Artificial intelligence-based learning recommendation system to promote critical and creative thinking on junior high school physics topics

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Article History
Received: 14 October 2024
Revised: 1 November 2024
Accepted: 11 November 2024

Keywords
Artificial intelligence
Recommendation system
Critical thinking
Creative thinking

Abstract
This study aims to design a learning recommendation system to support the development of critical and creative thinking skills in junior high school (SMP) physics topics. The system is designed to help students gain a deeper and more integrated understanding of scientific concepts, enabling them to relate physics to real-life contexts and other disciplines, such as biology and chemistry. The study employs a Research and Development (R&D) method, which includes needs analysis, system design, data collection and processing, and recommendation system development. The dataset consists of 7,524 learning objectives across various science topics selected per the 7th-grade SMP curriculum. The recommendation system is developed using a content-based filtering approach, allowing for personalised recommendations of learning materials and activities tailored to students' learning profiles. The results indicate that this system has the potential to serve as an effective tool in supporting integrated physics learning in junior high school, as well as in fostering thinking skills essential for 21st-century challenges.

How to cite: Prabandari, L. P. C., & Gunawan, K. D. H. (2025). Artificial intelligence-based learning recommendation system to promote critical and creative thinking on junior high school physics topics. *Momentum: Physics Education Journal*, *9*(1), 14-23. https://doi.org/10.21067/mpej.v9i1.10889

1. Introduction

In the current era of globalization and technological advancement, critical and creative thinking skills are becoming increasingly important for students to face the challenges of the 21st century (Gleason, 2018; UNESCO, 2019). These skills not only help students solve problems effectively but also equip them to adapt in dynamic and complex environments. (Dilekçi & Karatay, 2023). n the context of education, particularly in physics at the junior high school level, developing critical and creative thinking skills becomes one of the main objectives so students can better understand and apply scientific concepts. (Khoiri et al., 2023; Ma et al., 2023). This effort is also in line with the need to prepare a younger generation that is not only ready to compete in an increasingly competitive job market but is also capable of thinking solution-oriented and innovatively when facing everyday life challenges (Mujtahidin et al., 2020), However, to achieve this goal, there are various challenges in teaching physics that need to be overcome, especially considering the complex nature of physics material.

One of the main challenges in teaching physics at the junior high school level is that the material is often abstract and complex, requiring a deep understanding of fundamental concepts. (Assem et al., 2023; Banda & Nzabahimana, 2023). Physics concepts are often considered to require only mathematical knowledge and an understanding of how these concepts relate to other disciplines, which is difficult to achieve. Many students find it difficult to understand these concepts due to the lack of contextual and integrated approaches that connect theory with its real-life applications. (Kadek Dwi Hendratma Gunawan, 2023). As a result, learning often feels fragmented and less relevant to students, decreasing their interest in physics. (K. D. H. Gunawan et al., 2021; K D H Gunawan et al., 2020; Indrawati & Nurpatri, 2022). Teachers also face challenges in adjusting their teaching approaches to meet the diverse learning needs of students. With varied backgrounds in understanding and learning styles, teachers need to design adaptive content and pedagogical

doi: 10.21067/mpej.v9i1.10889

ISSN: 2548-9135

strategies that can support students' critical and creative thinking skills (Rubini et al., 2019). However, time and resource limitations often hinder teachers from developing comprehensive, integrated materials and presenting them in diverse ways (Wan & Lee, 2022). Learning that is too focused on theory can also make it difficult for students to see the practical relevance of physics in natural phenomena that should be well understood.

The development of artificial intelligence (AI) technology has opened up new opportunities in various sectors, including education (Kim et al., 2021; Yau et al., 2023). AI does not only serve as a tool in industry or business, but is now an important part of developing more adaptive and personalized learning methods and strategies (Ajevski et al., 2023; Yau et al., 2023). This technology offers a data-driven, structured, and individualized approach, allowing teachers to present material in a way that is more relevant and suited to each student's learning characteristics (Sun et al., 2023). This is becoming increasingly relevant given the need to provide learning that matches students' characteristics and level of understanding in complex areas such as physics.

Approaches that incorporate technology, particularly artificial intelligence, can play an important role in helping to overcome the challenges of learning physics (Yeadon & Hardy, 2024). AI can help analyze students' individual needs and recommend appropriate materials, make it easier for teachers to present physics concepts in a more contextual and relevant manner, and encourage students to develop their critical and creative thinking skills more effectively (K D H Gunawan et al., 2020). In the context of science learning, utilizing AI can help integrate different types of data from various disciplines (K D H Gunawan et al., 2021; Lee & Wan, 2022). This integration allows for a more integrated and in-depth approach to learning, where students are encouraged to see connections between concepts and understand science as an interconnected whole. Through AI's ability to analyze data in detail, teachers can identify effective learning patterns and design materials that connect concepts across disciplines, helping students develop a more holistic and in-depth understanding of science.

AI offers great potential to transform science learning to be more interactive and relevant, supporting students in developing the critical and creative thinking skills they need to face future challenges. The purpose of this research is to design a learning recommendation system that can support the development of critical and creative thinking skills on physics topics at the junior high school level so that it is expected to help students understand scientific concepts in a more in-depth and integrated manner.

2. Method

The research methods used in the development of this learning recommendation system include the Research and Development (R&D) approach (Kainulainen, 2023). In this research, limitations are made to the stages that include needs analysis, system design, data collection and processing, and recommendation system development. This stage begins with literature analysis and observation of physics learning needs at the junior high school level. This literature study also refers to various educational theories and models of critical and creative thinking skills used in science learning, as well as junior high school science curriculum data and learning indicators collected and compiled in accordance with learning outcomes. Based on the needs analysis results, the recommendation system was designed using learning analytics and machine learning approaches. The system design involves designing a recommendation framework that consists of components such as input, analysis process, and output in the form of recommended learning materials and activities. The system is designed to identify indicators of critical thinking skills such as providing simple explanations, building basic skills, making inferences, providing advanced explanations, and developing strategies and tactics. For creative thinking skills, the indicators include fluency, flexibility, originality and elaboration. The data used for the recommendation system is obtained from the used learning dataset that consists of 7,524 learning objectives. The data is organized into the following topics: 1) the nature of science and the scientific method, 2) classification of living things, 3) substances and their changes, 4) temperature, heat, and expansion, 5) energy in life, 6) organizational systems in life, 7) interactions between living things and their environment, 8) environmental pollution, 9) global warming, 10) the layers of the earth and natural disasters, and 11) the solar system. This data includes operational verbs related to critical and creative thinking skills based on Bloom's revised taxonomy. The recommendation system is developed by implementing a content-based filtering algorithm designed to map and suggest learning materials or activities according to the needs of students' critical and creative thinking skills.

3. Results and Discussion

3.1. Artificial Intelligence-based Learning Recommendation System

Based on the development results, this recommendation system can be identified as software designed to support integrating physics content in integrated science learning. The utilization of Artificial Intelligence (AI) technology as its main foundation has unique characteristics and can provide a more personalized and integrated learning experience. This system can provide relevant physics learning topic recommendations, integrate learning achievements, and improve the quality of science lesson planning to support critical and creative thinking skills. The details of the SAINS-Edu recommendation system are as follows: a) Based on Artificial Intelligence (AI): This system utilizes AI technology to provide learning topic recommendations to users. AI enables the system to gather and analyze datasets, learn preferences and needs, and provide recommendations that align with learning goals; b) Personalized Learning: This system can generate learning topic recommendations tailored to the needs and preferences of users. The system can identify interests in integrating integrated science learning according to the learning outcomes to be achieved, thus offering a more personalized and relevant learning experience; c) Integration of Learning Outcomes: This system is designed to integrate learning outcomes within the curriculum. It can map the learning outcomes users wish to achieve and recommend appropriate learning topics, facilitating the integration of their learning; d) User-Friendly: The system is designed with a web-based user-friendly interface, making it easy for anyone to use. Features such as theme search, intuitive navigation, and clear display make it easier for users to access and utilize the system; e) Relevance and Quality of Recommendations: SAINS-Edu provides relevant and high-quality learning topic recommendations. This system uses classification methods to analyze learning outcome datasets, thus offering recommendations that meet the users' needs. The system is designed with steps as outlined in Table 1.

Table 1. Steps for using the recommendation system

No.	Steps	Description
1	Formulating	Users formulate learning outcomes that will be integrated
2	Integrating	The system integrates the inputted learning outcomes to generate science learning themes
3	Customizing	Users customize parts of the recommendation results to be processed into a learning plan
4	Evaluating	The user uploads his/her work on the system to be evaluated in relation to his/her work with the recommended results

3.2. Integration of Physics Topics on Learning Themes

Physics topics in learning at the junior high school level are implemented by integrating the various fields of biology and chemistry into integrated science learning. Integrating science combines these different scientific fields into a cohesive and comprehensive curriculum to show how they are interconnected and interdependent. Integrated science learning is designed to provide a more holistic and integrated understanding of the natural world.

Integrating physics topics in science learning involves a dataset consisting of 11 7th grade science topics. These topics are selected based on their importance as fundamental concepts in seventh-grade science learning before moving on to more complex topics. The data includes operational verbs related to analysing, evaluating, and creating within the revised Bloom's taxonomy by Anderson and Krathwohl and indicators of critical thinking skills and creative thinking for each content in the learning objectives. After reviewing and categorizing the data, word clouds were created for each learning theme. A total of 10 learning themes were categorized based on the dataset used, where each theme consists of different word cloud representations, as shown in Table 2.

Table 2. Learning themes representation result

No.	The Wordclouds	Top 5 Terms	Learning Theme
1		*Benda, makhluk, hidup, campuran, kimia,* Translation: Objects, Living, Things, Mixtures, Chemistry	*Benda di sekitarmu* Translation: Objects around you
2		*Zat, makhluk, hidup, termoregulasi, perubahan* Translation: Substance, Living things, thermoregulation, changes, animals	*Karakteristik zat dan kalor* Translation: Matter and heat characteristics
3		*Energi, proses, pencernaan, makanan, terbarukan* Translation: Energy, digestive, process, food, renewable	*Kalor dan energi* Translation: Heat and energy
4		*Proses, pencernaan, zat, terlibat, makanan,* Translation: process, substance, digestive, involved, food	*Energi dari beragai zat* Translation: Energy from various substances
5		*Zat, pencernaan, makanan, proses, menganalisis* Translation: Substances, digestive, food, process, analysing	*Zat, kalor, dan energi* Translation: Substance, heat, and energy

No.	The Wordclouds	Top 5 Terms	Learning Theme
6		*jaringan, sistem, organ, menganalisis, sel* Translation: Tissue, system, organ, analysing, cell	*Sistem kehidupan* Translation: Living systems
7		*Pencemaran lingkungan, bentuk energi, menyelidiki, energi terbarukan, ekosistem* Translation: Environmental pollution, forms of energy, investigate, renewable energy, ecosystem	*Energi alternatif untuk masa depan lingkungan* Translation: Alternative energy for the future of the environment
8		*Lapisan ozon, penipisan, pemanasan global, merekomendasikan, solusi, ekosistem* Translation: Ozone layer, depletion, global warming, recommending, solutions, ecosystem	*Pemanasan global* Translation: Global warming
9		*Alam, pencemaran air, faktor penyebab, menganalisis faktor, mensimulasikan mitigasi* Translation: Nature, water pollution, causative factors, analysing factors, mitigation simulation	Berbagai Pencemaran di lingkungan kita Translation: Various pollution in our environment
10		*Tata, surya, karakteristik, komponen, menganalisis,* Translation: System, solar, characteristics, components, analysing,	*Alam semesta kita* Translation: Our universe

3.3. Learning Recommendation on Critical and Creative Thinking

A learning recommendation system has been designed to support critical and creative thinking skills in physics topics at junior high school level. The system is designed by providing recommendations for learning materials and activities designed to stimulate students' critical and creative thinking skills. The recommendations are in the form of learning objectives consisting of various activities that support critical and creative thinking skills. An example of the recommendation results is presented in Figure 1.

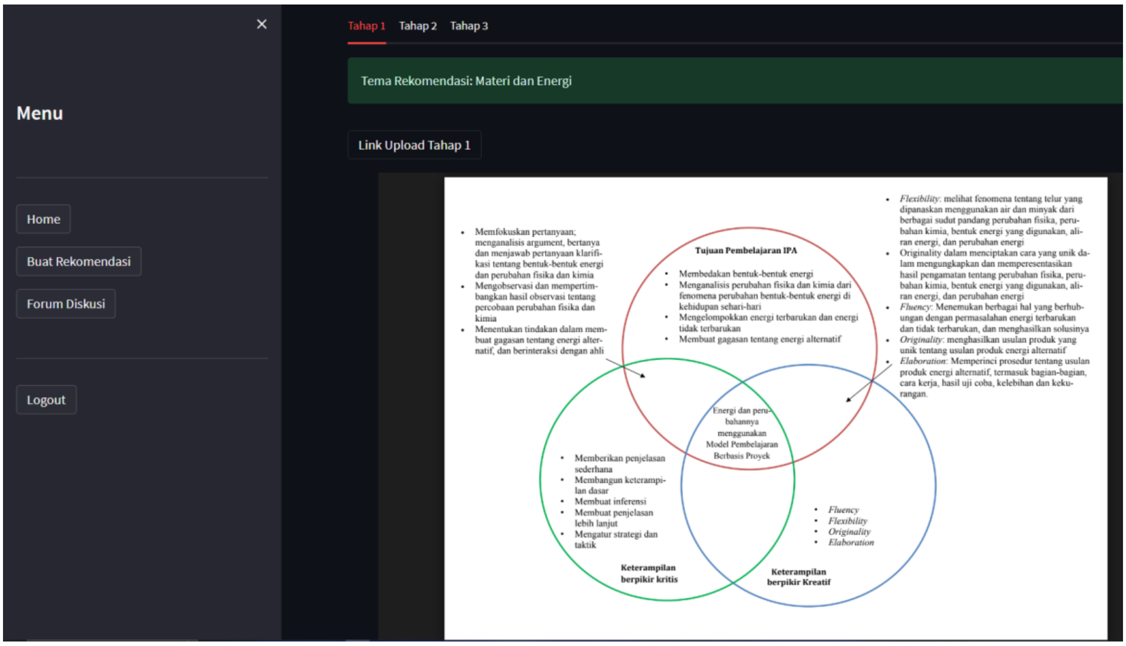

Figure 1. Results of learning recommendations to support critical and creative thinking skills on the theme of energy from various substances

Figure 1 indicates the learning recommendations for integrated science that support critical thinking and creative thinking skills. The recommended learning activities to support these critical and creative thinking skills are aligned with the learning objectives, which are also recommended by the system. The recommended learning objectives include 1) Differentiating types of energy; 2) Analyzing physical and chemical changes in energy transformations in everyday life phenomena; 3) Classifying renewable and non-renewable energy, and 4) Generating ideas about alternative energy. Based on the system recommendations, there are several learning activities that support critical thinking skills, such as: 1) Focusing questions, analyzing arguments, asking and answering clarification questions about energy types and physical and chemical changes; 2) Observing and considering the results of observations from physical and chemical change experiments; 3) Deciding on actions to generate ideas about alternative energy and interacting with experts. The system recommends learning activities based on these indicators, such as: 1) Flexibility: observing the phenomenon of eggs heated with water and oil from various perspectives, including physical and chemical changes, energy types used, energy flow, and energy transformations; 2) Originality in creating unique ways to express and present observations on physical changes, chemical changes, energy types used, energy flow, and energy transformations; 3) Fluency: identifying various issues related to renewable and non-renewable energy and generating solutions; 4) Originality: producing unique proposals for alternative energy products; 5) Elaboration: Detailing ideas and procedures for alternative energy product proposals.

3.4. Discussion

Integrated science learning that combines various fields of science provides a more holistic approach for students at the junior high school level, especially on physics topics. This incorporation seeks to show the interconnectedness of physics concepts scientifically in a comprehensive curriculum, so that students also understand how these concepts are interconnected in understanding the natural world. This integration is expected to overcome the challenges that often arise in science learning, namely the tendency of students to see science as a collection of separate disciplines (Indrawati & Nurpatri, 2022). By bringing these concepts closer together through relevant themes, students are expected to understand natural science as an interrelated whole.

In this study, the dataset used consists of 7,524 learning objectives covering 10 core themes, as outlined in Table 2. These themes were carefully selected as they are considered to be fundamental concepts in grade seven science learning, which will then form the foundation for more complex topics at the next level. Mapping the data using keywords in a word cloud allows for a visual presentation of the data and makes it easier to identify the learning focus of each theme (deNoyelles & Reyes-Foster, 2015).

Several studies show that an integrated approach allows students to see connections between relevant concepts across different disciplines, thus holistically strengthening their understanding. Research showed that integrated learning facilitates the connectedness between the concepts taught in the classroom, which helps students to see science as interrelated rather than as fragmented fields (Wan & Lee, 2022). This study supports the results of the research conducted, where the integration of physics with the fields of biology and chemistry in the context of science learning at the junior high school level helps students understand the basic concepts of physics in a broader and applicable context (Winarno, 2021). Integrated learning helps students understand real issues better because they can see interdisciplinary links directly (K. D. H. Gunawan et al., 2021). In the context of science learning, this research emphasised that integrated learning allows students to study natural phenomena in a more holistic way, giving them the skills to analyse problems from various scientific perspectives (Asrizal et al., 2018; Yamtinah et al., 2023). This study supports current research approaches, where learning recommendation systems structure themes such as energy in life, organism interactions, and environmental pollution to create integrated and meaningful learning experiences.

The learning recommendation system also demonstrated the potential to support students' critical and creative thinking skills through activities specifically designed for each topic. The system provides recommended materials and activities that focus on critical and creative thinking indicators adapted from Ennis' (1985) and Guilford's (1975) indicators. For critical thinking skills, the system includes indicators such as providing simple explanations, building basic skills, making inferences, providing further explanations, and devising strategies and tactics. These indicators are very important as they equip students with the ability to process information, evaluate arguments and draw logical conclusions, all of which are the foundation for effective problem-solving in science (Hidayati & Sinaga, 2019; Khoiri et al., 2023; Yusar & Kurniawati, 2023). On the other hand, indicators of creative thinking skills include aspects of fluency, flexibility, originality, and elaboration, which can nurture students' ability to generate new ideas, think flexibly, and develop original solutions in the face of scientific challenges (Aryanti et al., 2021; Kurdiati, 2022). They can see how the scientific method is applied across different fields of science, thus improving their ability to think analytically and critically (Rubini et al., 2019). This integration also helps them understand the impact of science on everyday life. These results support the research developed in the recommendation system that highlights the mastery of important concepts in science through activities that support the development of critical and creative thinking skills.

Although this recommendation system shows great potential, its effectiveness cannot be separated from the teacher's role and students' readiness. Teachers play an important role in applying the recommendations in the classroom and ensuring that the approach remains contextualised, linking physics concepts to everyday life (K. D. H. Gunawan et al., 2021; Li et al., 2022; Yeadon & Hardy, 2024). Teachers ‘skills in utilising technology are also a determining factor, as teachers need to understand and adapt each recommendation to make it relevant to students' individual learning needs. In this case, special training for teachers to operate and optimise the recommendation system is essential, as it will increase the accuracy and relevance of the material provided. Another challenge that needs to be considered is the sustainability of the recommendation system in meeting students' evolving learning needs. In this digital era, curriculum and learning methods are changing rapidly, so the recommendation system needs to be updated regularly to stay in line with the development of science and technology. Further development could include the integration of more sophisticated data analytics to analyse students' learning patterns in real-time, so that the system can provide more personalised and targeted recommendations.

4. Conclusion

This study successfully designed a learning recommendation system aimed at enhancing critical and creative thinking skills in junior high school physics. Integrating various science topics, such as physics, biology, and chemistry, into a cohesive learning experience offers a comprehensive approach to understanding scientific concepts. Using a content-based filtering method enabled the system to deliver personalized recommendations, ensuring that the learning materials and activities were relevant to students' needs and learning profiles. The findings suggest that the developed recommendation system can effectively support integrated physics learning and promote critical and creative thinking among students. Moreover, this system aligns with the goal of preparing students with the essential cognitive skills needed to face the challenges of the 21st century. As a tool, it holds significant potential to enhance the learning process, foster deeper engagement with science, and bridge the gap between theory and real-world applications. Future developments could further refine this system by incorporating more dynamic and adaptive features, increasing its effectiveness in diverse educational settings.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

Funding

This research is funded by the Ministry of Research Technology and Higher Education on the novice lecturer research scheme.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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