. It makes self-study much easier.
	If you were asked to use an AI-based module again in another lesson, would you be willing? Why?	Respondent 1	I'm willing. Because I feel freer to learn and understand better because I can ask questions anytime.
		Respondent 2	Yes. Because it's more interesting and I can learn in a more flexible way.
		Respondent 3	Willing. More interesting and more suitable for today's times.
Impact on Conceptual Understanding	Which part of the module did you find easiest to understand? Why?	Respondent 1	The section on understanding renewable energy. Because the explanation is brief and there's a video too.
		Respondent 2	Video about water energy.
		Respondent 3	An introductory section on energy and types of energy sources. The explanations are clear and illustrated.
	Which part was the most difficult to understand? How did you overcome it?	Respondent 1	The section on comparing energy types, such as biomass and biogas, I asked AI about it, and after getting a re-answer, I finally understood it better.
		Respondent 2	I was confused when discussing the environmental impacts of hydroelectric power plants. It was a long discussion. I read it slowly and highlighted the important parts.
		Respondent 3	The part about how wind turbines work was a bit confusing because I had a hard time visualizing the process. I finally opened the video, and it was very helpful.
	Do you feel that the renewable energy material is easier to understand after using this E-module?	Respondent 1	Yes. Now I can explain to my friends about the differences in energy sources.
		Respondent 2	Yes. So I can give you real-life examples of renewable energy around us. Before, I only knew about solar power.
		Respondent 3	I feel much more understanding. Previously, when I read books, I often felt sleepy. But this module made me more focused and able to ask questions immediately if I was confused.
Advantages and disadvantages of E-module	10 What are the advantages of this module in your opinion?	Respondent 1	It's flexible, accessible from my phone, and makes me more comfortable studying on my own.
		Respondent 2	It's interesting, there are videos, and it can help you learn at any time.
		Respondent 3	Good, can be used independently
	What are the shortcomings of this module that need to be corrected?	Respondent 1	Some of the technical terms are too complicated at first. Perhaps they could be simplified or provided with a glossary.
		Respondent 2	It still depends on the connection. Furthermore, not all students immediately understand how to use it.
		Respondent 3	Still depends on the connection.
Your suggestions for the development of E-modules	What are your suggestions for the future development of this E-module?	Respondent 1	Perhaps a discussion forum or chat feature could be added between students to exchange answers or opinions.
		Respondent 2	I hope that in the future this e-module can be used offline as well, so it doesn't depend on an internet connection which can sometimes be slow.
		Respondent 3	In my opinion, it would be more interesting if there were educational mini games or quick quizzes after each sub-chapter, to make it more challenging.

Based on observations and interviews, it was shown that discussion and presentation activities supported by AI features provided students with greater freedom of expression. They learned to convey ideas, receive automated feedback, and organize information in a more structured manner. During the implementation, students also demonstrated a high level of learning independence. They did not rely solely on the teacher but were also able to explore the material independently through various media available in the teaching materials. This aligns with the opinion of Apriadi et al. (2023) who stated that the use of AI technology can create more engaging and interactive learning. E-modules can also help students who experience learning difficulties, and they can also help students learn independently and measure their level of understanding (Laili, 2019). Furthermore, students no longer rely solely on teachers as their sole source of knowledge, but rather learn independently, in a structured, and directed manner to complete assigned tasks and problems. Alternative e-modules can stimulate, build, and strengthen students' interest in independent learning, making the learning process more effective and efficient, resulting in high-quality learning (Sidiq, 2020).

Furthermore, the interview results revealed the advantages and disadvantages of the e-module. Key advantages include an attractive interface, flexible learning schedules, and AI features that provide immediate feedback. Disadvantages include the need for an unstable internet connection and a lack of initial understanding of the AI features. This indicates the need for continuous improvement. These findings provide important insights for future e-module development, particularly regarding infrastructure readiness and user training to prevent students from experiencing technical confusion that hinders learning.

In general, the integration of quantitative and qualitative data in this study indicates that e-learning modules containing artificial intelligence have a significant positive impact on improving students' critical thinking and communication skills. This success is due to a personalized, interactive, and adaptive learning approach tailored to individual student needs. Although technical challenges remain, the results of this study confirm that developing e-learning modules containing artificial intelligence on renewable energy is a strategic step in supporting the implementation of the independent curriculum and relevant and meaningful 21st-century learning. With the right approach, e-learning modules containing artificial intelligence have great potential as a relevant and effective learning solution in the digital era.

Conclusion

Based on the research results, it can be concluded that the development of an e-learning module containing artificial intelligence has proven feasible, practical, and effective for use in learning and can improve students' critical thinking and communication skills. The integration of artificial intelligence into this e-learning module, such as virtual assistants and interactive simulations, can encourage students to think more analytically, evaluate information in depth, and convey ideas more clearly and effectively. This e-learning module also facilitates learning that is more responsive to student needs, thus creating a more active and communicative learning environment. However, this e-module also has limitations, such as being tied to internet access, teachers' skills in operating AI technology, and the limited devices some students own. Furthermore, the scope of this research is still limited to developing critical thinking and communication skills, thus not encompassing other dimensions of 21st-century skills. Therefore, future research should focus on developing e-modules that also emphasize collaboration and creativity, testing their effectiveness across various subjects and educational levels, and integrating more advanced AI-based evaluation systems to provide a more comprehensive picture of student development.

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