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Global Trends in Innovation and Evaluation of 21st Century Physics Learning: A Bibliometric and Systematic Review

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Abstract: *Physics education in the 21st century is undergoing various innovations to enhance its effectiveness and relevance in the digital era. This study aims to map current research trends in high school physics education through bibliometric analysis and SLR analysis methods on articles indexed in the Scopus database. This study utilized 62 articles on physics learning that were analyzed. The study results show that innovations in physics learning include the use of simulations and virtual reality, digital applications such as Getsmart and PhET, project-based learning (PBL) approaches, as well as the use of digital tools like Tinkercad and Arduino Uno. In addition, STEM-based learning approaches, flipped classrooms, and hybrid learning are increasingly being implemented to enhance 21st-century skills such as critical thinking, problem-solving, and creativity. This study also found that teacher training adopting the Nature of Science (NOS) approach and technology in teaching contributes to the improvement of pedagogical competence. Learning evaluations using HOTS-based instruments and technology-based e-assessments have proven effective in measuring students' understanding and interest in physics.*

Keywords: *21st-century, bibliometrics, education innovation, high school, physics education, SLR*

Tren Global Inovasi dan Evaluasi Pembelajaran Fisika Abad Ke-21: Tinjauan Bibliometrik dan Sistematis

Abstrak: Pendidikan fisika di abad ke-21 sedang mengalami berbagai inovasi untuk meningkatkan efektivitas dan relevansinya di era digital. Penelitian ini bertujuan untuk memetakan tren penelitian terkini dalam pendidikan fisika SMA melalui analisis bibliometrik dan metode analisis SLR pada artikel yang terindeks dalam basis data Scopus. Penelitian pada studi ini menggunakan 62 artikel tentang pembelajaran fisika yang dianalisis. Hasil penelitian menunjukkan bahwa inovasi dalam pembelajaran fisika meliputi penggunaan simulasi dan realitas virtual, aplikasi digital seperti Getsmart dan PhET, pendekatan pembelajaran berbasis proyek (PBL), serta penggunaan perangkat digital seperti Tinkercad dan Arduino Uno. Selain itu, pendekatan pembelajaran berbasis STEM, kelas terbalik, dan pembelajaran hibrida semakin banyak diterapkan untuk meningkatkan keterampilan abad ke-21 seperti berpikir kritis, pemecahan masalah, dan kreativitas. Penelitian ini juga menemukan bahwa pelatihan guru yang mengadopsi pendekatan Nature of Science (NOS) dan teknologi dalam pengajaran berkontribusi pada peningkatan kompetensi pedagogik. Evaluasi pembelajaran menggunakan instrumen berbasis HOTS dan *e-assessment* berbasis teknologi telah terbukti efektif dalam mengukur pemahaman dan minat siswa terhadap fisika.

Kata kunci: abad ke-21, bibliometrik, inovasi pendidikan, pendidikan fisika, sekolah menengah atas, SLR

INTRODUCTION

The complex developments of the times demand individuals to possess 21st-century skills. Education, playing a crucial role in developing these skills, has new standards that emphasize the mastery of knowledge and attributes by students necessary to successfully contribute to the 21st-century workforce and global economy (Bao & Koenig, 2019). 21st-century skills are so diverse, various literature mentions that 21st-century skills include the 4Cs, which consist of creativity, critical thinking, collaboration, and communication (Haryani et al., 2024; Novitra et al., 2021; Vebriani et al., 2024). Education plays a crucial role in developing 21st-century skills, including the 4Cs (creativity, critical thinking, collaboration, and communication), which are essential for success in the workforce and the global economy.

21st-century skills can be developed through learning in schools, including physics education. A good understanding of physics can support the development of 21st century skills (21CSs) in students, while the development of these skills can also enhance their success in physics (Oral & Erkilic, 2022). One study conducted by (Nurroniah et al., 2025) examined CPBL, which proved to be highly effective in fostering critical thinking skills within physics education. Similarly, the research undertaken by (Manggul & Pratiwi, 2025) emphasized the enhancement of 21st-century skills, particularly critical thinking. Physics is an interesting and enjoyable science because it forms the basis of many new discoveries and is an integral part of everyday life (Oral & Erkilic, 2022). However, many students consider physics to be a challenging subject, so it requires the right teaching approach.

Physics education is not just about teaching content but also about how students build their understanding accurately and effectively (Redish, 1994) that can be facilitated with technology (Liana & Alpindo, 2021). Physics teaching remains dynamic and interactive, with teachers adopting various strategies to actively engage students (Gumisirizah et al., 2024). The development of 21st-century skills in physics learning can be optimized through active and innovative approaches that dynamically engage students to support better physics understanding and learning outcomes.

Physics learning that can develop 21st-century student skills requires support and the use of appropriate learning components such as innovative teaching. The reality on the ground is that the learning activities implemented by teachers lack innovation and varied creativity, resulting in teacher-centered learning (Widiana et al., 2023) Nevertheless, numerous studies have been carried out to apply various strategies and approaches aimed at enhancing the effectiveness of physics learning and postering 21st-century competencies. Among these efforts is the integration of technology-enhanced physics instruction, such as the use of augmented reality, to promote students' 21st-century skills, particularly critical thinking (Allo et al., 2025), project-based learning that emphasizes the development of students' critical thinking skills (Widyaningsih & Yusuf, 2018), the development of e-module media on student learning outcomes (Sriyanti et al., 2021), and studies showing that student-centered learning models can enhance students' critical thinking (Ubaidillah et al., 2023). In addition, a literature review by Widyaningsih et al. (2024) highlights that problem-based learning in physics education plays a significant role in fostering students' metacognitive skills, which are closely associated with higher-order thinking and critical reasoning. Furthermore, the creative problem-solving model integrated with local culture has been shown to enhance students' creative thinking and problem-solving skills (Widyaningtyas et al., 2024).

This article aims to review recent research on high school physics education, focusing on innovation and the role of physics education in supporting technological development. This research uses bibliometric methods and systematic literature review (SLR), which aim to identify, evaluate, and interpret all relevant research related to specific issues, fields of study, or phenomena (Powell & Koelemay, 2022) . This study specifically explores how high school physics education plays a role in supporting the demands of the 21st century.

The results of this study are expected to provide significant contributions to researchers and practitioners in designing more relevant and effective physics learning approaches to meet the needs of the modern era. The research questions formulated are as follows:

R1. What are the latest innovations in physics education in the 21st century?
R2. How does physics education play a role in supporting the development of technology and innovation in the digital era?
R3. How effective is the physics teacher training program in improving pedagogical skills and mastery of the material?
R4. What are the physics learning evaluations conducted in the 21st century?

METHOD

Article on physics education in the 21st century, the article is made to map and summarize the latest body of knowledge regarding key research in the 21st century for physics education.

Search Strategi

In this review article, the author uses keywords or combinations of keywords that must be searched for in the article. The combinations are (1) education with its synonyms learning and teaching, (2) physics, and (3) high school. The search for articles related to physics education in the most popular database, Scopus. All related articles were retrieved on Friday, November 1, 2024. Document searches were conducted with category restrictions as shown in.

Table 1. Inclusion and Exclusion Criteria Table.

Type of criterion	Criteria	Inclusion	Exclusion
Type of publication	Journal articles	X	
	Conference papers		X
	Reports		X
	Disertations		X
	Book and book chapters		X
Publication period	Januari 2001 – Oktober 2024	X	
Language	English	X	
	Other		X
Place or study	Worldwide		X
	Other		
Reserach methods	Qualitative	X	
	Quantitative	X	X
	Mixed methods		
Research focus	Primary education		X
	Secondary education		X
	Senior High School	X	

Selection Criteria

The source of this article is based on one source, namely Scopus. 896 initial documents obtained using the keywords in table 2. Next, the inclusion criteria screening was conducted as shown in Table 1, resulting in 157 documents. The documents are exported in CSV file format. Then, a bibliometric analysis was conducted to obtain data on the most globally cited documents. The top 62 documents were selected for analysis using SLR. The selection process is shown in Table 2.

Table 2. Article Selection Process

Key words	Initial Article	Article Filtered	Article on Bibliometric Analysis	Article is Analyzed Manually
(TITLE (education) OR TITLE (learning) OR TITLE (teaching) AND TITLE (physics) AND TITLE-ABS-KEY ("high school")) AND PUBYEAR > 2000 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))	896	739	157	62

Scopus, Friday, November 1, 2024

Data Analysis

The author summarizes various issues and common themes, then analyzes them using bibliometrics and codes and extracts the top 62 most globally cited articles into a category matrix using Microsoft Excel software. This study was conducted by examining research trends in Figure 1 and the distribution of articles by country in Figure 2. To meet the research subject, the articles were coded and categorized as follows:

1. The physics topic discussed is considered during the analysis.
2. The approach used in the learning process is considered in synthesizing the article.
3. Innovations and novelties discussed in the learning process are considered during the analysis.
4. The results of the research are considered during the analysis.
5. The methods and models of learning discussed in the article are considered during the analysis.

RESULT AND DISCUSSION

Trends of Research

The analysis revealed a trend of decreasing publications on high school physics education. In 2022, there were 14 research articles published, whereas in 2023, there was an increase in article publications to 19 articles. Considering that the data collected at the end of this year in November 2024 shows only 17 articles, it is already predicted that the number of articles will likely decrease in 2025. This study was conducted by examining research trends in Figure 1, the result of bibliometric analysis.

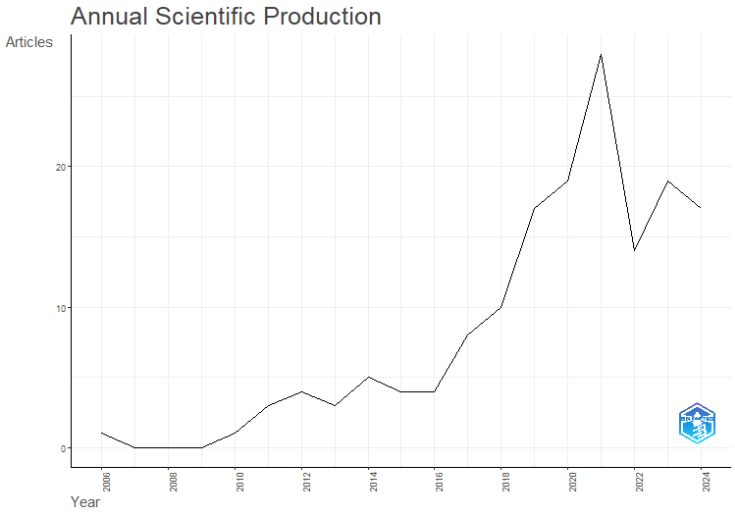

Figure 1. Tren in Physics Learning in High School

The Country that Mostly Conducts Research

Additionally, a bibliometric analysis was conducted to assess the contributions of countries conducting physics learning research in upper secondary schools. Figure 2 shows the distribution of article writing by country. Indonesia dominates with 30 published articles. Followed by Brazil with 8 articles and China, Spain, USA with 6 articles. The calculation of the number of articles is based on the number of authors per country. For example, if an article consists of 3 authors from Indonesia, Brazil, and China, the researcher records the data as one author from Indonesia, one from Brazil, and one from China. On the other hand, if the article is written by five people from the same country, the researchers record it as one country, but the number of authors is still counted as 5.

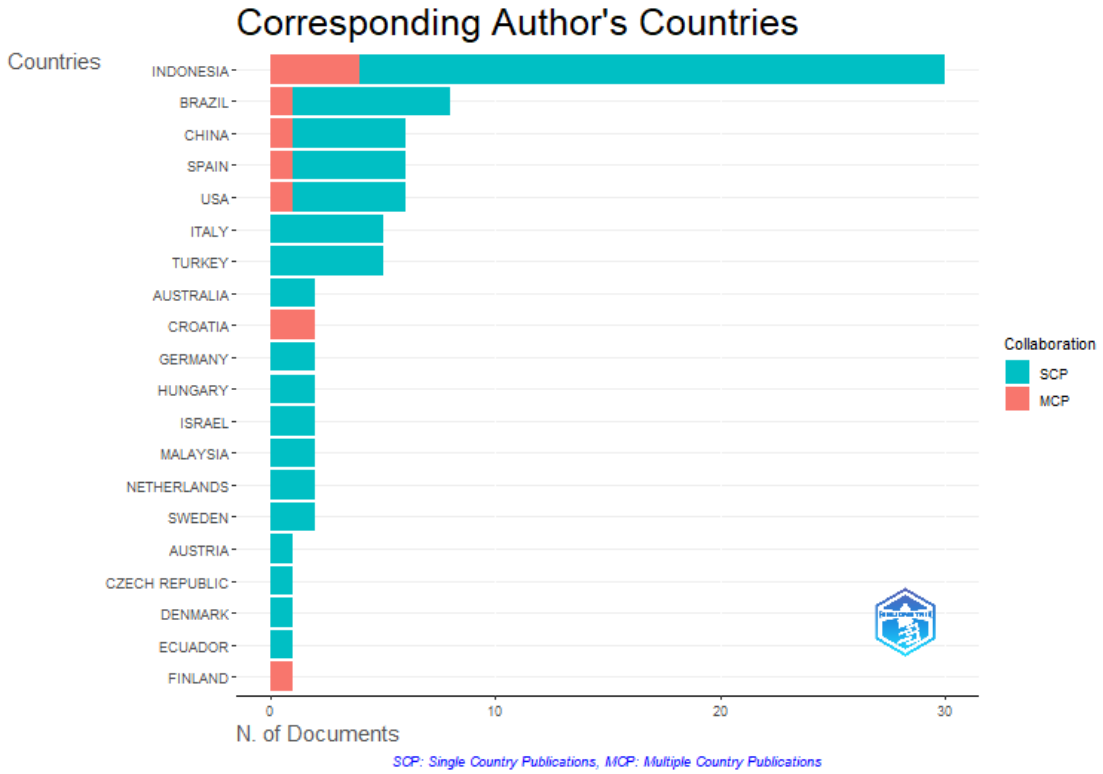

Figure 2. The Distribution of Articles Autors by Country

The Institution that Conducts the Most Research

Based on the data, Yogyakarta State University (UNY) dominates with 26. Universitas Negeri Surabaya (UNESA) and Universitas Negeri Makassar (UNM) have 9 and 8 articles, respectively. Ruhr University (8 articles), while the Graduate School of UNY, Universidade Estadual de Campinas, and UPI each have 7 articles. Universidade Federal do Rio de Janeiro and Wigner Research Center (6 articles).

Table 3. The Institution that Conducts The Most Research

Institution	Article
Universitas Negari Yogyakarta	26
Universitas Negeri Surabaya	9
RUHR Universitas	8
Universitas Negeri Makassar	8
Graduate School Of Yogyakarta State University	7
Universidade Estadual De Campinas	7
Universita Pendidikan Indonesia	7
Universidade Federal Do Rio De Janeiro	6
Wigner Research Center For Physics	6

Innovation and Approaches to Physics Learning in the 21st Century

21st-century physics learning involves various innovations and approaches to enhance students' conceptual understanding and skills. The use of simulations and virtual reality (VR) supported by 7 studies facilitates the visualization of abstract concepts. Web and Android applications, such as Getsmart and PhET (7 studies), enable independent and flexible learning. The project-based learning (PBL) \approach (5 studies) involves students in real projects that encourage critical thinking skills. The use of digital tools, such as Tinkercad and Arduino Uno (5 studies), strengthens practical skills and IoT understanding. Game-based learning (4 studies) enhances student motivation and engagement. Inquiry-based, STEM, and hybrid learning approaches (each with 3 studies) strengthen investigation, integration of knowledge, and learning flexibility. Flipped classroom (2 studies) reverses the traditional learning process, while multiple intelligences-based learning (2 studies) optimizes students' potential through methods tailored to their dominant intelligence. These innovations align with the needs of the 21st century, which emphasize mastery of technology, collaboration, and problem-solving skills.

Table 4. Innovations and Approaches to Physics Learning in The 21st Century

Autors	Innovation and Approaches to Physics Education	Number of Articles
(Arista & Kuswanto, 2018), and Watters, 2012), (Shabrina & Kuswanto, 2018), (Liliarti & Kuswanto, 2018), (Dasilva et al., 2019), (Saputra & Kuswanto, 2019), (Rodriguez et al., 2020), (Yanto et al., 2023), (Putranta, Setiyatna, et al., 2021), (Putranta,	Development and use of web (Getsmart, PhET, Golab), virtual laboratories (ViPhyLab), software technology (CmapTools), and Android applications (Facebook, Interactive Physics Mobile Learning Media (IPMLM)).	12

Autors	Innovation and Approaches to Physics Education	Number of Articles
Supahar, et al., 2021), Apriyanti *et al.*, 2020), (Agyei et al., 2019)		
(N. Suprapto et al., 2021), (Lisana & Suciadi, 2021), Purba and Hwang, 2018), (Rahmat et al., 2023), (Cai et al., 2021), (Rahmasari & Kuswanto, 2023)	The Use of Simulation and Virtual Reality (VR)	6
Sujanem and Putu Suwindra, 2023), (K. Stadermann & Goedhart, 2020), (Jabaliah et al., 2021), (Toenders et al., 2017b), (Krumphals & Haagen-Schutzenhofer, 2021), (Peres et al., 2020)	The creation and development of learning instruments in the form of media (modules, E-Books, LKPD, PowerPoint, and videos)	6
Gunawan *et al.*, 2019), (Abdulfattah & Supahar, 2019), (Batlolona and Diantoro, 2023, Parcerisas *et al.*, 2022, (Rizki et al., 2024)	Project-Based Learning and Problem-Based Learning (PBL)	5
(E. Suprapto et al., 2020), Pulgar *et al.*, 2022), (Kolçak et al., 2014), (Maison et al., 2020), (Grebenev et al., 2014)	Development and creation of Assessment	5
(H. K. E. Stadermann & Goedhart, 2021), (Kang & Seo, 2021), (Robertson et al., 2017), (Mohottala, 2013)	The role and training of teachers	4
(Rokhmat et al., 2019), (Çetin & Özdemir, 2018), (Shakhman & Barak, 2019), (Abdulfattah & Supahar, 2019), (Marušić & Sliško, 2012)	Developers of learning models (Scaffolding, instructional model, new taxonomy model (PPST), and outdoor learning) and learning methods (Reading, Presenting, and Questioning (RPQ), Experimenting and Discussion (ED),	4
(Kang & Seo, 2021), (Festiyed et al., 2022), (Pulgar et al., 2022)	Hybrid Learning and Online Learning	3
(Samsudin et al., 2020), (Cwik and Singh, 2021), (Hasanah, 2020)	STEM-based learning	3
(Souza & Duarte, 2015), (Novitra et al., 2021), (Ferrarelli & Iocchi, 2021)	The Use of Digital Tools and Applications (Tinkercad, Arduino Uno, and IoT) for Robotics	3
(Carr & Bossomaier, 2011), (Chang et al., 2015),	Creation and development of games for physics learning	2

Autors	Innovation and Approaches to Physics Education	Number of Articles
(Maison *et al.*, 2021), (Festiyed et al., 2022),	Inquiry-Based Learning (Inkuiri)	2
(Djudin, 2021), (Rochman et al., 2017)	3-2-1 reading technique literacy and refutation text. scientific literacy based on natural resources and minerals (NMRs)	2
(Ahamad et al., 2021), (Maison et al., 2021)	Learning Based on Multiple Intelligences and Student Attitudes	2
(Capone et al., 2017), Capone et al. (2017), (Chandra & Watters, 2012)	Flipped Classroom	2

The Role of Physics Education in the 21st Century

Physics education in the 21st century has transformed through innovations such as simulations, virtual laboratories, and digital tools that enhance conceptual understanding (24 articles) and student motivation (9 articles). Approaches such as STEM, flipped classroom, and project-based learning encourage 21st-century skills, including critical thinking, problem-solving, independence, and creativity. Physics education in the 21st century plays a crucial role in enhancing conceptual understanding, motivation, and 21st-century skills, such as critical thinking, problem-solving, and creativity, through technological innovations like simulations, virtual laboratories, and digital tools.

Table 5. The Role of Physics Education in The 21st Century

Autors	Research Results	Number of Articles
(Eylon & Bagno, 2006), (Carr & Bossomaier, 2011), (Dasilva et al., 2019), (Radulović et al., 2016), (Souza & Duarte, 2015), (Novitra et al., 2021), (Ferrarelli & Iocchi, 2021), Rodriguez, Veen and Anjewierden, 2020), Maison *et al.*, 2021), Djudin, 2021), (Putranta, Supahar, et al., 2021), (Santos & Corbi, 2019), (Kolçak et al., 2014), (H. K. E. Stadermann & Goedhart, 2021), Rochman *et al.*, 2017), Rahmat *et al.*, 2023), bertson *et al.*, 2017), (Chang et al., 2015), (K. Stadermann & Goedhart, 2020), (Jabaliah et al., 2021), (Agyei et al., 2019), (Toenders et al., 2017b), (Chang et al., 2015), (Peres et al., 2020)	Improvement of Students' Conceptual Understanding	24
(Cwik & Singh, 2021), Maison *et al.*, 2021), (Maison et al., 2020), (Kang & Seo, 2021), (Toenders et al., 2017a), (Sujanem & Putu Suwindra, 2023), (Marušić & Sliško, 2012), Apriyanti *et al.*, 2020), (Parcerisas *et al.*, 2022)	Increase in motivation and interest	9
(Cai et al., 2021), Samsudin *et al.*, 2020), (Lisana & Suciadi, 2021)	Increase in self-efficacy	3
(Gunawan et al., 2019), d Kuswanto, 2019), *t al.*, 2020), (Mohottala, 2013),	Improvement of critical thinking skills	3

Autors	Research Results	Number of Articles
(Suprapto, Ibisono and Mubarok, 2021, (Purba & Hwang, 2018), (Ahamad et al., 2021)	Improvement in academic performance	3
(Arista & Kuswanto, 2018), (Putranta, Supahar, et al., 2021)	Improvement of Learning Independence	2
Shabrina and Kuswanto, 2018), (Rokhmat et al., 2019),	Improvement in problem-solving skills	2
Chandra and Watters, 2012)	Improvement in students' performance in knowledge	1
Chandra and Watters, 2012)	complex reasoning skills	1
Shabrina and Kuswanto, 2018)	Improvement in creative thinking skills	1
(Liliarti & Kuswanto, 2018)	Improvement of diagrammatic representation competence	1
(Pulgar et al., 2022)	Collaboration with friends (strong relationships) has a positive impact on students' physics grades.	1
(Capone et al., 2017),	Improvement of Student Performance and Memory Retention	1
(H. K. E. Stadermann & Goedhart, 2021),	Increasing curiosity	1
(Hasanah, 2020)	Overcoming students' misconceptions about	1
(Batlolona & Diantoro, 2023)	Improvement of creative skills	1
(Rahmasari & Kuswanto, 2023)	Improving mathematical representation skills	1
Rizki *et al.*, 2024)	Improvement in communication	1

The Role of Teachers and Teachers Training

Teachers play an important role in 21st-century physics education by applying modern approaches such as ecological interventions, social practices, and the Nature of Science (NOS) to clarify concepts and enhance students' curiosity. Through technology-based methods such as Wiki and interaction-based learning (CKT-E), teachers can encourage students to think critically, solve problems, and collaborate. Continuous training helps

teachers adapt learning strategies, increase student engagement, and ensure that physics education is relevant in the digital era.

Table 6. The Role of Teachers and Teacher Training

Autors	The Role and Training of Teachers	Learning Model	Research Results
(Stadermann and Goedhart, 2021)	Ecological intervention approach.	NOS-based model (Nature of Science) in quantum physics education.	Using NOS to Clarify Concepts: Most teachers felt that discussing the role of scientific models was important to understanding quantum physics concepts. Discussing Controversies in Science: Some teachers acknowledged that discussing interpretations of quantum physics could increase curiosity.
(Kang and Seo, 2021)	Social practice theory approach	Content Explanation Emphasis Participatory Learning Emphasis Independent First-Hand Experience Emphasis	Encourage student engagement in learning by connecting physics models to everyday phenomena. Professional Development: Teachers learn new technologies, develop innovative teaching methods, and gain motivation to improve teaching practices
(Robertson et al., 2017),	A qualitative approach that aims to explore and analyze content knowledge for teaching energy (Content Knowledge for Teaching Energy, abbreviated as CKT-E).	Centered on teacher-student interaction-based teaching.	Teachers use CKT-E to interact with students, especially in interpreting their ideas and responding to them.
(Mohottala, 2013)	Based on collaborative and technology-based learning.	JiTT based Wiki	Active involvement and collaborative interaction through contributions on Wiki pages. critical thinking and solving problems independently without focusing solely on the final answer

Evaluation of Physics Learning

Various approaches have been used in evaluating physics learning to improve the quality of student learning outcomes. HOTS-based instruments effectively improve students' analytical, evaluative and creative abilities (Suprapto et al., 2020), while the social network approach (SNA) shows that student collaboration in face-to-face learning has a positive impact on physics grades (Pulgar et al., 2022) . Validated diagnostic tests help improve students' conceptual understanding (Kolçak et al., 2014), while technology-based e-assessments, such as the MySQL system, are used to measure students' interest in physics (Maison et al., 2020). In addition, identifying students' cognitive styles allows for more personalized and effective learning (Grebenev et al., 2014).

Table 7. Evaluation of Physics Learning

Autors	Development and Creation of Evaluation	Research Result
(E. Suprapto et al., 2020)	HOTS instrument development-based approach	Students' higher order thinking abilities (HOTS) increase: This instrument allows students to hone analytical, evaluative, and creative skills. HOTS questions are effective for measurement: HOTS-based questions allow teachers to evaluate students' abilities more thoroughly
Pulgar *et al.*, 2022),	Social Network Approach (Social Network Analysis - SNA) and Instrument development	Collaboration with friends (strong relationships) has a positive impact on students' grades in physics. Development of Social Interaction: Collaboration networks became denser from semester 1 to semester 2, especially as students returned to face-to-face learning and had more opportunities to build
(Kolçak et al., 2014)	Experimental Approach to Diagnostic Test Development. Instrument Validation	Increased Understanding of Concepts:
(Maison et al., 2020)	The approach used is a technology-based e-assessment development approach.	The main result of this research is the development of a MySQL-based e-assessment system to measure students' interest in learning
(Grebenev et al., 2014)	Identifying students' cognitive styles to create more personalized and effective physics learning	Concluded that students can be grouped into four cognitive style categories (field-impulsive dependent, field-reflective dependent, field-impulsive independent, field-reflective

Autors	Development and Creation of Evaluation	Research Result
	Method for Determining Student Cognitive Style based on tests and observations	independent). This grouping allows for more personalized and effective teaching in physics teaching

Physics Material

This document presents a few articles discussing various topics in physics. The material with the most articles is Renewable Energy and Particle Physics, each with 8 articles, followed by Rectilinear and Parabolic Motion and Thermodynamics (Heat and Energy) which has 7 articles. Topics such as Electricity and Magnetism and Elasticity (Hooke's Law) received moderate attention with 6 and 5 articles respectively. However, some materials such as Planetary Motion (Kepler), Solar Energy (Solar Panels), Friction Force, Newton's Laws and Momentum, Deformation of Solid Objects, and Sound Waves only have 2 articles. Quantum Physics and Planetary Motion are the topics least discussed with only 1 article each. This data shows the focus of research on certain themes and the need for further exploration of topics with limited articles for an even understanding of physics.

Table 8. Physics Material

No	Physics Material	Number of Articles
1	Renewable energy	8
2	Particle Physics	8
3	Straight and Parabolic Motion	7
4	Thermodynamics (Heat and Energy)	7
5	Thermodynamics (Heat and Energy)	6
6	Electricity and Magnetism	6
7	Elasticity (Hooke's Law)	5
8	Oscillation and Frequency	5
9	Planetary Motion (Kepler)	2
10	Solar Energy (Solar Panels)	2
11	Friction Force	2
12	Newton's Laws and Momentum	2
13	Deformation of Solids	2
14	Sound Waves	2
15	Quantum Physics	1
16	Planetary Motion	1

Research methods

Research in the field of physics applies various methods according to the objectives and characteristics of the topic being studied. The quasi-experimental method was most dominant with 10 articles, showing a preference for partial control of variables. Experimental methods were applied in 7 articles, confirming the importance of full control of variables. Quantitative methods were used in 8 articles for statistical data processing, while qualitative methods were adopted in 5 articles to explore phenomena in more depth. Mixed methods were applied in 6 articles, combining quantitative and qualitative approaches, while Research and Development (R&D) methods were used in 5 articles to

develop learning products or instruments. This variety of methods reflects the flexibility and depth of analysis in physics education research.

Table 9. Research Methods

No	Research Methods	Number of Articles
1	Quasi-Experimental Method	10
2	Experimental Method	7
3	Qualitative Research Methods	5
4	Quantitative Research Methods	8
5	Mixed-Methods	6
6	Research and Development (R&D)	5

R1. What are the latest innovations in physics learning in the 21st century? Key innovations include: simulation and VR, digital applications (Getsmart, PhET, ViPhyLab), PBL, digital tools (Tinkercad, Arduino Uno, IoT), game-based learning, flipped classroom & hybrid learning, as well as inquiry and STEM-based learning. R2. How does physics education play a role in supporting technological development and innovation in the digital era? Increase scientific understanding, prepare students for the Industrial Revolution 4.0, develop critical thinking skills, encourage the use of AI and digital tools, and increase student interest in STEM fields. R3. How effective is the physics teacher training program in improving pedagogical skills and mastery of the material? Teacher training involves NOS & ecological intervention approaches, technology in teaching (Wiki, CKT-E), HOTS-based evaluation, as well as social approaches to online and face-to-face learning. R4. What physics learning evaluations are carried out in the 21st century? Evaluation uses HOTS instruments, Social Network Analysis (SNA), diagnostic tests, technology-based e-assessment, and identification of students' cognitive styles to increase learning effectiveness.

The results and discussion should be presented in the same part, clearly and briefly. Results can be presented in figures, graphs, tables and others that make the reader understand easily. The discussion part should contain the benefit of the research result, not the repeat result part. The results and discussion part can be written in the same part to avoid the extensive quotation. Tables or graphs must present different results. The results of data analysis must be reliable in answering research problems. References to the discussion should not repeat the references in the introduction. Comparisons to the findings of previous studies must be included.

CONCLUSION

Physics learning in the 21st century continues to develop with various innovations and approaches that support improving the quality of education. Research shows that the use of technology-based instruments, such as e-assessment, simulation, and virtual reality, can increase students' understanding of concepts and their interest in learning. Approaches such as HOTS, PBL, and STEM encourage critical thinking, problem solving, and creativity skills that are relevant to 21st century needs. In addition, student collaboration through a social networking approach has been proven to have a positive impact on learning outcomes. The variety of research methods, including quasi-experimental, experimental, and R&D, reflects flexibility in exploring and developing physics learning. However, the distribution of research topics is still uneven, with some themes such as renewable energy and particle physics being discussed more frequently than quantum

physics and planetary motion. This shows the need to focus more on themes that receive less attention for the equitable development of physical science.

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