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AI-Based Digitalization of Teaching Materials to Detect and Analyze Conceptual Errors in Science Learning

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Abstract

The digitalization of artificial intelligence (AI)-based teaching materials aims to improve the quality of science learning by detecting and analyzing conceptual errors made by students. AI technology can be used to identify common mistakes students make in understanding complex science concepts and provide faster and more accurate feedback. Using machine learning algorithms and data analysis, AI-based systems can analyze students' answers, recognize error patterns, and provide explanations or additional materials to help improve their understanding. This approach not only simplifies the evaluation process but also enables more personalized and tailored instruction. Another advantage of digitalizing teaching materials is its ability to provide more interactive and engaging learning and help teachers identify areas that need more attention in the learning process. The aim of this research is to develop a system that can help students and teachers identify and correct conceptual errors in science learning materials. This approach utilizes artificial intelligence (AI) to analyze student interactions with digital teaching materials, such as practice problems or simulations, to detect potential common conceptual errors. This research method uses a mixed method that utilizes interviews, observations, and student analysis results with the interaction of an AI-based system with Natural Language Processing (NLP) and Machine Learning technology used to analyze student answers and detect conceptual errors. The results of this study indicate that of the 40 teacher respondents and 90 students, the use of interactive media using AI greatly facilitates the material being taught. Thus, the use of AI in science education can play a significant role in improving the effectiveness of teaching and students' understanding of the subject matter.

Keywords: Digitalization; Artificial Intelligence; Technology; Learning; Science.

INTRODUCTION

Science learning is an important aspect of education that aims to develop students' understanding of natural phenomena and applicable scientific principles. The role of learning is to provide, demonstrate, guide, and motivate learners so that they are able to interact with existing learning resources in the form of learning media (Yani, 2025). However, in practice, many students face difficulties in understanding complex scientific concepts. Conceptual errors, such as misunderstandings of the laws of physics, chemical theories, or biological principles, often occur and can hinder the development of students' overall knowledge. The main causes of these conceptual errors can vary, ranging from ineffective teaching, students' ignorance of the right way to learn, to the lack of fast and relevant feedback during the learning process. From these factors, technology has emerged that can be utilized for the development of digitalization that is developing among technology users.

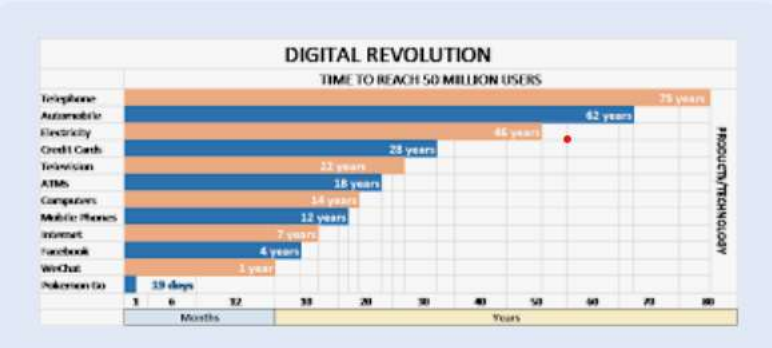

Figure 1. Graph of the Development of Digitalization in the Era of the Society 5.0 Revolution

The current era of revolution should utilize technology in addressing education to be more effective and efficient, including errors that are not directly detected by teachers, so that students continue learning with a wrong understanding, resulting in worsening their understanding of the material. Furthermore, it is very important in the development of digitalization of teaching materials to improve the concept of science learning using Artificial Intelligence (AI) so as to improve human resources in education, this is very important in improving the quality of output from the learning results carried out. To improve students' thinking power and actions in the teaching and learning process activities that have been carried out. Research on digitalization of learning based on artificial intelligence (AI) is very important to be carried out along with the increasingly rapid development of technology and the demand to improve the quality of education in Indonesia, one of which is linking the language of science components that form the concept of science learning that is interesting and easy to understand by students such as in the diagram of the implementation of functions from the concept of digital system algebra (Dian, 2025).

RESEARCH METHODS

This research flowchart uses a mixed method to analyze the statistical results of the digitalization of science learning using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation).

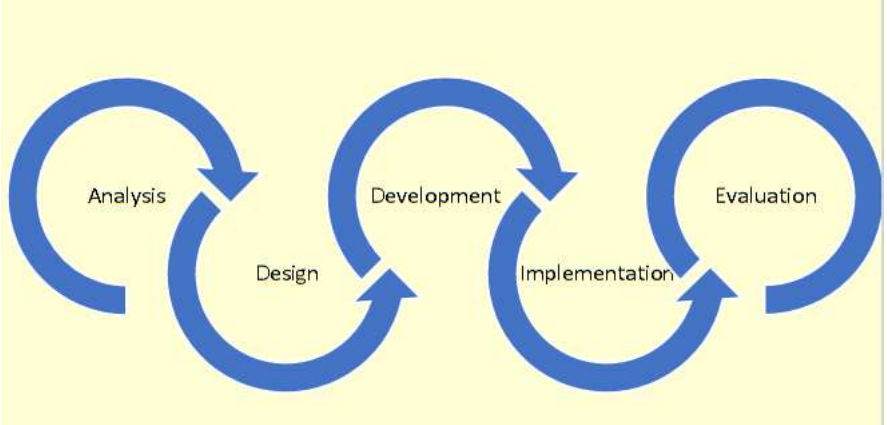

Figure 3. Research Flowchart

1) The development model used is the ADDIE model, which consists of five stages:
2) Analysis: Identifying user needs (teachers and students), science materials prone to conceptual errors, and relevant AI technology.

3) Design: Designing digital content and AI systems (Natural Language Processing, machine learning) to visualize science concepts for physics learning in high schools/vocational schools.
4) Development: Conducting a literature review on the development of AI technology in education, including concepts such as TF-IDF, cosine similarity, and adaptive learning (Wang, dkk. 2019); (Huang, 2019). Development involves creating interactive AI-based digital teaching materials and integrating a physics learning conceptual error detection system with a web-based physics-focused application.
5) Implementation: Testing the media on students to detect misconceptions in physics lessons using interactive exercises and simulations, with initial system testing and collecting feedback from teachers and students to assess the system's effectiveness (19). Test the system on a larger scale, involving more users (students and teachers) and evaluate its success in improving learning outcomes (Spector, 2019)

Evaluation: Assess the effectiveness of the teaching materials and AI system through formative and summative evaluations, including content, technical aspects, and physics learning. Refine the system based on the results of previous trials and integrate additional features as needed, such as NLP-based chatbots or advanced recommendation systems (He Jetli,dkk. 2020).

RESULT AND DISCUSSION

Digitalization of artificial intelligence (AI) based learning brings great potential to solve various problems in education, such as difficulties in understanding concepts, limited access to equitable learning, and limitations of traditional teaching systems (Almarashde, 2020);(Mahoney, 2018);(Chen. Dkk. 2020). Here are some approaches and problem-solving strategies that can be applied to optimize the use of AI in learning (Sharma, 2020);(Yang,Y.dkk. 2021). 1.) Adaptive Approach and Personalization of Learning Each student has different reasoning and thinking abilities because uniform learning cannot fulfill each individual's desires so that digitalization is needed to determine students' abilities in understanding the concepts of the material being studied (Wang,W.dkk. 2021). 2) Detection and correction of conceptual errors in the learning system if not knowing the concept of the material to be studied will make students feel difficult and hinder learning the next material so that learning achievements are not achieved in each individual (Sharma, 2020). 3) Increasing access to learning limitations in delivering material are also one of the causes of students' lack of understanding of the learning carried out, so there needs to be a strategy with AI-based online learning that can enable wider access. Teaching materials can be accessed anywhere and anytime with digital devices. 4) simplifying the learning process by utilizing AI can provide direct virtual interaction between students and teaching materials (Chen,dkk.2018).

Interactive media that has been created using the web with the following appearance:

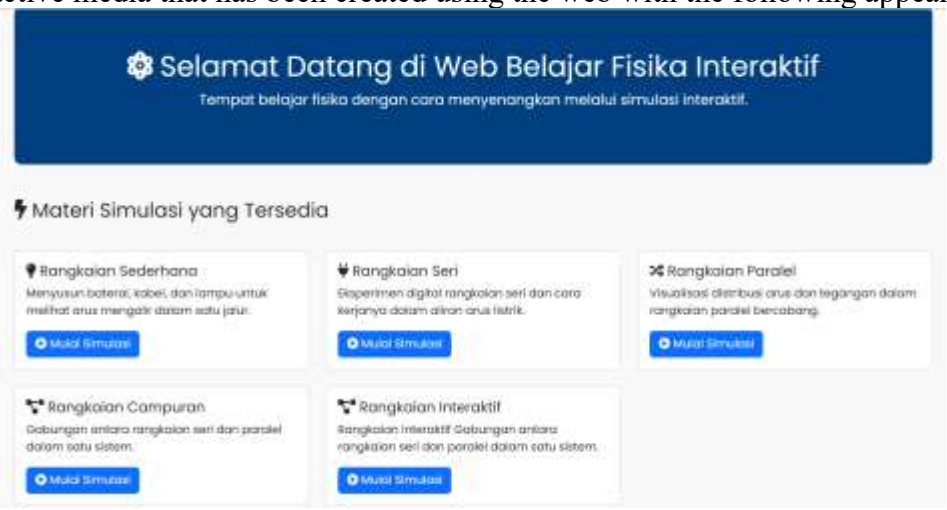

Figure 4. Display of AI-Based Learning Media

The image shows the AI-based science learning media display, with concepts and explanations available for each display. This media can be used by teachers and students during science learning, particularly regarding electricity. The material explains the initial concepts for analyzing current flow in a desired circuit. The display provides simple circuits, series circuits, parallel circuits, mixed circuits, and interactive circuits. Here, we directly use AI in our learning. If we select the interactive circuit, the following display will appear:

Figure 5. Display on the interactive circuit

The image shows a circuit consisting of battery components, cables, switches, and lights that we created using the toolbar on the right side of the screen with various components according to the desired circuit concept, whether in simple, series, parallel, or mixed circuits. Students can be creative and create the circuit concept that has been described and then test it by clicking on the components that have been created. And teachers can also explain while using additional tools on the following screen.

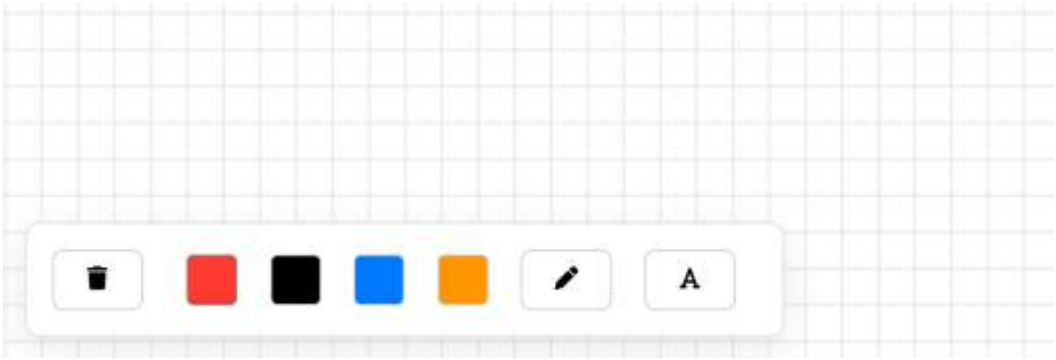

Figure 6. Display of tools in interactive media

It appears that the available tools can assist teachers in using pen marks and letter concepts to help students be more engaged and understand the material we are presenting, while also providing important notes they need to know to facilitate learning and encourage students to actively conduct experiments related to the material being studied. For signs like the trash can image, it means deleting written explanations and sentences we have created..

Analysis of learning media before using interactive media can be seen in the observation results.

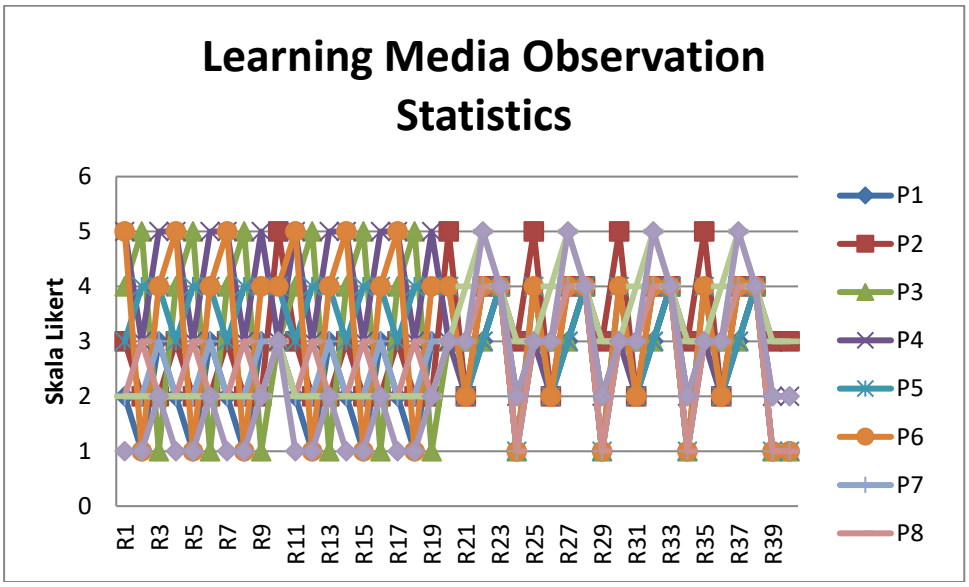

Figure 7. Observation Results Regarding Learning

Based on the results obtained, it is clear that many students still lack a grasp of the application of concepts in electrical circuits when learning only theoretically. They are still at the stage of only knowing about electrical circuits, types of resistance, and only symbols in calculations. Based on their average understanding of the use of interactive media in Islamic and Vocational High Schools (MA) and Vocational High Schools (SMK) in Labuhanbatu Regency, it is clear that the number of respondents, including teachers and students, is 1. Using a Likert scale, statements regarding the digitalization of AI-based learning are as follows:

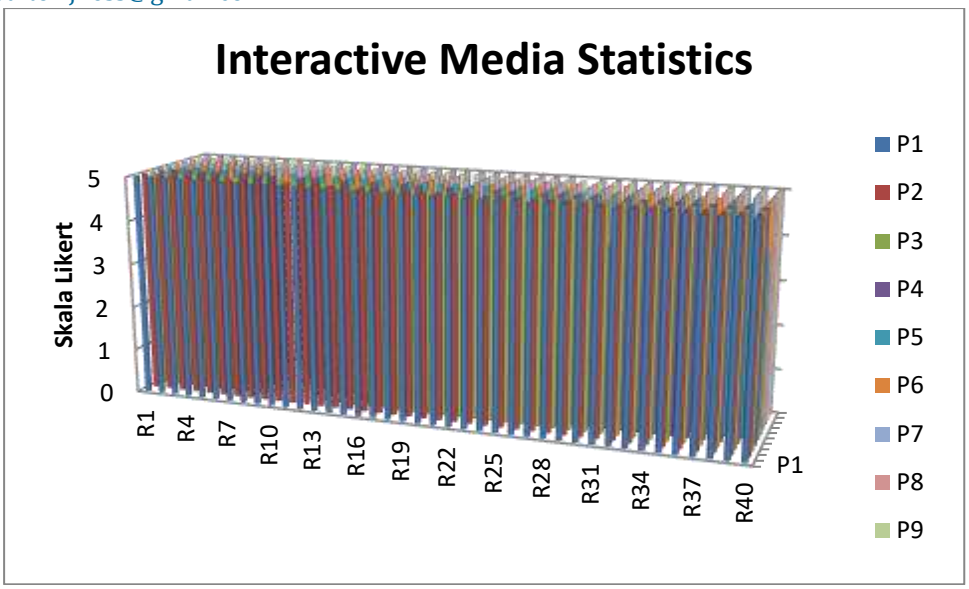

Figure 8. Statistical Results of AI Media Questionnaire by Students

Based on the statistical results of the graph in the image, it can be seen from 40 respondents with a large number of statements in 10 questions that after using AI-based interactive media learning, more students gave statements that strongly agree (SS) regarding science learning using AI. This shows that these students are directly very happy with science learning using interactive media.

CONCLUSION

The digitization of AI-based teaching materials is a strategic step in improving the quality of science learning. With the ability to detect and analyze conceptual errors, AI can help students understand the material more deeply while supporting teachers in creating adaptive, personalized, and effective learning. This implementation will move science education towards a more modern, innovative direction, and in line with the needs of the digital generation. AI-powered web-based interactive media offers a new approach to science learning by providing a more engaging, adaptive, and personalized learning experience. The integration of digital simulations, AI analysis, and web-based interactivity can help students understand science concepts more deeply while supporting teachers in creating effective learning. With infrastructure support and increased digital literacy, this media has the potential to become a key strategy in transforming science education in the digital era.

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