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Intensity of Artificial Intelligence (AI) Use for Physics Learning in High Schools

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Abstract:

This study investigates the intensity of Artificial Intelligence utilization in Physics education at a public high school in Manado City, Indonesia. The research aimed to understand the patterns and extent of AI integration, as well as the influencing factors, through a qualitative case study approach. The methodology involved in-depth interviews, classroom observations, and document analysis with six Physics teachers, students, and school management selected via purposive sampling. Data were analyzed using Miles and Huberman's model and thematic analysis. Key parameters examined included the forms of AI usage, intensity levels (low, medium, high), frequency, depth of utilization, and both supporting (teacher digital competence, school policy support, student enthusiasm) and hindering factors (lack of formal pedagogical training, infrastructure limitations, cultural resistance). Important findings indicate that AI adoption is predominantly at a medium level, primarily utilizing interactive simulations like PhET Interactive Simulation for abstract concept visualization, which significantly enhances student engagement and comprehension. However, comprehensive AI integration for adaptive, personalized learning remains rare. While school facilities are generally supportive, teachers' digital readiness varies, and AI usage frequency averages one to two times per week, the depth of its application often remains instrumental rather than transformational. In conclusion, AI adoption in Physics learning is still nascent, not yet fully optimizing AI's potential as an adaptive intelligent learning system, largely due to variations in teacher competency, school policies, and infrastructure readiness.

1. Introduction

The rapid advancement of digital technology in the era of the Industrial Revolution 4.0 and Society 5.0 has brought about significant transformations in the world of education, including in the field of science, particularly Physics. One of the most prominent innovations is the application of Artificial Intelligence in the learning process. AI has the capability to emulate human thought processes, analyze large datasets, and provide adaptive feedback tailored to individual needs. In the context of education, AI is utilized to support personalized learning, automate evaluations, and provide interactive simulations and models that can help students understand abstract concepts that are difficult to visualize in Physics lessons. This aligns with the demands of the digital age for learners to master technology, making AI an important tool to enhance the learning experience [1]. The utilization of AI, such as ChatGPT, helps improve teaching skills, professional development, and provides support in assessment and learning management for students and teachers [2].

Physics is a subject rich in abstract and mathematical concepts, which often pose a challenge for students to understand deeply. Many students experience difficulties in connecting theoretical concepts with real phenomena, especially in material that requires visualization or laboratory experiments. The use of AI has the potential to be a solution that bridges this gap. For example, AI-based applications like PhET Interactive Simulations, Labster, Gemini, or ChatGPT can be used as learning aids for concept exploration, experimental data analysis, or even conceptual discussions. Through adaptive and interactive systems, AI can provide a more personal and contextual learning experience for students, thereby enhancing their conceptual understanding and learning motivation. The application of AI can also increase student independence and efficiency in information gathering, as well as enhance their active involvement in the learning process through exploratory discussions [3].

The reality shows that the level of AI implementation in Physics learning in senior high schools is not yet evenly distributed. Based on initial observations and various previous studies, many teachers are still in the early stages of exploring the use of digital technology. Most teachers only utilize AI tools in a limited capacity, such as to create practice questions or search for teaching materials, without integrating them comprehensively into the learning process; however, most often deliver material in the learning process with PowerPoint presentations or they present material via YouTube videos. This indicates a gap between the potential use of AI and its application in education, especially in teaching and learning activities, particularly in Physics subjects. This phenomenon is interesting because it illustrates how teachers and students interact with this relatively new technology, and how social, cultural, and institutional contexts also influence the intensity of its use. The use of AI in education broadly shows an increasing trend, with surveys in Indonesia reporting that 86.21% of students and university students regularly use it to support learning activities [4].

The intensity of AI utilization is determined not only by how often the technology is used, but also by the depth of its application in a pedagogical context. For example, a teacher who uses AI merely as a visual aid is different from a teacher who utilizes it to create adaptive and reflective learning experiences. Artificial Intelligence can have a significant impact on students' learning interest by providing customized content, recommending relevant materials, and facilitating active engagement through digital platforms [5].

There are also logically and scientifically influencing factors for the adoption rate of AI in learning, such as teachers' digital competence, school policy support, availability of technological infrastructure, and attitudes and perceptions towards the effectiveness of AI. According to the Technology Acceptance Model theory, technology adoption is greatly influenced by the perceived ease of use and usefulness. Teachers who feel AI is difficult to operate or irrelevant to the Physics learning context tend to use it with low intensity [6]. Conversely, teachers who see AI as an effective tool to improve student understanding are more likely to use it routinely and creatively.

Therefore, it is important to conduct in-depth research to understand how and to what extent AI is used in Physics learning in high schools, and what factors support or hinder it. The results of this study are expected to provide a comprehensive understanding of the intensity of artificial intelligence utilization in the context of Physics learning, which can ultimately serve as a basis for developing strategies to improve technological literacy and AI-based learning innovation in secondary education environments. Nevertheless, AI adoption in Indonesia has not yet reached a high percentage in education, so further encouragement is needed to integrate such systems so that machines can be more beneficial in facilitating student learning according to their experiences [7].

2. Method

This research adopted a qualitative approach with a case study design, aiming to understand the phenomenon of AI utilization in depth within a real-world context. This approach was chosen because the intensity of AI usage cannot be measured solely statistically; rather, it needs to be understood based on the experiences, perceptions, and social practices of the educational stakeholders involved. The study was conducted at a public senior high school in Manado City. The research subjects consisted of six Physics teachers, students, and school management. Informant selection was carried out through purposive sampling, where participants were chosen based on their direct involvement with AI usage. Data were collected using three primary techniques: in-depth interviews, classroom observations, and documentation studies. Interviews were conducted to explore teachers' and students' perceptions and experiences regarding AI utilization. Observations were used to directly witness how AI was implemented in teaching and learning activities. Documentation, including lesson plans, platform screenshots, and learning outcomes, was used to strengthen the data. Data analysis was performed using the Miles and Huberman model, encompassing four stages: data collection, data reduction, data display, and conclusion drawing [8][9]. Thematic analysis was also employed to group findings based on themes such as "forms of AI usage," "intensity levels," and "supporting/hindering factors." Data validity was obtained through triangulation of sources and techniques, member checking, and peer debriefing to ensure the reliability of the findings.

3. Result and Discussion

The school designated as the research location is a public senior high school in Manado City, which has commenced the implementation of digital technology-based learning. School facilities are generally supportive, including the availability of computer laboratories, internet networks, and projectors in every classroom. However, not all schools possess optimally supportive devices for the application of Artificial Intelligence-based technology. Physics teachers in these schools exhibit diverse levels of digital literacy. Some teachers are accustomed to utilizing digital devices and online learning platforms, while others are still limited to using simple presentation media such as PowerPoint and educational videos from YouTube.

Interview results, obtained from six Physics teachers, indicated that teachers are still not accustomed to digital technology; they remain hesitant and tend to consider AI as complex and inefficient within the context of learning time. This picture illustrates that human resource readiness is a key factor in determining the intensity of AI implementation in schools. This is consistent with the Technology Readiness theory proposed by Parasuraman (2000), which posits that the acceptance of technology is greatly influenced by an individual's readiness to interact with that technology. In this context, teachers with high readiness will be more capable of utilizing AI for pedagogical purposes, whereas teachers with low readiness tend to be passive users [10].

The research findings show that there is a variation in the level of AI implementation in Physics learning in senior high schools, which can be classified into three main categories: low, medium, and high. At the low level, AI is used merely as an additional tool. Teachers utilize applications such as ChatGPT, Google Gemini, or Copilot to assist in preparing practice questions, writing material summaries, or searching for examples of Physics concept applications. This use is instrumental and not directly integrated into the classroom learning process. For example, a teacher might use AI to find example questions about Newton's laws, and then manually explain the results to students. At the medium level, AI begins to be used interactively in the learning process. Teachers employ AI-based simulations like PhET Interactive Simulation to visualize concepts that are difficult for students to understand. For instance, when studying waves and sound, teachers display interactive simulations to help students observe the relationship between wavelength, frequency, and amplitude. This use demonstrates more active student involvement as they can control variables within the simulation. In contrast, at the high level, AI is comprehensively integrated into learning. Teachers not only use AI for material delivery but also in student evaluation and learning feedback. For example, some teachers utilize adaptive learning systems that analyze student learning progress and provide exercises tailored to each student's abilities. Nevertheless, practices at this level are still rarely found because they require adequate infrastructure and teacher training. From the field data, most teachers are at the medium level, with AI use focusing on learning media and simulations. This indicates that AI integration is still limited to the visualization aspect of concepts, not yet encompassing a comprehensive pedagogical transformation. This finding is consistent with the results of research by Li (2024), which states that AI use in secondary schools is still predominantly in the function of learning support tools, rather than in data-driven adaptive learning. Thus, AI's potential to provide personalized learning experiences has not yet been optimally utilized [11].

The intensity of AI use in Physics learning can be viewed from two main dimensions: frequency of use and depth of utilization. In terms of frequency, teachers generally use AI one to two times per week, depending on the topic being taught and the availability of devices. For example, teachers more often use AI for topics requiring dynamic visualization, such as parabolic motion or optics, but rarely for theoretical topics like measurement and units. The intensity of AI use is also higher when teachers want to provide virtual experimental experiences that are difficult to conduct in a physical laboratory due to equipment limitations. Regarding the depth of utilization, most teachers still use AI instrumentally rather than for pedagogical transformation. This means AI is used to assist in material delivery but has not significantly changed the pattern of learning interactions. Students remain information recipients, not knowledge discoverers through interaction with Artificial Intelligence. This aligns with previous findings indicating that despite early AI adoption by educators, its use often remains superficial and has not fully optimized AI's potential for adaptive personalized learning [12][13].

Observations of Physics learning activities in the school show that, on average, 80% of students are proficient enough in using AI technology in learning activities. When AI is used directly in the classroom, students become active and find it easier to understand complex Physics concepts, especially when given the opportunity to interact with simulations. Students reported a better understanding of concepts when they could "see" Physics phenomena occur through digital media. However, on the other hand, there are still constraints in the form of time limitations and a lack of devices for every student. This analysis indicates that the intensity of AI use does not only depend on the teacher's intention to use technology but also on systemic support involving infrastructure, school policies, and student skills. In the context of Physics learning, AI should not only be positioned as a visual aid but also as a means to develop students' scientific thinking skills and conceptual reasoning. Therefore, comprehensive curriculum integration and teacher training are needed to ensure that AI can be optimally utilized to improve the quality of Physics learning [14][15].

Through interviews and observations, two main categories of factors influencing the intensity of AI use in Physics learning were identified: supporting factors and hindering factors. The following are the supporting factors in optimizing Artificial Intelligence technology in Physics learning. First is teachers' digital competence, which determines their ability to operate and integrate technology into learning. Teachers accustomed to using digital platforms find it easier to adapt to AI systems. Second is school policy support, such as providing internet access, technology training, and encouragement from the principal for learning innovation. Third is student enthusiasm, where students who are curious about technology show higher engagement in AI-based learning. The main constraint found is the lack of formal training on AI use in a pedagogical context. Teachers generally learn through self-study and use AI simply without understanding its adaptive learning potential. Another factor is infrastructure limitations, such as insufficient computers for all students or unstable internet networks. In addition, there is cultural resistance where some teachers feel that AI technology can reduce the human role in the teaching process, thus making them reluctant to use it intensively. These findings reinforce the basic theory of the Technology Acceptance Model, which states that two main factors influencing technology acceptance are perceived usefulness and perceived ease of use [6]. Teachers who perceive AI as beneficial and easy to use will use it more intensively, while those who feel otherwise will tend to avoid its use. Therefore, strategies to strengthen teacher capacity are very important so that positive perceptions of AI can grow and encourage sustainable technology adoption.

Based on the overall findings, it can be stated that the use of AI in Physics learning in senior high schools is currently in the early stages of adoption. AI serves as a tool to explain concepts and increase student engagement but has not yet been fully utilized as an intelligent learning system capable of adapting to individual needs. AI implementation has great potential in overcoming classic problems in Physics learning, such as low comprehension of abstract concepts and minimal laboratory experiments. However, its utilization is not yet optimal due to factors of teacher competence, school policies, and infrastructure readiness. The qualitative approach in this study reveals that the intensity of AI use is not just a technical issue, but also a matter of pedagogical culture. AI will be effective if teachers not only use it as a tool but also as a medium to transform the learning paradigm into a more participatory and reflective one. To achieve this, policies supporting continuous professional development for teachers in AI literacy, as well as investment in adequate technological infrastructure in schools, are needed [16]. In the context of 21st-century education, the ability to critically and creatively utilize AI is part of the digital literacy that teachers and students must possess. Therefore, the results of this study recommend integrated training programs and curriculum development that explicitly integrate Artificial Intelligence into Physics learning, so that AI becomes not only a complement but also a transformer in the teaching-learning process.

4. Conclusion

This study reveals that the intensity of Artificial Intelligence utilization in Physics learning at senior high schools, specifically in a public senior high school in Manado City, is still in the early stages of adoption. The majority of teachers operate at a medium level, primarily focusing on using AI as interactive media and visual simulations, such as PhET Interactive Simulation, to visualize abstract concepts. Although school facilities are generally supportive and students exhibit high enthusiasm for AI, which enhances conceptual understanding, the comprehensive utilization of AI for adaptive, personalized learning remains uncommon. Supporting factors include teachers' digital competence, school support, and student enthusiasm, while the main hindering factors are the lack of formal pedagogical training, infrastructure limitations, and cultural resistance among teachers. Consequently, the implications of this research highlight the necessity for continuous teacher training, the integration of AI literacy into teacher education curricula, and robust government policy support for infrastructure investment and AI training programs. For future research, it is recommended to conduct longitudinal studies, cross-regional comparisons, focus on developing adaptive learning models, and delve deeper into teacher qualifications and psychological factors in AI adoption, to optimize AI's potential as a pedagogical transformer.

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