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Bibliometric Analysis in Artificial Intelligence-Based Physics Learning to Support the Achievement of Sustainable Development Goals (SDGs)

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Abstract

This study aims to identify and analyze research trends on the role of AI in physics learning to support the achievement of SDGs in secondary and higher education systems. In addition, this study explores opportunities for further research using the SLR method. There are 943 articles that have been published in the Scopus database that were searched through publish or perish, then the articles were strictly selected based on exclusion and inclusion criteria. The literature review process uses the PRISMA guidelines to ensure the quality of the article selection results is good. For data analysis of research results, a bibliometric method was used with the help of Vosviewer 1.6.20 software. The results of the study show that AI integrated with physics learning in supporting the achievement of SDGs has been studied by previous researchers. However, it has not been integrated with physics learning and SDGs, so there is still an opportunity for further research, both in terms of integration, methods, and the number of publications that integrate the three. For this reason, researchers recommend further research on the integration of the three. The limitations of this study include the database used from Scopus sources and analyzed using the Vosviewer tool.

Keywords: *Artificial Intelligence (AI), Physics Learning, Sustainable Development Goals (SDGs), systematic literature review* (SLR), *Bibliometric Analys.*

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1. INTRODUCTION

Education plays an important role in achieving the Sustainable Development Goals (SDGs) (Alfathy et al., 2024), especially SDG 4 which focuses on quality education (Astuty et al., 2024). Learning that is in line with the goals of the SDGs is to create an inclusive, innovative, and sustainability-oriented learning environment (Suprapto & Hidaayatullaah, 2023). The advantages of learning with the SDGs approach are the ability to instill sustainability values in students, improve 21st century skills, and increase scientific creativity and innovation (Maharani Putri Kumalasani & Kusumaningtyas, 2022; Wahyuni & Rahayu, 2021). The SDGs provide hope for the education system, especially in Indonesia. This hope is in the form of creating a generation that is aware of global issues, has critical and creative skills in facing future challenges (El-Kholei, 2023; Yi, 2023). In addition, SDGs-based learning methods, strategies, and models also have the potential to reduce educational gaps by ensuring that every individual gets equal and quality learning opportunities (Mitarlis et al., 2023). This hope is in line with the aspirations of the four presidents of the Republic of Indonesia, namely human resource development and gender equality. These aspirations emphasize human resource development through improving the quality of education, health, and access to technology. A good learning process will have an impact on the quality of education (Arzak & Prahani, 2023).

Artificial Intelligence (AI) is a technology that supports processing and analyzing large amounts of data quickly and accurately (Shofiyah et al., 2024). AI is able to learn from experience through machine learning techniques, identify patterns, and make predictions and decisions automatically based on existing data. This is very useful in various fields, including education, AI can simplify complex tasks and increase work efficiency. In addition, AI also contributes greatly to innovation and the development

of new solutions. In the academic world, AI can be used to personalize learning, support big data-based research, and help researchers analyze research results more efficiently (Li & Yin, 2025). AI also drives new discoveries in science and technology, accelerating the resolution of complex problems that previously required large amounts of time and resources (Kortemeyer, 2023).

Physics learning is not only focused on understanding concepts and formulas, but physics learning must emphasize soft skills and hard skills, these skills can be honed with the help of technology, one of the technologies that can be used in the learning process is AI, AI has great potential in improving physics learning at the high school level through a more personal and adaptive approach. With AI's ability to analyze physics learning data in real-time, the system can adjust the material, delivery style, and level of difficulty according to individual needs (Jiao et al., 2024). This helps students who have difficulty understanding abstract physics concepts such as motion, force, or energy. AI can recommend simulation videos, virtual experiments, or interactive questions that suit each student's learning style (Huang et al., 2025).

In addition, AI allows physics teachers to save time on administrative tasks and focus on more meaningful teaching processes, AI can automatically correct multiple-choice assignments or exams and provide instant feedback to students. AI is also able to systematically detect misunderstandings so that teachers can immediately intervene appropriately. On the research side, the use of AI opens up opportunities to develop more accurate data-based learning models in improving the understanding of physics concepts among high school students.

Based on several research results on AI, physics education, and the SDGs above, it has been found that technology-assisted physics learning has the potential to improve soft skills and hard skills in supporting the achievement of SDGs, especially SDG 4 in the field of education. However, there are still weaknesses and limitations in several of these studies, including the lack of specific links between AI as a tool for learning physics. In addition, AI indirectly supports the achievement of SDGs, especially in improving the achievement of SDG 4 in the field of education. These weaknesses require an in-depth study to map the sustainability of research on the role of AI in physics education and supporting the SDGs. Specifically, this article discusses a bibliometric analysis of articles from 2019 to 2024. This study aims to review the literature on AI-assisted physics learning to achieve SDGs with a broad research perspective and reveal trends in physics learning by considering various variables using the bibliometric mapping method.

2. METHODS

This study is an exploratory study using Bibliometric-based Systematic Literature Review (SLR) to describe the results of a literature study on integrated physics learning with Artificial Intelligence (AI) to support the achievement of the SDGs. The articles reviewed come from the Scopus database from 2019 to 2024. Research with bibliometric analysis in science learning, especially physics lessons, is increasingly popular along with advances in information technology, especially AI technology. Bibliometric analysis has many useful approaches, including mathematical and statistical approaches in examining a research subject sourced from bibliography (Alfaro-Ponce et al., 2024). In essence, research using bibliometric analysis provides a clear picture, both in the form of research mapping and intellectual frameworks in various cross-research subjects extensively. In this bibliometric analysis, there are two techniques, namely scientific mapping and performance evaluation, both of which are interrelated to support the validity of a study or performance (Yalcinkaya, 2023).

This bibliometric analysis is an instrument for developing literature studies that allows for contributions to broader fields of knowledge and insight in the future. With literature studies changing from qualitative to quantitative data (Baraibar-Diez et al., 2020). Research trends with bibliometric analysis aim to evaluate the quality of a study, visualize intellectual, conceptual, and social structures and predict the direction of future research. The bibliometric method consists of three stages, namely: data collection, data mapping, and refinement of publication data on physics learning assisted by AI media to support the achievement of SDGs as shown in Figure 1

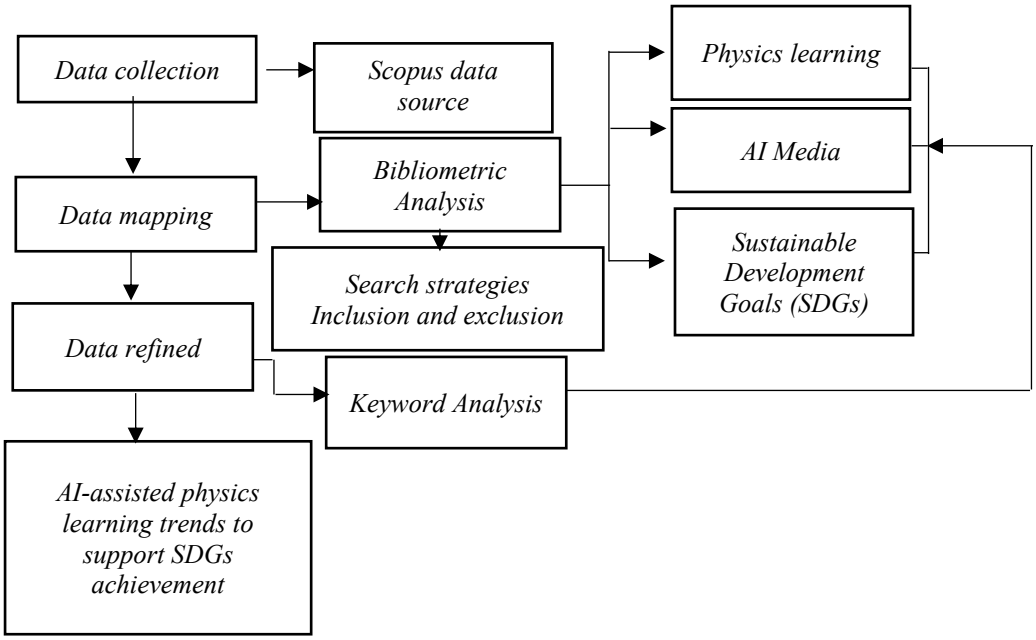

Figure 1. SLR Research Stages

Data Collection Strategy

At the data search stage, researchers use the main source of research data, namely Scopus, from this source articles are searched using publish or perish, this is done to collect articles that are relevant to the criteria of the database-based search strategy. Scopus as a source of articles was chosen because it has high quality, a large number of article themes, and is easy to access (Prieto-Andreu & Labisa-Palmeira, 2024). The search strategy based on the database is shown in Table 1.

Table 1. Database search strategy

Filter	Description
Years	2019-2024
Subject area	Education, scince
Search string	SDGs, AI, and Physics learning
Source type	Journal
language	English
Document type	Open acces
Rank type	Index by scopus

Based on the search results from the Scopus database, 943 articles were obtained indexed by Scopus. Furthermore, the articles were identified and analyzed for their level of relevance to the research study topic. To determine the level of relevance of the collected articles, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used to filter relevant articles. This relevance is based on the title, year of publication, type of publication, language used, access, and journal indexing (Shabira & Yanti, 2024; Solimun, et. al, 2023).

Data Selection Criteria

At the literature selection stage, it is carried out carefully and thoroughly to obtain good library documents that are in accordance with the keywords SDGs, AI, and physics learning. Kholid *et al.*, (2023) stated that in selecting literature documents for review, two criteria must be met, namely inclusion and exclusion. These criteria in this study are shown in Table 2.

Table 2. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion criteria
The title and content of the article are relevant to the research topic.	Title and content are irrelevant
Publication year 2019-2024	Published outside the 2019-2024 period
Journal article publication types	Proceding and non-research
Language English	Others
Research focus on SDGs, AI, and Physics learning	Others
Participants, junior high school, high school, and college students	Others
Accessibility fulltext	Others
Scopus indexed journals	Others

Data selection process

After the selection of articles based on inclusion and exclusion criteria, a second sorting was carried out to ensure the level of validity of the articles to be reviewed (Zhang, 2020). This selection was carried out to ensure the wetness and integrity of the data so as to avoid research bias, while the main focus of the study was to identify articles that were in accordance with the research topic (Schmitt et al., 2023). Furthermore, the data was selected with the help of covidence software by extracting relevant data. The mapping of this research data was carried out in April 2024 and the data mapping stages were carried out through three stages, namely identification, data screening, and data inclusion. For more details, see Figure 2.

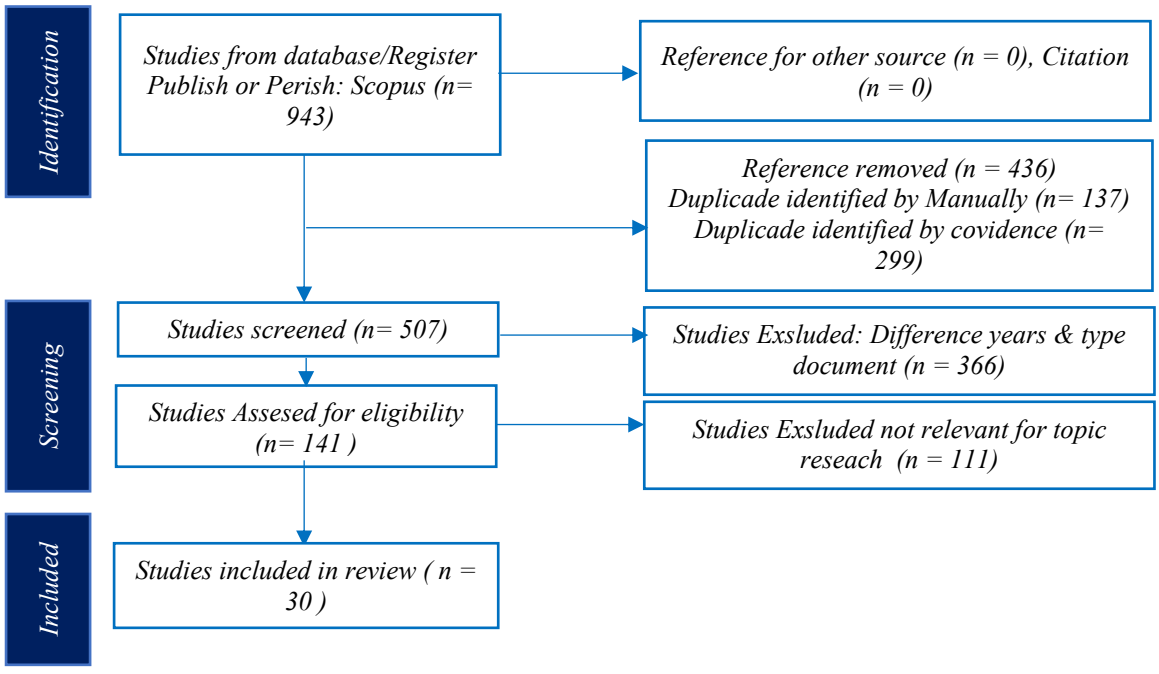

Figure 2. PRISMA Flow diagram

The articles that have been selected as literature to be reviewed, then input into prism as many as 943 articles, from these articles then conducted a more in-depth analysis based on several provisions. A total of 436 articles were identified with references that are still unclear, 137 articles were duplicated, this happened because in the search process with the Publish or Perish application having the same algorithm will also be netted. 299 articles were identified as having similarities in terms of discussion, the remaining 507 articles were then screened, then excluded based on differences in year and document type as many as 366. Furthermore, the remaining 141 articles were screened based on relevance to the topic as many as 111, so that the final remaining articles for a comprehensive review were 30 articles.

Data Analysis

The collected data is then exported into RIS and CSV formats, then the data is imported into Mendeley for verification and metadata correction. The verified data is then mapped using the Vosviewer application, while the CSV data is tabulated in Excel for gap analysis, development potential and follow-up. There are several factors that are considered in the study in bibliometric analysis, including annual publication trends, number of citations, country of origin of the author, and consideration of the research methods used. The results of the analysis are then used to identify further research needs (Al-Kamzari & Alias, 2025). The final step in this study is to identify research results related to physics learning using AI media to support the achievement of SDGs.

3. RESULT AND DISCUSSION

This study reviews research topics related to AI-assisted physics learning at the global level using publication characteristics analysis. Based on bibliometric analysis, it was found that 943 articles obtained from the Scopus databases spread from 2019 to 2024 were used as data sources in this study. Overall, it is presented in Table 3.

Table 3. Article information based on keyword search

Description	Result
Rentang waktu publikasi	2019-2024
Sumber scopus	943
Penulis	1321
Kata kunci	749
Tipe journal	Open acces

The information listed in table 3 shows that during the period 2019 to 2024, there were 943 scientific works published in 29 international journals indexed by Scopus, and 12 National Journals indexed by Scopus. The collaboration of authors reached 522 people, resulting in a total of 749 keywords. The publication development map can be seen in Figure 3.

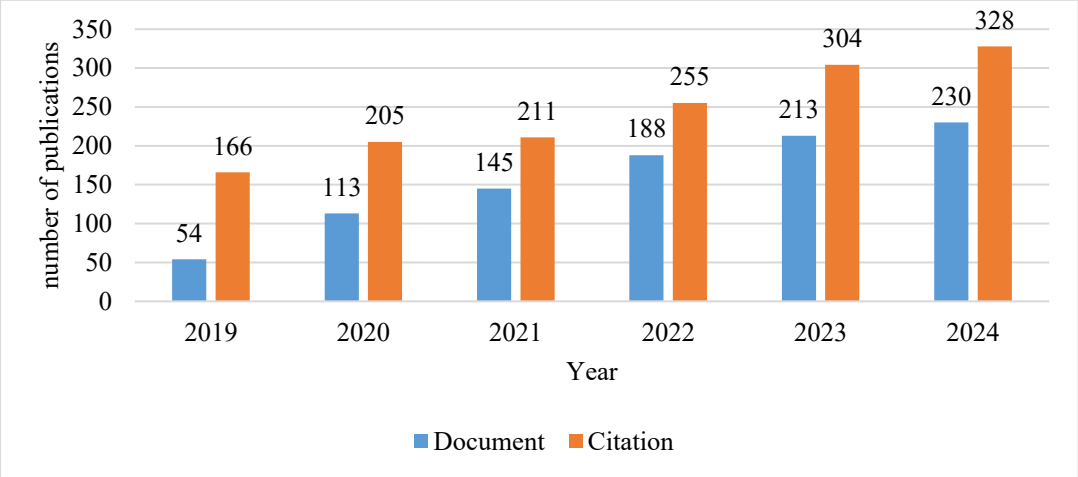

Figure 3. Publication and citation trends

Figure 3 illustrates that research on AI-assisted physics learning has shown a significant upward trend from 2019 to 2024. Over the five years, there has been a consistent increase in the number of publications. The most prominent spike occurred between 2023 and 2024 with the number of publications increasing from 213 to 230. Although the increase is not always significant every year, the data shows a continued positive trend in this area of research, with publications increasing from 54 in 2019 to 230 in 2024. This research trend is in line with previous research on the use of Artificial

Intelligence to support the SDGs such as research from (Tannar & Susilowati, 2025) which states that the technology that can be utilized in achieving the SDGs goals includes AI. AI is not only a technological innovation but more on the use of a technological revolution that can support aspects of the SDGs (AlSagri & Sohail, 2024; Lainjo, 2024).

Sustainable development goals in education are improving the quality of education, one of the indicators of which is improving the learning process, among the lessons related to AI and its use to achieve the SDGs goals is physics. The physics learning process can use AI technology to facilitate and accelerate obtaining relevant information (Ding et al., 2023; Jiao et al., 2024). The use of AI in the science learning process, especially physics, has begun to be researched from year to year by various countries such as China, Switzerland, and America. This proves that scientific publications on AI and its use in the world of science and education (Bakri et al., 2020; Piloto et al., 2022; Tschisgale et al., 2023) with one of the goals of achieving the SDGs (Rahayu, 2021; Suprapto & Hidaayatullaah, 2023) Based on several literature studies and the number of citations for each article published in the Scopus indexed international journal database, this indicates that this topic is an important research topic that needs to be continuously developed. The link to the SDGs is particularly evident in Goal 4, Quality Education, which emphasizes improving the quality of inclusive and sustainable education. The use of AI in physics learning can help students understand abstract concepts, accelerate access to information, enhance scientific creativity, and support more personalized and interactive learning. Thus, AI is a strategic technology for improving the quality of science education and supporting the transformation of 21st-century education.

Based on the results of the bibliometric analysis, it shows that there are 10 authors with the top positions in the context of using AI media in physics science learning with the largest number of publications from 2019 to 2024 as shown in Figure 4.

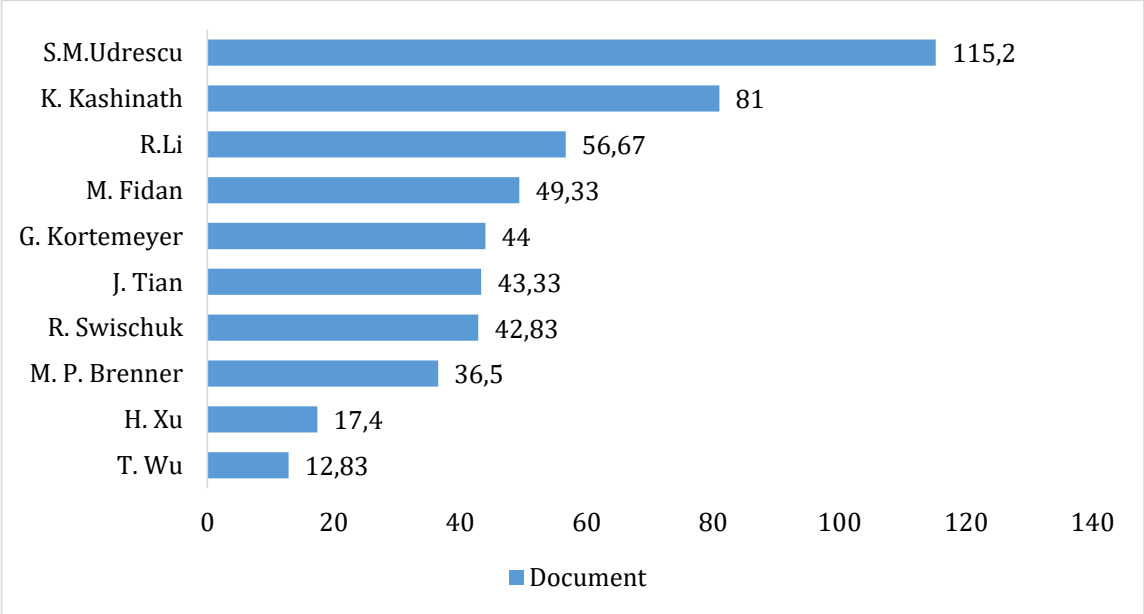

Figure 4. 10 Authors with the most articles from 2019-2024

Based on information from Figure 4, author Udrescu has the most publications, namely 115 publications per year, each publication they publish collaborates with other authors who discuss the role of AI, especially in education. The ability to collaborate shows that this research is a study with a high contribution to knowledge (Fahrudin et al., 2025). The middle position in the number of publications each year is occupied by Kortemeyer (2023) with 44 publications per year, Kortemeyer stated that physics learning does not only depend on contextual learning processes and empirical formulas, but the use of technology-based media has an important role in the development of knowledge. While in last

place is T. Wu with the number of publications per year reaching 12, 83 in the study stated that physics has an important role in the advancement of engineering technology. Furthermore, researchers conduct a selection of articles that are relevant to physics learning with AI integration. This process is carried out to investigate the role of AI technology as a physics learning medium. This selection is based on the highest to lowest number of citations with a top 10 ranking. The results of the article selection process with the highest number of citations in the 10 categories are presented in Table 4

Table 4. Top 10 articles with the highest number of citations

Title	Author, year	Source	Citation	Quartile
Intuitive physics learning in a deep-learning model inspired by developmental psychology	Luis S. et al., 2022	Nature human behaviour	126	Q1
Student Worksheet With Ar Videos: Physics Learning Media In Laboratory For Senior High School Students	Fauzi Bakri, et al., 2020	Journal of Technology and Science Education	92	Q2
How understanding large language models can inform the use of ChatGPT in physics education	Giulia Polverini Gregorci, 2023	European Journal of Physics	86	Q2
Educational data augmentation in physics education research using ChatGPT	Kieser, et al., 2023	Physical Review Physics Education Research	57	Q1
How do physics students evaluate artificial intelligence responses on comprehension questions? A study on the perceived scientific accuracy and linguistic quality of ChatGPT	Dahlkemper., 2023	Physical Review Physics Education Research	32	Q1
Effects Of Augmented Reality Integration (Ari) Based Model Physics Independent Learning (Mpil) For Facilitating 21st-Century Skills (21-Cs)	F C Wibowo, 2023	Journal of Technology and Science Education	32	Q2
Integrating artificial intelligence-based methods into qualitative research in physics education research: A case for computational grounded theory	Tschisgale, et al., 2023	Physical Review Physics Education Research	20	Q1
A Study for Student Perception of Mathematical Physics E-Module Based on Gender	Astalini,et al, 2022	Journal of Turkish Science Education	15	Q2
AI meets physics: a comprehensive surve	Licheng Jiao, et al, 2024	Artificial Intelligence Review	7	Q1
AI Adaptivity in a Mixed-Reality System Improves Learning	Yannier, 2024	International Journal of Artificial Intelligence in Education	7	Q1

In table 4, there are 10 articles that are most cited and published in reputable international journals so that they become the main references that are relevant and credible for developing knowledge, especially in the field of physics learning studies by utilizing Artificial Intelligence (AI) or Chatgpt-based media with a total number of citations reaching 474. The highest citation in 2023 with a total of 126 citations. After a strict process of identification and selection of articles based on suitability to the topic, number of publications, and number of citations. Furthermore, a keyword evaluation is carried out to understand the relationship between research variables, namely physics learning and the use of

AI technology as a learning medium. In addition, the evaluation is carried out through bibliometric analysis to determine the visualization of trends in the development of science (AlSagri & Sohail, 2024; Prahani et al., 2025). The relationship between terms in keywords is marked with color, where the color displayed is brighter indicating that there is a lot of research that has been done and has been popularly researched (Araújo, 2020), while the relationship between two keywords that are marked with color with a network that connects the two keywords, namely physics learning and artificial intelligence, is shown in Figure 5.

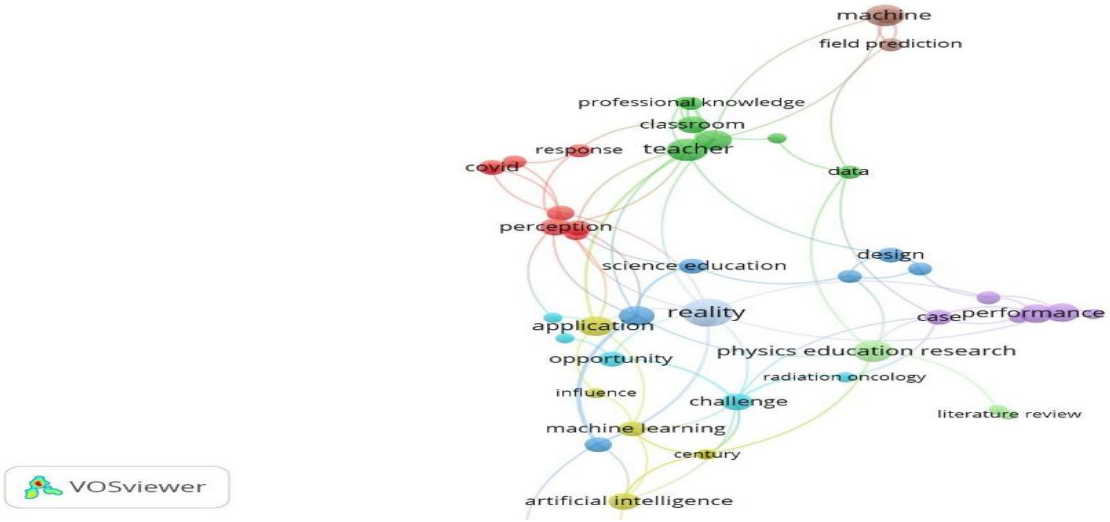

Figure 5. Visualization of the relationship network between physics learning and AI

Figure 5 illustrates the collaboration network between the keywords of physics learning and the use of AI technology over the past 5 years resulting from bibliometric analysis, the same and adjacent colors and the same color indicate that the two keywords are integrated. Based on the information visualization of the color network from physics learning and the use of AI, the colors are not the same but are still in one network, this indicates that artificial intelligence (AI) technology that is directly integrated with physics learning is still relatively rarely studied. This fact provides an opportunity for further research. Based on the visualization results, one of the start of the art from the results of bibliometric analysis is the similarity of the network in the visualization (Rahim & Widodo, 2024; Shabira & Yanti, 2024). The connection between AI and physics learning can be seen in the use of AI technology to enhance the learning process, such as the use of intelligent tutoring systems, adaptive learning, virtual laboratories, learning data analysis, and automated student ability evaluation. AI helps make physics learning more interactive, personalized, and data-driven, thereby improving students' conceptual understanding and problem-solving skills. To see the novelty of the two keywords analyzed using vosviewer which is visualized with an overlay, it can be seen in Figure 6.

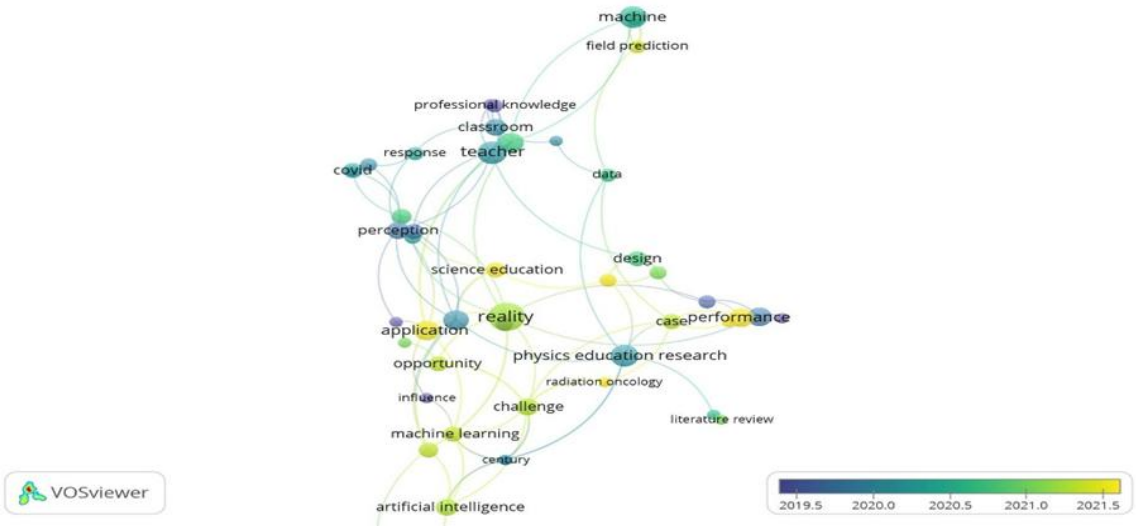

Figure 6. Overlay visualization between physics learning and AI

The results of the bibliometric analysis with overlay visualization in Figure 6 show that research on physics, especially in the field of education, has been carried out in the last five years from 2019. The cluster that appears with the keyword physics educational research is colored blue, from 2019 to early 2021, this shows that physics education research has been widely studied by previous researchers. Meanwhile, AI only emerged in the early period of 2021 and the integration of the two has rarely been studied from 2022 to 2024. Integrating AI with physics learning is relatively new based on the overlay visualization showing a yellow color which means this research has high novelty (Jiao et al., 2024; Piloto et al., 2022). As for finding out the two variables with the most and most frequently conducted research, it is shown in Figure 7.

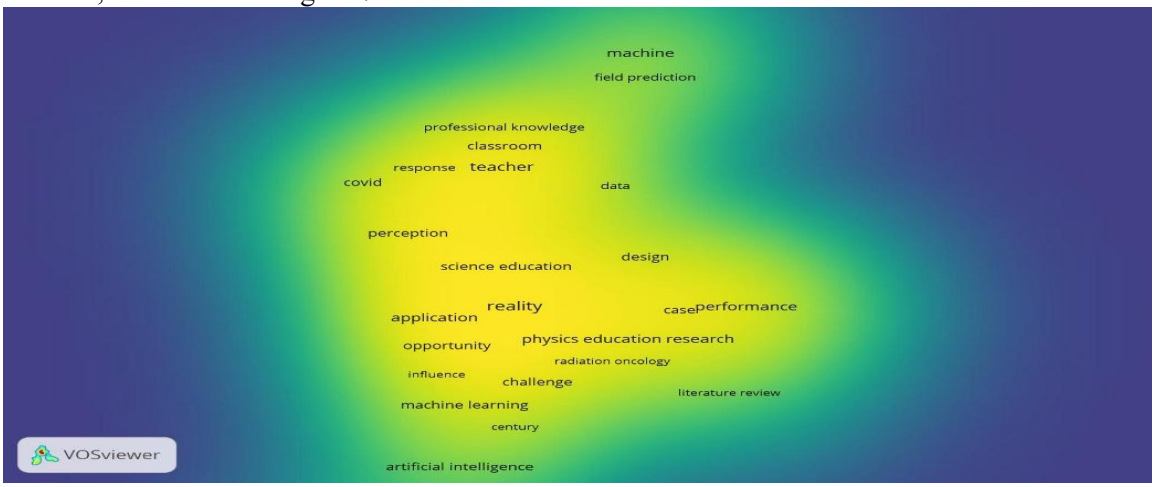

Figure 7. Research density on Physics learning and AI

Based on the information presented in Figure 7, it shows a strong relationship between the frequency of keywords about AI and Physics Education as its center, the area around this keyword is very bright and several topics around it are also bright, this indicates that the keyword has been widely researched. While the light or color of the keyword Artificial Intelligence (AI) is not so bright and the distance between this keyword and physics education is quite far, this indicates that the integration of these two keywords is still rarely studied and discussed, so this is considered relevant for further research (Misbah et al., 2023; Sidek et al., 2020). Based on information from the results of the bibliometric visualization analysis taken from Figure 5 to Figure 7. Provides important information that research on physics learning still needs further research. This will make a positive contribution to the development of knowledge, especially in the fields of technology and physics (Coban et al., 2025; Revalde et al., 2025).

To conduct research on SDGs, AI, and Physics learning, a research method is needed to explore all three, many researchers have used various research methods to collect and analyze data. This is done to obtain valid and reliable data (Ajib Shofwanthoni et al., 2019; Suprapto & Hidaayatullaah, 2023; Tegeh et al., 2021). From the 30 articles that have been selected, the methods used in researching three keywords, namely SDGs, AI, and Physics learning and the trend of using research methods in the last five years were analyzed. In the context of physics education, the implementation of AI also contributes to achieving the Sustainable Development Goals (SDGs), particularly SDG 4 on quality education through innovative and technology-supported learning. Physics learning integrated with AI can encourage problem-solving skills, critical thinking, and environmental awareness that are closely related to sustainable development issues. The percentage of use of research methods for the three keywords is shown in Figure 8.

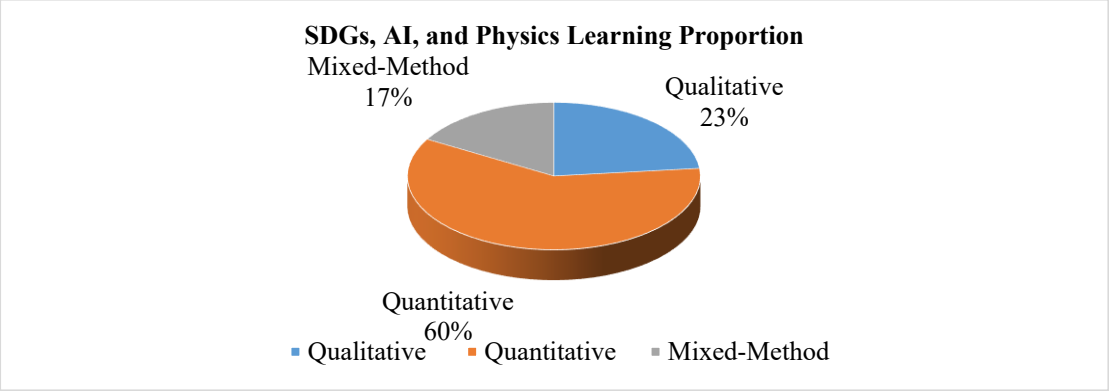

Figure 8. Proportion of research methods in the topics SDGs, AI, and Physics Learning

The distribution of research methods shown in Figure 8 with quantitative having a percentage of 60% (18 articles), followed by the use of qualitative methods of 23% (7 articles), and finally the percentage of mixed research with a percentage of 17% (5 articles). Based on the results of the distribution of the percentage of the use of research methods, quantitative methods are most widely used by SDGs, AI and Physics learning researchers, possibly because the data obtained from quantitative research results are more measurable and can be generalized (Franklin, 2023). The other two research methods have a smaller percentage than quantitative research, although having a smaller percentage does not mean reducing the essence of research on the implementation of SDGs, AI and Physics learning. The qualitative research method from the 7 articles analyzed revealed that case studies with the three keywords above were more dominant. This case study is often used to explore SDGs and AI in real-life contexts such as the achievement of SDG 4, technology and the environment globally (Eneva & Dogan, 2025; Kieser et al., 2023; Lainjo, 2024). Exploration of knowledge, especially science, in research clearly explains how technology is formed and its use as an answer to achieving the SDGs (Al-adwan et al., 2025; Mitarlis et al., 2023).

4. CONCLUSION

The trend of research publications on SDGs, AI and physics learning from 2019 to 2024 has increased well. Although there has been an increase in the number of publications, the integration of the three is still relatively rarely discussed and carried out by researchers. The themes that are often studied are sustainable development goals and physics learning. Based on the results of the study, the integration of Artificial Intelligence with SDGs and Physics learning has not been widely researched. The most widely used research method in conducting research is the quantitative method at 60%. While other methods are used as an approach in case studies. The findings of this study provide recommendations for further researchers to follow up and develop research on the integration of AI and SDGs which is still empty.

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REFERENCES

Ajib Shofwanthoni, M., Ridlo, S., & Elmubarok, Z. (2019). The Development of Authentic Assessment Instrument of Hajj Manasik Practices of IX Grade of SMP PGRI 10 Candi in Sidoarjo Regency. *Journal of Educational Research and Evaluation*, *8*(1), 14–21. https://doi.org/10.15294/jere.v8i1.28361

Al-adwan, M. A. S., Mohamed, E., & Qutieshat, A. (2025). Artificial Intelligence In Medicine : Legal Pathways To Sustainable Development Goals (SDGS). *Journal of Life Style & SDGs Review*, *5*, 1–28.

Al-Kamzari, F., & Alias, N. (2025). A systematic literature review of project-based learning in secondary school physics: theoretical foundations, design principles, and implementation strategies. *Humanities and Social Sciences Communications*, *12*(1), 1–18. https://doi.org/10.1057/s41599-025-04579-4

Alfathy, R. M., Saputro, S., Sarwanto, S., & Ramli, M. (2024). Implementation of sustainable development goals in higher education modalities: Literature review. *Journal of Turkish Science Education*, *21*(1), 22–43. https://doi.org/10.36681/tused.2024.002

AlSagri, H. S., & Sohail, S. S. (2024). Evaluating the role of Artificial Intelligence in sustainable development goals with an emphasis on “quality education.” *Discover Sustainability*, *5*(1), 442–458. https://doi.org/10.1007/s43621-024-00682-9

Araújo, C. C. S. de. (2020). A bibliometric analysis of the intellectual structure of studies on slavery in the 21st century. *International Journal of Professional Business Review*, *5*(1), 105–127. https://doi.org/10.26668/businessreview/2020.v5i1.175

Arzak, K. A., & Prahani, B. K. (2023). Practicality of Augmented Reality Books in Physics Learning: A Literature Review. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *12*(2), 138–154. https://doi.org/10.26740/jpps.v12n2.p138-154

Astuty, E., Ikhsan, R. B., & Aryanto, R. (2024). Sustainable entrepreneurial culture in promoting innovation: a higher education perspective. *International Journal of Evaluation and Research in Education* , *13*(1), 170–186. https://doi.org/10.11591/ijere.v13i1.26740

Bakri, F., Permana, H., Wulandari, S., & Muliyati, D. (2020). Student worksheet with ar videos: Physics learning media in laboratory for senior high school students. *Journal of Technology and Science Education*, *10*(2), 231–240. https://doi.org/10.3926/JOTSE.891

Coban, A., Dzsotjan, D., Küchemann, S., Durst, J., Kuhn, J., & Hoyer, C. (2025). AI support meets AR visualization for Alice and Bob: personalized learning based on individual ChatGPT feedback in an AR quantum cryptography experiment for physics lab courses. *EPJ Quantum Technology*, *12*(1). https://doi.org/10.1140/epjqt/s40507-025-00310-z

Ding, L., Li, T., Jiang, S., & Gapud, A. (2023). Students’ perceptions of using ChatGPT in a physics class as a virtual tutor. *International Journal of Educational Technology in Higher Education*, *20*(1), 1–18. https://doi.org/10.1186/s41239-023-00434-1

El-Kholei, A. O. (2023). Embedding sustainability and SDGs in architectural and planning education: reflections from a KAP survey, Egypt. *International Journal of Architectural Research: Archnet-IJAR*, *17*(3), 459–477. https://doi.org/10.1108/ARCH-07-2022-0156

Eneva, Y., & Dogan, B. (2025). Evaluation of Medical Diagnosis Capabilities of Three Artificial Intelligence Models – Chatgpt-3.5, Google Gemini, Microsoft Copilot: Sustainable Development Goals (Sdgs). *Journal of Lifestyle and SDG’S Review*, *5*(2), 1–13. https://doi.org/10.47172/2965-730X.SDGsReview.v5.n02.pe03545

Fahrudin, A., Purwaningsih, S., & Marzal, J. (2025). *Science literacy and skills of physics education*

students by developing a project-technology skills learning model. *19*(3), 1197–1207. https://doi.org/10.11591/edulearn.v19i3.21839

Franklin, R. (2023). Quantitative methods II. *Big Theory. Progress in Human Geography*, *1*(47), 178–186. https://doi.org/https://doi.org/10.1177/03091325221137334

Huang, L., Zhou, X., & Zhu, W. (2025). The Teaching Model (IT-CSTP) for Integrating Intelligent Technology into Scientific Thinking Cultivation in Physics: A Practical Study for High School Students. *Journal of Science Education and Technology*. https://doi.org/10.1007/s10956-025-10225-0

Jiao, L., Song, X., You, C., Liu, X., Li, L., Chen, P., Tang, X., Feng, Z., Liu, F., Guo, Y., Yang, S., Li, Y., Zhang, X., Ma, W., Wang, S., Bai, J., & Hou, B. (2024). AI meets physics: a comprehensive survey. In *Artificial Intelligence Review* (Vol. 57, Issue 9). Springer Netherlands. https://doi.org/10.1007/s10462-024-10874-4

Kholid, M. N., Hendriyanto, A., Sahara, S., Muhaimin, L. H., Juandi, D., Sujadi, I., Kuncoro, K. S., & Adnan, M. (2023). A systematic literature review of Technological, Pedagogical and Content Knowledge (TPACK) in mathematics education: Future challenges for educational practice and research. *Cogent Education*, *10*(2), 1–18. https://doi.org/10.1080/2331186X.2023.2269047

Kieser, F., Wulff, P., Kuhn, J., & Küchemann, S. (2023). Educational data augmentation in physics education research using ChatGPT. *Physical Review Physics Education Research*, *19*(2), 20150. https://doi.org/10.1103/PhysRevPhysEducRes.19.020150

Kortemeyer, G. (2023). Toward AI grading of student problem solutions in introductory physics: A feasibility study. *Physical Review Physics Education Research*, *19*(2), 20163. https://doi.org/10.1103/PhysRevPhysEducRes.19.020163

Lainjo, B. (2024). The Role of Artificial Intelligence in Achieving the United Nations Sustainable Development Goals. *Journal of Sustainable Development*, *17*(5), 30. https://doi.org/10.5539/jsd.v17n5p30

Li, C., & Yin, W. (2025). Interactive online learning method for students based on artificial intelligence. *Discover Artificial Intelligence*, *5*(1). https://doi.org/10.1007/s44163-025-00401-x

Maharani Putri Kumalasani, & Kusumaningtyas, D. I. (2022). 21 St Century Skill In Learning Models With A Steam Approach. *Jurnal Riset Pendidikan Dasar*, *05*(April), 74–81.

Misbah, M., Hamidah, I., Sriyati, S., & Samsudin, A. (2023). Research Trend of Dynamic Fluid in Learning: A Bibliometric Analysis. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *9*(2), 263–272. https://doi.org/10.21009/1.09209

Mitarlis, Azizah, U., & Yonata, B. (2023). The Integration Of Green Chemistry Principles In Basic Chemistry Learning To Support Achievement Of Sustainable Development Goals (Sdgs) Through Education. *Journal of Technology and Science Education*, *13*(1), 233–254. https://doi.org/10.3926/jotse.1892

Piloto, L. S., Weinstein, A., Battaglia, P., & Botvinick, M. (2022). Intuitive physics learning in a deep-learning model inspired by developmental psychology. *Nature Human Behaviour*, *6*(9), 1257–1267. https://doi.org/10.1038/s41562-022-01394-8

Prahani, B. K., Nisa', K., Suliyanah, & Deta, U. A. (2025). Evaluation of ChatGPT research in STEAM education. *International Journal of Evaluation and Research in Education*, *14*(1), 598–611. https://doi.org/10.11591/ijere.v14i1.30423

Prieto-Andreu, J. M., & Labisa-Palmeira, A. (2024). Quick Review of Pedagogical Experiences Using Gpt-3 in Education. *Journal of Technology and Science Education*, *14*(2), 633–647. https://doi.org/10.3926/jotse.2111

Rahayu, M. S. I. (2021). The effectiveness of the use of the android-based carom games comic integrated to discovery learning in improving critical thinking and mathematical representation abilities. *Journal of Technology and Science Education*, *11*(2), 270–283. https://doi.org/10.3926/JOTSE.1151

Rahim, F. R., & Widodo, A. (2024). Computational mapping analysis of artificial intelligence in education publications: A bibliometric approach utilizing vosviewer. *Momentum: Physics Education Journal*, *8*(2), 304–317. https://doi.org/10.21067/mpej.v8i2.9774

Revalde, G., Zholdakhmet, M., Abola, A., & Murzagaliyeva, A. (2025). Can ChatGPT Pass a Physics Test? *Technology, Knowledge and Learning*, *0123456789*. https://doi.org/10.1007/s10758-025-09814-0

Schmitt, J. B., Goldmann, A., Simon, S. T., & Bieber, C. (2023). Conception and Interpretation of Interdisciplinarity in Research Practice: Findings from Group Discussions in the Emerging Field of Digital Transformation. *Minerva*, *61*(2), 199–220. https://doi.org/10.1007/s11024-023-09489-w

Shabira, Q., & Yanti, Y. (2024). *Mapping the Literature of Technological Pedagogical and Content Knowledge (TPACK) in Elementary Education : A Bibliometric Review*. *10*(9), 631–643. https://doi.org/10.29303/jppipa.v10i9.8731

Shofiyah, N., Suprapto, N., Prahani, B. K., Jatmiko, B., Anggraeni, D. M., & Nisa', K. (2024). Exploring undergraduate students' scientific reasoning in the force and motion concept. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2365579

Sidek, R., Halim, L., Buang, N. A., & Mohamad Arsad, N. (2020). Fostering Scientific Creativity in Teaching and Learning Science in Schools: A Systematic Review. *Jurnal Penelitian Dan Pembelajaran IPA*, *6*(1), 13. https://doi.org/10.30870/jppi.v6i1.7149

Solimun, S., Fernandes, A. A. R., Nurjannah, N., Erwinda, E. G., Hardianti, R., & Arini, L. H. Y. (2023). Metodologi Penelitian: Variabel Mining Berbasis Big Data dalam Pemodelan Sistem untuk Mengungkap Research Novelty. *In Metodologi Penelitian: Variabel Mining Berbasis Big Data Dalam Pemodelan Sistem Untuk Mengungkap Research Novelty*. https://doi.org/643 https://doi.org/10.11594/ubpress97862329670 52

Suprapto, N., & Hidaayatullaah, H. N. (2023). University Students' Perspectives on Physics Education in Sustainable Development Goals. *Journal of Physics: Conference Series*, *2623*(1), 1–10. https://doi.org/10.1088/1742-6596/2623/1/012001

Tannar, O., & Susilowati, E. (2025). The significance of artificial intelligent for SDGs civitas academica. *Journal of Lifestyle & SDGs Review*, *5*, 1–23.

Tegeh, I. M., Astawan, I. G., Sudiana, I. K., & Kristiantari, M. G. R. (2021). Murder Learning Model Assisted By Metacognitive Scaffolding To Improve Students' Scientific Literacy and Numeracy Skills Through Science Studies in Elementary Schools. *Jurnal Pendidikan IPA Indonesia*, *10*(4), 618–626. https://doi.org/10.15294/jpii.v10i4.32926

Tschisgale, P., Wulff, P., & Kubsch, M. (2023). Integrating artificial intelligence-based methods into qualitative research in physics education research: A case for computational grounded theory. *Physical Review Physics Education Research*, *19*(2), 20123. https://doi.org/10.1103/PhysRevPhysEducRes.19.020123

Wahyuni, L., & Rahayu, Y. S. (2021). Pengembangan E-Book Berbasis Project Based Learning (PjBL) untuk Melatihkan Kemampuan Berpikir Kreatif pada Materi Pertumbuhan dan Perkembangan Tumbuhan Kelas XII SMA. *Berkala Ilmiah Pendidikan Biologi (BioEdu)*, *10*(2), 314–325. https://doi.org/10.26740/bioedu.v10n2.p314-325

Yi, C. (2023). Exploration And Analysis Of Middle School Teachers' Classroom Questioning Methods From The Perspective Of Dialogue Education. *Journal of Law and Sustainable Development*, *11*(6), 234–255. https://doi.org/10.55908/sdgs.v11i6.834

Zhang, Z. (2020). Deep reinforcement learning for power system applications: An overview. In *CSEE Journal of Power and Energy Systems* (Vol. 6, Issue 1, pp. 213–225). https://doi.org/10.17775/CSEEJPES.2019.00920

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