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DEVELOPMENT OF AI-BASED E-MODULES ON CELL MATERIALS TO IMPROVE STUDENT LEARNING OUTCOMES AND CREATIVITY

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ABSTRACT

Learning of cell material in science education often faces several challenges, particularly low student learning outcomes and limited student creativity due to the lack of interactive and innovative learning media. In addition, the integration of artificial intelligence (AI) in learning resources is still rarely implemented in classroom practice. Therefore, the development of innovative digital teaching materials is needed to support more effective and engaging learning. This study aims to develop an AI-based e-module on cell learning in science education to improve learning outcomes while fostering student creativity. This study employed a Research and Development (R&D) method using the 4-D model (Define, Design, Develop, and Disseminate). The effectiveness of the developed e-module was tested using a true experimental design with a pretest–posttest control group. Subjects included media experts, learning material experts, and students at MTs Mada Nusantara. The results showed that the AI-based e-module on cell learning achieved a high level of validity and was declared highly feasible by both media experts and learning material experts. Learning outcomes were improved in the experimental class, with the average score increasing from 68.96 to 76.58. Students' creativity also improved, with most students categorized as creative to very creative after using the module. The average practicality score from teachers and students was 3.66, indicating that the e-module is easy to use, effective, and relevant as a teaching material to support the learning process. This study contributes to the development of innovative AI-based digital learning media in science education and implies that AI-based e-modules can be effectively used as interactive teaching materials to enhance students' conceptual understanding, creativity, and technology-integrated science learning.

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1. INTRODUCTION

Electronic modules, or e-modules, are now widely used in modern education because they can be used independently by students as learning resources. Learning content in e-modules is regularly structured and varied, ranging from digital text, audio, to animation, making the material

feel more alive (Sattvika 2024). The learning process becomes more flexible because students can adjust their own learning pace, and this condition strengthens independent learning (Akhsan 2024). E-modules also encourage understanding of the material for students with diverse abilities because the flow is structured and easy to follow (Sartika 2025). Easy access makes e-modules, as well as the process of using them easily anywhere and anytime, so students are less dependent on and also waiting for the presence of instructors and are more accustomed to learning independently (Salsabila 2024). Continuously developing technological support makes e-modules in line with digital learning, which presents new and more engaging learning experiences (Sartika 2025).

The e-module content is presented in various formats, such as visual text and videos, designed to build student learning motivation. The attractively packaged material makes the lessons easier to understand (Putu 2025). E-modules provide space for educators to create interactive and varied learning processes related to biology learning materials. In interactive learning, educators are required and required to provide educational services that enable students to understand easily on their own without feeling dependent on the educator (Hidawati and Isnawati 2025). The coherent structure of the material combined with the freedom to learn without complete dependence on teacher explanations makes e-modules an effective learning tool (Seplianti and Syarifuddin 2025). The role of teachers remains crucial in designing learning strategies and selecting methods appropriate to the character of the material. The use of technology in delivering material opens up opportunities for the use of visual media such as images and animations, thereby improving the quality of learning, in line with Trianto's view on the importance of thorough learning planning.

Various learning media, including e-modules, have been proven to contribute to improving student learning outcomes. Diverse media makes it easier for students to follow lessons and understand the material more comprehensively (Prianto 2025). The presence of smartphones has also expanded access to learning and reduced reliance on printed textbooks, thus increasing student interest in learning (Setiawan 2025). A strong interest in learning is a marker of successful learning and can be fostered through the selection of appropriate media (Rori 2025).

The development of e-modules is also aimed at strengthening student creativity. Creativity helps students generate new, innovative ideas that are relevant to their learning needs (Wijaya 2023). Creative thinking skills support students in solving problems and generating original ideas, enabling them to create useful learning media (Rengkung 2025). Creativity indicators such as flexibility and originality need to be continuously developed because they play a significant role in encouraging student innovation (Al Fajri and Chusni 2024).

Observations at MTs Mada Nusantara indicate that student learning outcomes on cell topics remain low, likely related to the suboptimal development of e-modules. Formative assessments indicate that many students have not yet reached the Minimum Completion Criteria, further highlighting the need for more relevant teaching materials. E-module development is seen as a solution to improve student learning outcomes and creativity through more focused, independent learning. A positive response from students and teachers is expected through the implementation of e-modules tailored to learning needs.

Previous studies have shown that e-modules can improve learning independence and students' understanding of learning materials. Akhsan (2024) found that the use of e-modules encourages students to learn independently because the material can be accessed flexibly. Similarly, Sartika (2025) reported that structured e-module content helps students understand

complex concepts more easily. In addition, Salsabila (2024) emphasized that e-modules allow students to learn anytime and anywhere, reducing dependence on teachers. However, most previous studies focused primarily on learning outcomes and accessibility, while studies examining the role of e-modules in enhancing students' creativity are still limited.

Furthermore, previous studies on e-modules in science learning have mostly focused on digital learning materials without integrating artificial intelligence to support interactive and adaptive learning processes. Conventional (non-AI) e-modules generally present content in a static and linear manner, with limited opportunities for real-time interaction, immediate feedback, and personalized learning support. As a result, students often experience delays in obtaining explanations when facing difficulties, and the learning process tends to remain one-directional despite being delivered in digital form. In addition, conventional e-modules have not optimally facilitated the development of higher-order thinking skills, such as creativity, because they lack adaptive features that can respond to individual student needs and learning patterns. This limitation highlights a critical gap where digital modules have not fully transformed learning into an interactive, responsive, and student-centered experience. The integration of artificial intelligence becomes crucial in addressing these shortcomings, as AI enables dynamic interaction, instant feedback, and personalized learning pathways that cannot be achieved through conventional e-modules. AI-based systems can simulate two-way communication, provide context-sensitive explanations, and adjust content based on student responses, thereby supporting deeper understanding and fostering creativity. Research specifically examining the effectiveness of AI-based e-modules in improving both learning outcomes and student creativity on cell material is still limited. Therefore, this study seeks to fill this research gap by developing and evaluating an AI-based e-module on cell topics to improve student learning outcomes and creativity. The study, "Development of AI-Based E-Modules on Cell Topics to Improve Student Learning Outcomes and Creativity," emphasizes the importance of educational innovation in improving the quality of learning.

2. METHOD

In this study, researchers used a Research and Development (R&D) approach focused on improving student learning outcomes and creativity through the development of AI-based e-modules (Rachman 2024). The AI-based e-module integrates several artificial intelligence technologies, including a Natural Language Processing (NLP)-based chatbot that allows students to interact with the module through automated question-and-answer sessions, as well as an adaptive learning feature that provides immediate feedback and adjusts explanations based on student responses. In addition, the system applies rule-based and machine learning–assisted mechanisms to analyze student input and deliver contextual explanations in real time. The research stages employed the 4D model developed by Thiagarajan (Judijanto 2024), which consists of four main stages: define, design, develop, and disseminate, where the define stage involved a needs analysis to identify problems in the learning process, particularly related to student learning outcomes on cell material and the need for innovative learning media, including curriculum analysis, student characteristics analysis, and learning objectives analysis; the design stage involved preparing the structure and initial design of the AI-based e-module, including determining learning objectives, selecting learning materials, designing learning activities, and

preparing evaluation instruments; the develop stage involved producing the e-module prototype and validating it by media experts and subject matter experts to ensure its feasibility and quality, followed by revisions based on expert suggestions before testing on students; and the disseminate stage involved implementing the validated e-module in the classroom and evaluating its effectiveness in improving student learning outcomes and creativity.

Effectiveness testing was conducted through an experimental method using a True Experimental Design with a Pretest–Posttest Control Group Design. The assessment instruments were analyzed first to ensure their validity and reliability before being used in a large-scale trial. The validation process involved subject matter experts, media experts, and teachers appointed based on school recommendations. Empirical testing was conducted by administering the instruments to students, and the results were analyzed using SPSS Statistics 24 to accurately determine the validity of each item (Abdussamad 2024). A summary of the instrument testing results is presented in Table 1.

Table 1. Instrument Validity Test Results

Criteria	Amount
Valid	2 5

Meanwhile, the reliability of the instrument was tested using the Cronbach's alpha method with a limit of more than 0.60 indicating that the questions were reliable. This can be seen in Table 2.

Table 2Reliability Test Results

Cronbach's Alpha	N of Items	Conclusion
0 . 641	2 5	Reliable

Once the instrument has been declared valid and reliable, the next step is data analysis. This includes analyzing the validity of the e-module, obtained from the validator's responses to the material and media experts using a scale of one to four. The initial data was analyzed to test for normality and homogeneity, as shown in Tables 3, 4, and 5.

Table 3Normality Test

Tests Of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	Df	Sig.	Statistic	Df	Sig.
Hasil	Pretest Kelas Kontrol Hasil Belajar	0.166	25	0.074	0.947	25	0.217
	Posttest Kelas Kontrol Hasil Belajar	0.116	25	0.200*	0.956	25	0.338
	Pretest Kelas Eksperimen Hasil Belajar	0.145	25	0.187	0.953	25	0.298
	Posttest Kelas Eksperimen Hasil Belajar	0.123	25	0.200*	0.930	25	0.088

The test findings in Table 3 provide information on the existence of a significance value above 0.05, thus indicating that the resulting data is normally distributed.

Table 4Homogeneity Test of Control Class

Test Of Homogeneity Of Variance					
		Levene Statistic	Df1	Df2	Sig.
Hasil Belajar	Based On Mean	0.293	1	48	0.591
	Based On Median	0.214	1	48	0.646
	Based On Median And With Adjusted Df	0.214	1	44.867	0.646
	Based On Trimmed Mean	0.236	1	48	0.629

The findings in Table 4 provide information with a value of 0.591 > 0.05 which indicates the existence of a homogeneous form of data in each class.

Table 5Experimental Class Homogeneity Test

Test Of Homogeneity Of Variance					
		Levene Statistic	Df1	Df2	Sig.
Hasil Belajar	Based On Mean	3.216	1	48	0.079
	Based On Median	3.200	1	48	0.080
	Based On Median And With Adjusted Df	3.200	1	41.833	0.081
	Based On Trimmed Mean	3.204	1	48	0.080

The significance value of the homogeneity of the experimental class according to Table 5 is 0.079 > 0.05 which indicates the existence of a homogeneous form of data in each class (Sumbodo 2024) . After the initial test results showed the existence of a normal distribution of data and also proved the homogeneous data in each class, the next stage carried out by the researcher in this study was to conduct tests in the next stage in the form of a t-test and also the N-gain test used to show the best ability (Slamet 2022) .

3. RESULTS AND DISCUSSION

3.1 Validity of AI-Based E-Modules on Cell Material Used as Student Learning Media

The validity assessment of the AI-based e-module on cell material was conducted to ensure the product's suitability as a learning material ready for use in the classroom. The validation process involved two expert lecturers, Dr. Sigit Saptono, M.Pd. and Arif Widiyatmoko, S.Pd., M.Pd., and one biology teacher, Fariza Amelia, S.Pd., who jointly reviewed the content presentation and language use in the e-module. The assessment was carried out comprehensively so that the module not only met academic standards but could also be used effectively and interestingly for students during the learning process. The results of the e-module validity scores obtained from media experts and material experts are presented in Tables 3, 4, and 5.

Table 6Validation Results from Media Experts

Validator 1	Aspect	V Value	Information
Validator 1	suitability of content	1	Very Worthy
	Presentation Eligibility	1	Very Worthy
	Language	0.75	Worthy

Table 7Validation Results from Media Experts

Validator 2	Aspect	V Value	Category
Validator 2	Content suitability	1	Very Worthy
	Presentation Eligibility	1	Very Worthy
	Language	1	Very Worthy

Table 8Validation Results from Material Experts

Validator 1	Aspect	V Value	Information
Validator 1	Content suitability	1	Very high
	Presentation Eligibility	1	Very high
	Language	1	Very high

The assessment results in Tables 3, 4, and 5 show that the e-module received a "very appropriate" category from media experts, with high ratings across all aspects. The average V score approached the maximum, indicating that the display design, color choices, and page layout were in accordance with the characteristics of digital learning media. However, the validator provided input for improvements, such as larger font sizes and improved white space for a more proportional and attractive appearance. The assessment from material experts also showed very satisfactory results. All aspects, including the appropriateness of content and presentation, received a "very high" category. The regularly structured and relevant content of the material to the basic competencies of junior high school biology was appreciated, although there were suggestions to adjust the practice questions to align with the latest assessment model, the Minimum Competency

Assessment (AKM). The addition of graphic elements and context to the questions is expected to train students in critical thinking.

Revisions to the e-module, based on validator suggestions, focused on visual and substantive improvements. Researchers adjusted the font size for readability, adjusted the page layout, and added illustrations to enhance the visual appeal. By adjusting the questions in each sub-chapter to AKM standards, the e-module is now not only engaging but also relevant to competency-based assessments. These improvements have had a significant impact on how students interact with the learning materials, as evidenced by the positive feedback from teachers and whose students assessed the e-module as being able to stimulate learning interest. The attractive presentation combined with easy-to-understand language helps students better grasp cell concepts, thereby increasing their curiosity and motivation to learn. Several feedback points regarding the clarity of the writing have been addressed and adjusted, resulting in the AI-based e-module being deemed suitable for use.

3.2 Effectiveness of AI-Based E-Modules on Cell Material Developed to Improve Student Learning Outcomes

The application of AI-based e-modules on cell material has been proven to be able to improve student learning outcomes in the experimental class compared to the control class, as seen from the implementation of learning in two meetings through a pretest without the use of e-modules and a posttest with AI-based e-modules as shown in Table 9.

Table 9Increasing the Effectiveness of E-Modules

Class	Average Pretest	Average Posttest	N-Gain	Category
Control	63.04	65.44	0.51666	Moderate
Experimental	68.96	76.48	0.75736	High

The data in Table 9 shows the difference in the level of effectiveness of the e-module between the control class and the experimental class based on the comparison of pretest and posttest results. The results indicate that the experimental class experienced a higher improvement in learning outcomes compared to the control class. This finding suggests that the implementation of the AI-based e-module provides a more effective learning experience by supporting interactive and independent learning processes. The higher improvement in the experimental class can be attributed to the features of the AI-based e-module, which allow students to explore the material more actively and flexibly. Digital learning media such as e-modules provide opportunities for students to access learning materials repeatedly and at their own pace, which can enhance conceptual understanding.

In addition to the improvement in overall learning outcomes, improved learning outcomes were also evident in the achievement of each cognitive aspect (C1–C6). After learning using the AI-based e-module, the experimental class showed significant improvement in all aspects, particularly in the higher-order cognitive skills of synthesis (C5) and evaluation (C6). This result indicates that the use of AI-based e-modules not only improves basic understanding but also supports the development of higher-order thinking skills. These findings support previous studies which state that digital learning media can facilitate deeper learning processes and promote

students' analytical and evaluative abilities. Consistent improvements in these cognitive aspects indicate that the e-module broadens students' thinking skills, especially at a higher level. This can be seen in Table 10.

Table 10Aspects of Learning Outcomes in the Experimental Class Posttest

Code	Learning Outcome Aspect	Indicators	Mean Score	Percentage (%)	Total Score
C1	Knowledge	Remember; Memorize; Mention	2.52	84.00%	63
C2	Comprehension	Explain; Describe; Summarize	2.16	72.00%	54
C3	Application	Calculate; Prove; Complete	4.80	68.57%	120
C4	Analysis	Select; Differentiate; Divide	2.36	78.67%	59
C5	Synthesis	Arrange; Design; Create	3.60	90.00%	90
C6	Evaluation	Critique; Assess; Interpret	3.68	73.60%	92

Based Table 10, research on cell materials shows that AI-based e-modules can significantly improve student learning outcomes. This improvement is reflected in average grades, cognitive achievement, and student responses during the learning process. The experimental class using the AI-based e-module showed a higher jump in scores than the control class, both at lower cognitive levels such as remembering and understanding, and at higher cognitive levels such as analyzing and evaluating. These findings confirm that the use of AI technology in e-modules can help students understand abstract cell concepts in a more concrete and interactive way. The implementation of AI-based e-modules on cell learning has also been shown to improve overall learning effectiveness. Students not only achieved better grades but also demonstrated greater learning engagement thanks to adaptive features that tailor the material to their needs (Ismail and Hasanah 2024) . This success demonstrates that integrating AI technology into e-module development can be an innovative strategy for improving the quality of education in the 21st-century learning era (Akbar and Rimo 2025) .

3.3 The Effectiveness of the Developed AI-Based E-Module on Cell Material on Student Creativity

The use of AI-based e-modules for cell material in class VIII A has had a positive impact on increasing student creativity during the learning process. Students are able to utilize the digital features in the modules to explore ideas, understand broader concepts, and develop ideas independently. The interactive learning environment also makes students more confident in expressing themselves and trying new approaches to completing assignments. The results of the student creativity response test are shown in Table 11.

Table 11Results of Student Creativity Responses

Creativity Aspects	Average	Percentage (%)	Total Score	Information
Originality	4,736	94.72%	118.4	Very Creative
Flexibility	4,552	91.04%	113.8	Very Creative
Elaboration	3,580	71.60%	89.5	Quite Creative
Smoothness	4,368	87.36%	109.2	Creative

Based Table 11, shows that originality is the most prominent indicator, with an average score of 4.736 (94.72%). AI-based features that provide visualizations of cell concepts, interactive simulations, and examples of idea development encourage students to be more imaginative and connect knowledge to other relevant contexts. Furthermore, flexibility also experienced a strong increase, with an average score of 4,552 (91.04%). This improvement illustrates students' ability to view a concept from multiple perspectives and generate more varied alternative ways of thinking. When faced with biological problems related to cell matter, they were able to develop more solution options and assess which approach was most appropriate. Elaboration skills also showed significant improvement, with an average score of 3.580, or 71.60%. The use of AI-based e-modules provided students with the opportunity to expand their explanations through additional examples, detailed descriptions, and supporting visualizations provided within the module. These skills help students not only articulate an idea but also elaborate it more regularly and in-depth. Fluency in thinking also improved significantly, with an average score of 4.368 and a percentage of 87.36%. The digital learning environment, which facilitates direct interaction through AI, enabled students to be more active in processing information. They were aided by AI features that provided quick feedback, additional examples, and thought-provoking questions. This facilitated a more fluid and responsive flow of thought during learning.

The findings of this study also align with those of Suharta et al. (2025) , who found that interactive digital e-modules can enhance originality and flexibility through material visualization and exploratory activities. This is further supported Fitri et al. (2025) , who reported that learning with AI-based modules can enhance fluency and idea elaboration thanks to the stimulation of questions, additional examples, and instant feedback.

3.4 Practicality of Developed Cell Material AI-Based E-Module

The practicality test of the AI-based e-module on cell learning provides a clear picture of the level of ease and efficiency of use by both teachers and students. This evaluation process is crucial, not only to assess the reliability of the theory but also to assess its effectiveness in the implementation of learning in the real world. Through a Likert-scale questionnaire, respondents can provide valuable feedback on various aspects such as ease of use, content suitability, interactivity, and visual appeal. The results of the e-module practicality test can be seen in Tables 12 and 13.

Table 12Results of the Practicality Test of Teachers as Expert Practitioners

No	Assessment Aspects	Average Score
1	Ease of use of the module	3.7
2	Suitability of material with curriculum	3.8

No	Assessment Aspects	Average Score
3	Interactivity and AI features in the module	3.5
4	Availability of instructions for use	3.6
5	Efficiency of usage time	3.7
	Total Average	**3.66**

Table 13Results of the Practicality Test of Students as End Users

No	Assessment Aspects	Average Score
1	Ease of access via digital devices	3.6
2	Easy to understand language and display	3.5
3	Suitability of materials to learning needs	3.7
4	Interest in AI features (simulation/chat)	3.8
5	Clarity of navigation and instructions	3.6
	Total Average	**3.64**

The findings in Tables 12 and 13 demonstrate the critical importance of e-modules in supporting 21st-century learning, which relies heavily on digital technology for the learning process. Science teachers' assessments demonstrated a high level of satisfaction across all aspects of the module's practicality. The aspect of material suitability to the curriculum received the highest score of 3.8, indicating that the material was aligned with the applicable curriculum framework. The module's ease of use was also rated high, with a score of 3.7, enabling teachers to implement the e-module directly without significant obstacles. The interactivity and AI features received a score of 3.5, indicating good performance and opening up opportunities for development to strengthen AI-based interactions. Instructions for use and time efficiency were considered important factors supporting the module's practicality, with scores of 3.6 and 3.7 indicating a rapid adaptation process without technical obstacles during learning. The average teacher assessment score of 3.66 confirmed that this e-module has a high level of practicality and is capable of optimally supporting teaching and learning activities in the classroom.

Responses from students in grades VIII A and VIII B of MTs Mada Nusantara also led to a positive assessment of the practicality of the e-module. Access via digital devices was deemed easy with an average score of 3.6, indicating the module can be used through various digital media. The display and language used in the module were well understood by students, achieving a score of 3.5, indicating that the material can be accepted by students with different levels of digital literacy. The AI feature was the main attraction, with the highest score of 3.8, demonstrating the role of interactive features in increasing student interest and enthusiasm during the learning process.

The suitability of the material to students' learning needs, which achieved a score of 3.7, indicates that the e-module is capable of facilitating a deeper and more contextual understanding of cell concepts. This finding reflects the principles of constructivist learning theory, which emphasizes that students actively construct knowledge when learning materials are relevant to their needs and prior understanding. The clarity of navigation and user instructions, with a score of 3.6, further supports an effective learning process by reducing confusion and enabling students

to focus on essential content. This condition aligns with cognitive load theory, where well-structured and clearly organized learning resources help minimize extraneous cognitive load, allowing students to process information more efficiently. The overall average score of 3.64 places the e-module in the very practical category, indicating that it successfully supports independent learning and aligns with the principles of active learning, where students are encouraged to take an active role in managing their own learning process.

The practicality of the e-module is also reflected in its ability to provide a flexible and responsive learning experience (Wariani 2025). This flexibility allows students to learn at their own pace and revisit materials as needed, which is consistent with the concept of self-regulated learning theory. In this context, students are given the opportunity to plan, monitor, and evaluate their own learning activities without complete dependence on the teacher. The integration of AI-based interactions strengthens this aspect, as students can directly engage with the module content through automated question-and-answer sessions and simulated conversations. Such interaction supports the idea of student-centered learning, where learners become the main actors in the learning process, while the system functions as a facilitator that provides guidance and support when needed.

Furthermore, the AI system's ability to provide rapid responses contributes significantly to students' understanding of concepts, as they do not need to wait for teacher explanations. This immediacy aligns with the concept of scaffolding in social constructivism, particularly in Vygotsky's theory, where timely assistance helps learners bridge gaps in their understanding. The adaptive nature of the e-module, which adjusts to students' learning rhythms and styles, also reflects the principles of personalized learning theory, where instruction is tailored to individual needs and characteristics. This personalization not only enhances comprehension but also increases student engagement and motivation, making the learning process more meaningful and enjoyable (Resmana 2025). Overall, these findings demonstrate that the integration of AI in e-modules not only improves practicality but also strengthens theoretical foundations related to effective and modern learning approaches.

4. CONCLUSION

The conclusion related to the research findings conducted by this researcher provides information regarding the development of an AI-based e-module with a cell material showing that the resulting product has high quality and is suitable for application in learning. The validity of the e-module was assessed as very good by experts and teachers which indicates the suitability of the content and display related to the existence of very high hopes in bridging the process and in the implementation related to learning in the 21st century so that it can provide a good impact on the learning process of students. The findings contained in this study provide results namely an increase or improvement related to learning outcomes produced by students in the experimental class. N-Gain analysis shows that the influence of e-modules not only impacts the increase in grades but also on how the students are able and can understand and also motivate in the learning process. Student creativity also develops as reflected in the high assessment of the aspects of originality, flexibility and elaboration. The practicality test shows that the e-modules are easy to use and efficient for both teachers and students without significant technical obstacles. These findings confirm that AI-based e-modules can play a role as an interesting, adaptive and effective

learning tool in supporting the academic development and creativity of class VIII A students at MTs Mada Nusantara.

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