JPPIPA 11(3) (2025)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Interactive Web-Based Modern Physics Learning Media with PjBL Model to Improve Scientific Attitudes: A Systematic Review

Aris Doyan[1*], Susilawati[1], Ahmad Harjono[1], Syarful Annam[2,4], Muhammad Ikhsan[3], Nuraini Rachma Ardianti[3], Syamsul Hakim[5]

[1] Department of Physics Education, Universitas Negeri Mataram, Lombok, Indonesia.
[2] Elementary School Teacher Education Study Program, STKIP Taman Siswa, Bima, Indonesia.
[3] Balai Publikasi Indonesia, Mataram, Indonesia.
[4] Deparment of Science Education, Universitas Negeri Makassar, Makassar, Indonesia.
[5] SMAN 1 Pringgarata, Lombok Tengah, Indonesia.

Received: January 18, 2025
Revised: February 24, 2025
Accepted: March 25, 2025
Published: March 31, 2025

Corresponding Author:
Aris Doyan
aris_doyan@unram.ac.id

DOI: 10.29303/jppipa.v11i3.10440

Abstract: Scientific attitude requires mastery of processes that include science process skills, namely the ability to carry out an action concept, theory, and principle, law in the form of facts or evidence. Scientific attitude can be facilitated through learning with a Project Based Learning (PjBL) model and interactive web. This research aims to identify and analyze research trends of modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. This research method is descriptive and analytical. The data used in this research was obtained from documents indexed by Google Scholar from 2015-2024 using Publish or Perish and Dimension.ai. Research procedures use PRISMA guidelines. The data analysis method uses bibliometric analysis assisted by VOS viewer software. The results of the analysis show that research trend indexed by Google Scholar from 2015 to 2024 has experienced a fluctuating increase. Where the research trend is with an increase in the number of publications every year, namely from 2015 to 2023. However, in 2024 the research trend on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude has decreased. There are many documents in the form of articles, proceedings, book chapters, edited, preprint and monograph books that discuss research about the trend. Key words that are often used in research of scientific attitude are critical thinking, scientific literacy, scientific approach, creativity, etc.

Keywords: Interactive web; Modern Physics; Project based learning; Scientific attitude

Introduction

Human resources are the main indicator of successful education. Good education will produce superior and competitive human resources. Basically, education is a conscious human effort to develop the potential of students by encouraging and facilitating students in the learning process. Learning is a process of behavioral change related to cognitive, affective and skills to become better (Santosa et al., 2021). The paradigm shift in the learning process requires teachers to be able to design creative and innovative learning by utilizing technology that is in line with the Industrial Revolution 4.0 Era. Learning activities are designed in

How to Cite:
Doyan, A., Susilawati, Harjono, A., Annam, S., Ikhsan, M., Ardianti, N. R., & Hakim, S. Interactive Web-Based Modern Physics Learning Media with PjBL Model to Improve Scientific Attitudes: A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, *11*(3), 30-39. https://doi.org/10.29303/jppipa.v11i3.10440

such a way that they can facilitate students to construct their own knowledge and apply it, practice skills, and expand the knowledge they have acquired during learning (Izzati et al., 2019). The industrial revolution 4.0 is in line with the demands of the 21st century and the government must prepare a strategy to face the era of globalization and respond to the demands of the 21st century (Stehle & Peters-Burton, 2019; Larson & Miller, 2011; González-Pérez & Ramírez-Montoya, 2022). This strategy is expected to produce individuals who are competent in technology and science so that they can advance the nation (Dewi Muliani & Citra Wibawa, 2019; Mynbayeva et al., 2015). It is known that the demands of the 21st century are the main things that must be considered, especially in the field of education to face future challenges (Geisinger, 2016; Kaufman, 2013). So, in other words the skills required in the 21st century must be mastered (DiCerbo, 2014; Fry & Seely, 2011; Griffin, 2017; Jang, 2016; Lambert & Gong, 2010; Sibille et al., 2010).

Education that is able to prepare students to be able to face technological advances is education with student-centered learning. Student-centered learning aims to build their cognitive structure through data, theories, or facts observed by students, especially in science learning. One of the objectives of the subject matter includes: as a means of fostering students' scientific attitudes; appreciating individual and group work; and developing reasoning skills in inductive and deductive analysis with scientific concepts and principles. Based on the objectives of science learning, the implementation process must be a means of training students to have a high scientific attitude. Scientific attitudes are included in the educational character that students must have, and the implementation of learning is expected to be able to train students' scientific attitudes. Scientific attitudes describe open-mindedness, curiosity, and an optimistic approach to failure as scientific training values (Amaliyah et al., 2024). One part of science is modern physics. Modern physics is one of the important courses in physics because it underlies several other advanced courses, including quantum physics, solid state physics, statistical physics and nuclear physics.

In general, the concept of modern physics includes the special theory of relativity, quantum theory for electromagnetic radiation and matter, hydrogen-like atoms, multielectron atoms, nuclear physics, and atomic systems (Knecht et al., 2020). Another factor is the still rare use of learning media in the Modern Physics course that can provide a better understanding of abstract materials. In science learning, there is one aspect that students must pay attention to, namely scientific attitudes. Scientific attitude requires mastery of processes that include science process skills, namely the ability to carry out an action concept, theory, principle, law in the form of facts or evidence, which includes the skills of observing, making hypotheses, making questions, predicting, designing experiments, using tools and materials, grouping, interpreting, applying concepts, and communicating. Students must have these abilities to be able to have a scientific attitude and work scientifically. Science learning must be taught comprehensively consisting of facts, concepts, principles, laws, and theories. This can be achieved by training students' scientific skills and attitudes. (Fitriansyah et al., 2021), One of the efforts to improve students' scientific attitude is by developing interactive web-based media using a model that can facilitate the improvement of scientific attitude of students. The learning model used is Project Based Learning (PjBL). Project-Based Learning (PjBL) is a form of learning that focuses on students. Students are actively involved in the learning process. Students' thinking skills in dealing with problems will be trained through PjBL. Students work together with others and reflect on what they have learned.

In addition, students can be active in the search and decision-making process by improving their practical thinking skills (Rossouw & Steenkamp, 2025). The use of learning models is very good when combined with the use of learning media (Risnawati et al., 2018). This is closely related to the use of information and communication technology which is increasingly developing rapidly as an effort to digitize education in the implementation of the independent curriculum. Information and Communication Technology (ICT)-based learning in the world of education cannot be separated from the needs of 21st century learning, especially in science learning (Darling-Hammond et al., 2020). One alternative that can be done is that learning media is integrated with technology, such as interactive web-based media. Through interactive website-based learning media, lecturers can monitor the learning process and development of students. This will help the learning evaluation process in Modern Physics courses (Mahulae et al., 2023). Therefore, this research wants to know the research trend of the development of modern physics learning media based on interactive web using the PjBL model to improve scientific attitude.

Method

This research method is descriptive and analytical, which aims to understand and describe research trends in the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. The data used in this study was

obtained from information sources indexed by Google Scholar using analytical tools such as Publish or Perish and Dimension.ai. To carry out a search on Google Scholar, keywords related to research trends on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. In this research, an analysis was carried out on 1,000 documents that had been indexed by Google Scholar between 2015 and 2024.

The Google Scholar database was chosen as a place to search for documents because Google Scholar applies consistent standards in selecting documents to be included in its index, and Google Scholar displays more documents than the top databases. Others, especially research in the field of education. To filter data that has been collected via Publish or Perish, researchers used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Result and Discussion

This research aims to describe research trends on modern physics learning media based on interactive web using the PjBL model to improve scientific attitude conducted from 2015 to 2024. Research documents on research trends are taken from documents from 2015 to 2024. Figure 1 is presented below regarding research trends on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. Figure 1 shows that the trend in research on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude experiencing increases and decreases. Where the research trend with an increase in the number of publications from 2015 to 2024 has increased. Where the research trend is with an increase in the number of publications every year, namely from 2015 to 2023. However, in 2024 the research trend has decreased. The increasing trend in research on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude caused by 21st century education has focused on improving scientific attitude.

In 2015 there were 56 publications related to the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude, then this will continue to increase to 931 publications in 2023. This increasing research trend provides a deeper understanding the problem which is low of scientific attitude in science learning and ways to solve that problem. Research is able to improve scientific attitude through various methods, one of them is Project Based Learning Model. Below are also table 1 presented research of modern physics learning media based on interactive web using the PjBL model to improve scientific attitude based on the type of publication.

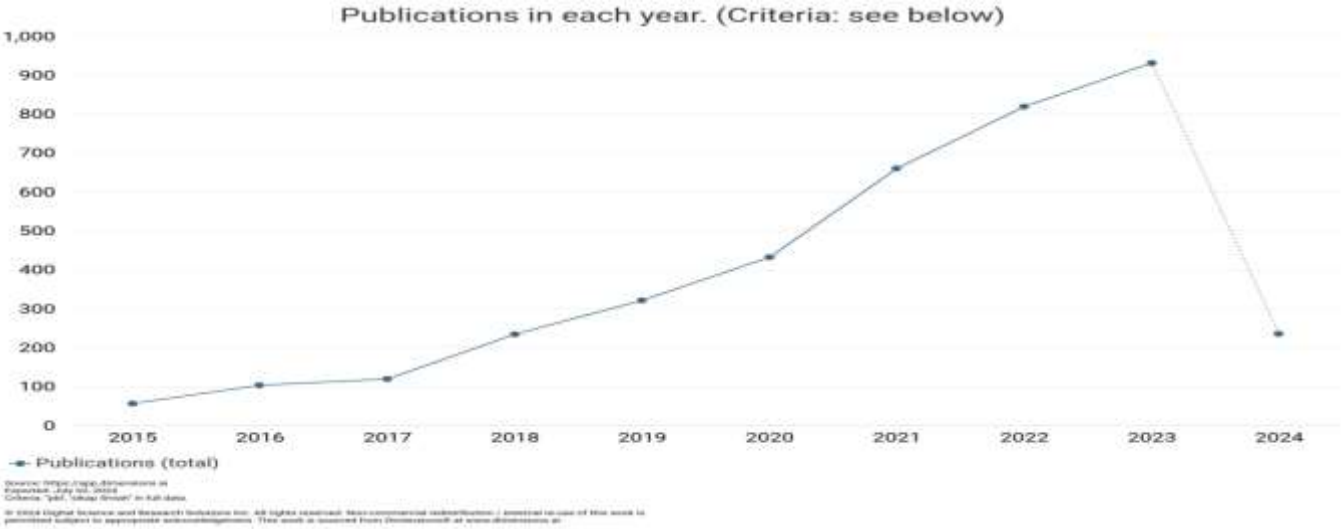

Figure 1. Research trends in modern physics learning media based on interactive web using the PjBL model to improve scientific attitude

Based on Table 1, it is known that research modern physics learning media based on interactive web using the PjBL model to improve scientific attitude from 2015 to 2024 contained in 6 types of publications. In the form of articles there were 3.85 documents, chapters as many as 7 documents, proceedings as many as 38 documents, edited books as many as 67 documents, preprint and monographs only 1 document each. Research trends in article form is the type of publication that contains the most research about modern physics learning media based on interactive web using the PjBL model to improve scientific attitude compared to other types of publications. Meanwhile, the type of publication contains the least amount of research results modern

physics learning media based on interactive web using the PjBL model to improve scientific attitude is preprint and monograph. Research conducted by Susilawati et al. (2024) states that an article is a complete factual essay of a certain length created for publication in online or print media (via newspapers, magazines or bulletins) and aims to convey ideas and facts that can convince and educate. These articles are usually published in scientific journals both in print and online (Suseno & Fauziah, 2020; Burns, 2023; Harvey, 2022).

Table 1. Trends in Modern Physics Learning Media Based on Interactive Web Using the PjBL Model to Improve Scientific Attitude Research Based on Publication Types

Publication Type	Publications
Article	3.85
Edited Book	67
Proceeding	38
Chapter	7
Preprint	1
Monograph	1

Below are also table 2 presented top ten (10) sources title trends in research on modern physics learning media based on interactive web using the PjBL model to improve scientific attitude which are often cited by other researchers related to this matter. Table 2 shows that the most widely published source of research trends on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude is the Jurnal Basicedu, namely 114 publications with 904 citations and an average citation of 7.93. Basicedu Journal is a journal which is managed by the Study Programe of Elementary Teacher Education in the Faculty of Education Universitas Pahlawan Tuanku Tambusai. Basicedu Journal publishes the result of literature studies as well as research result in the scope of education in general and basic education in particular. The study cover education and learning in basic education, guidance and counselling in basic education, the studies of five areas of elementary school namely mathematics, Indonesian language, science, social studies, and civics and additional fields such as English in basic education includes the study of local content studied in the scope of basic education. Below are also table 3 presented top ten (10) article title trends in research on modern physics learning media based on interactive web using the PjBL model to improve scientific attitude which are often cited by other researchers related to this matter.

Table 2. Top 10 Sources Title Trend of Modern Physics Learning Media Based on Interactive Web Using the PjBL Model to Improve Scientific Attitude Research in 2015-2024

Name	Publications	Citations	Citations Mean
Jurnal Basicedu	114	904	7.93
Jurnal Penelitian Pendidikan IPA	85	165	1.94
Edukatif Jurnal Ilmu Pendidikan	64	374	5.84
Advances in Social Science, Education and Humanities Research	61	60	0.98
Jurnal Ilmiah Profesi Pendidikan	54	30	0.56
AKSIOMA Jurnal Program Studi Pendidikan Matematika	38	77	2.03
Jurnal Pendidikan Teori Penelitian dan Pengembangan	37	70	1.89
Jurnal Cendekia Jurnal Pendidikan Matematika	37	172	4.65
Jurnal Ilmiah Pendidikan dan Pembelajaran	36	64	1.78
Journal of Education Action Research	35	60	1.71

Table 3 shows that research on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude that is widely cited by other researchers is about "PBLPOE: A Learning Model to Enhance Students' Critical Thinking Skills and Scientific Attitudes" which is 29.00. Then the research entitled "The Critical Thinking Skills and Scientific Attitudes of Pre-Service Chemistry Teachers Through the Implementation of Problem-Based Learning Model" was cited 19.00 times per year (Wahyudiati, 2022), Research by Hikmawati et al. (2021) entitled "The Effect of Problem-Based Learning Integrated Local Wisdom on Student Hots and Scientific Attitude" is also widely cited by other researchers, namely 8.33 per year. Sakliressy et al. (2021) and Cacciamani et al. (2022), in their research entitled "Students Scientific Attitude in Learning Physics Using Problem Based Learning Model with Experimental and Project Methods" was cited 8.33 per year. This research data is comparable to data on the increasing trend of research on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude model to improve scientific attitude in science learning from 2015 to 2024. This means that in that year, research related to it was continuously cited by other researchers. In the articles researched and written by these researchers, there are many terms related to modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. Below are presented ten (10) popular keywords related to modern physics learning

media based on interactive web using the PjBL model to improve scientific attitude.

Table 3. Top 10 Citations on Trend of Modern Physics Learning Media Based on Interactive Web Using the PjBL Model to Improve Scientific Attitude Research in 2015-2024

Cites/year	Year	Author	Title
29.00	2020	Fitriani, Apriza; Zubaidah, Siti; Susilo, Herawati; Al Muhdhar, Mimien Henie Irawati	PBLPOE: A Learning Model to Enhance Students' Critical Thinking Skills and Scientific Attitudes
19.00	2022	Dwi Wahyudiati	The Critical Thinking Skills and Scientific Attitudes of Pre-Service Chemistry Teachers Through the Implementation of Problem-Based Learning Model
8.33	2021	H Hikmawati, I W Suastra, K Suma, A.A. I A R Sudiatmika, R Rohani	The Effect of Problem-Based Learning Integrated Local Wisdom on Student Hots and Scientific Attitude
8.33	2021	M T Sakliressy, W Sunarno, F Nurosyid	Students Scientific Attitude in Learning Physics Using Problem Based Learning Model with Experimental and Project Methods
5.20	2019	Mustika Wati	The Effectiveness of Problem-Based Learning in Improving Students Scientific Literacy Skills and Scientific Attitudes
5.00	2019	I W Suastra and N P Ristiati	Developing Critical Thinking, Scientific Attitude, and Self-efficacy in Students through Project Based Learning and Authentic Assessment in Science Teaching at Junior High School
1.67	2021	A Dirmanto, E Cahyono,T Sulistyaningsih	The Effectiveness of Problem Based Learning on Acid-Base Materials to Improve Scientific Attitude and Creativity of SMA N 1 Comal Students
1.00	2019	A N Arini, H Hartono, K Khumaedi	Analysis of Problem Solving Skills and Students Scientific Attitudes through the Implementation of Problem Based Learning Module
1.00	2022	L Pujiarto	Problem-Based Physical Learning with Experimental and Demonstration Methods: Analysis with Scientific Attitude and Student Creativity
0.67	2021	Indah Wulandari, Muhammad Syukri, Murniati	Enhancing Senior High School Students' Scientific Attitude Through Problem Based Learning

Table 4. Keywords on Trend Modern Physics Learning Media Based on Interactive Web Using the PjBL Model to Improve Scientific Attitude Research in 2015-2024

Terms	Occurrences	Relevance
Scientific literacy	8	3.20
Scientific approach	10	1.29
Creativity	10	1.23
Critical thinking	9	1.19
Biology	12	1.18
Curriculum	13	1.02
Elementary school	12	0.91
Science process skill	25	0.74
Physics	37	0.70
Inquiry	32	0.56

Table 4 shows that the keywords that often appear related to research on the the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude are critical thinking 9 times with a level of 1.19. This indicates that scientific attitude are often researched together with critical thinking abilities (Ospankulova et al., 2025; Ogundiwin et al., 2024; Savelsbergh et al., 2016). Table 4 also shows that scientific literacy is also a keyword that appears frequently in research trends on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude, namely 8 times with a relevance of 3.20. Scientific attitude are often researched together with scientific literacy (Ploj Virtič, 2022; Queiruga-Dios et al., 2020; Thornhill-Miller et al., 2023).

Below are the visualization is accomplished by generating a landscape map, which offers a visual representation of subjects related to scientific studies. The outcomes of bibliometric mapping for the co-word network in articles related to the topic modern physics learning media based on interactive web using the PjBL model to improve scientific attitude are illustrated in Figure 2. Figure 2 shows the results of bibliometric keyword mapping on research trends on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. In Figure 2 there are 65 keyword items that are often used in research on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude from 2015 to 2024. Figure 2 also contains 6 clusters, where the first cluster is colored red and consists of 17 keyword items, namely creativity, critical thinking, curiosity, project, scientific literacy, etc.

The second cluster in green consists of 16 keyword items, namely inquiry, effectiveness, physics, achievment, etc. The third cluster in blue consists of 15 keyword items, namely biology, curriculum, development, implementation, etc. The fourth yellow cluster consists of 12 keyword items, namely ability, learning model, student, teacher, etc. The fifth purple cluster consists of 4 keyword items, namely activity, experiment, observation and science process skill. And the last cluster consists only 1 keyword item, namely analysis.

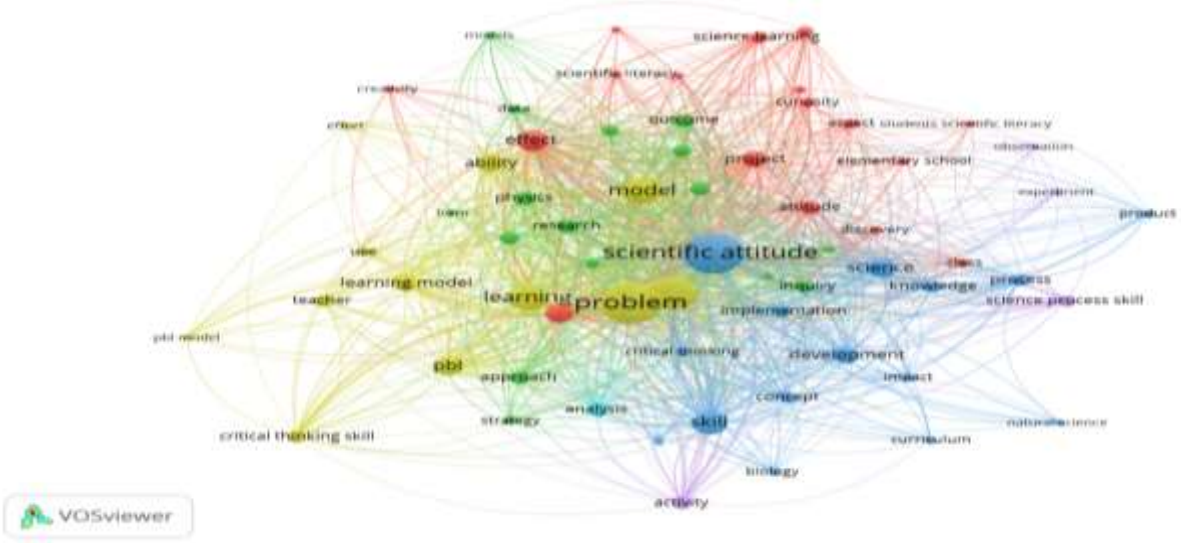

Figure 2. Network visualization on trend modern physics learning media based on interactive web using the PjBL model to improve scientific attitude research

Figure 2 above also shows that network visualization shows the network between the terms being visualized. Keywords classified into six clusters are arranged in a color chart showing the divisions that are connected to each other. The results of this analysis can be used to determine keyword research trends in the last year. This analysis shows several keywords that are often used in research on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. The more keywords that appear, the wider the visualization displayed. Below are also presented keywords regarding the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude based on overlay visualization (Purwaningsih et al., 2024; Hikmah & Jauhariyah, 2021; Susilawati et al., 2023).

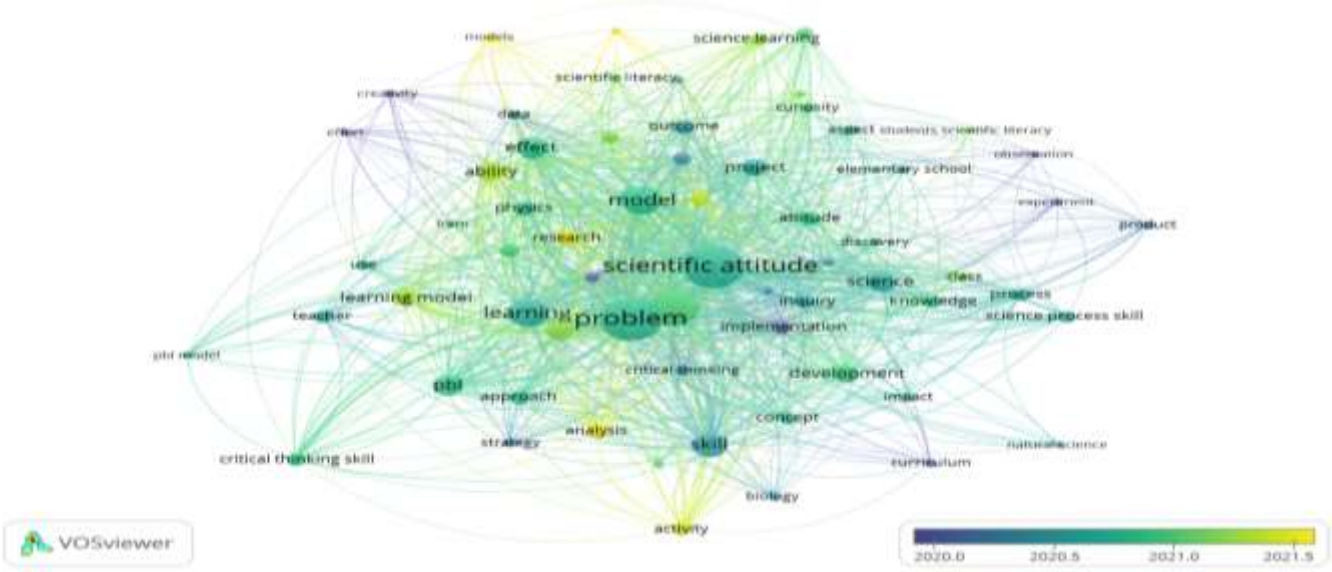

Figure 3. Overlay visualization on trend modern physics learning media based on interactive web using the PjBL model to improve scientific attitude research

Figure 3 shows the trend of keywords related to research on modern physics learning media based on interactive web using the PjBL model to improve scientific attitude in Google Scholar indexed journals from 2015 to 2024. Trends in the themes of writing articles related to the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude from the oldest to the newest year are marked with purple, blue themes, turquoise, dark green, light green and yellow. In the picture above you can see that the experiment, creativity, implementation, scientific approach, etc. This shows that these keywords were widely used by researchers in 2020. In 2021, the keywords that frequently appeared were critical thinking, scientific literacy, inquiry, PBL, etc.

Research on modern physics learning media based on interactive web using the PjBL model to improve scientific attitude is one area of research that has developed rapidly in recent years. The following also presents keywords for modern physics learning media based on interactive web using the PjBL model to improve scientific attitude research based on density visualization. Figure 4 shows density visualization. The density of research themes is shown in bright yellow. The brighter the colors of a theme, the more research is done. The fainter the color means the theme is rarely researched (Stamou, 2022; Pelowski et al., 2022). Faintly colored themes such as scientitfc approach, physics, scientific literacy are dimly colored keywords. This shows that these keywords can be used as a reference for further research. Doyan et al. (2023) and Bahtiar et al. (2023), stated that yellow indicates keywords that are currently and frequently used in research.

.

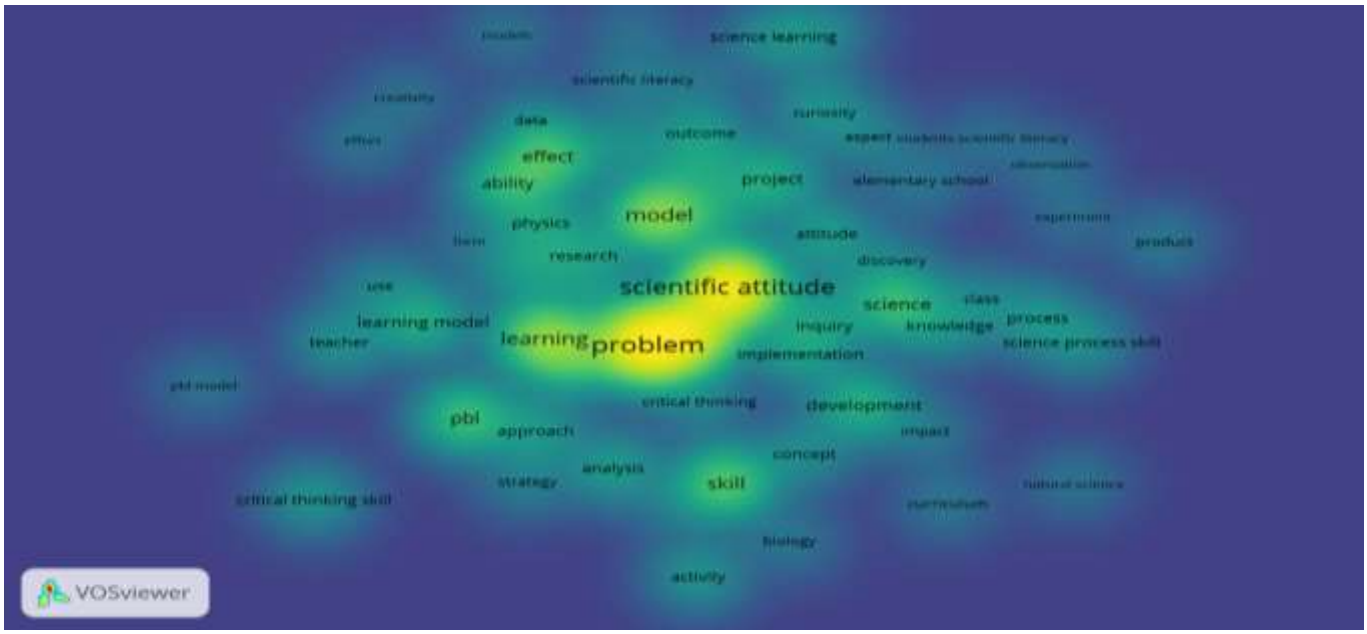

Figure 4. Density visualization on trend modern physics learning media based on interactive web using the PjBL model to improve scientific attitude research

Overall, research on modern physics learning media based on interactive web using the PjBL model to improve scientific attitude is important because it makes significant contributions to the 21st century education and PjBL model is a learning model that is able to facilitate scientific attitude. Scientific attitude are very important so that students are able to process information to solve problems both in learning and in real life. The research trend in modern physics learning media based on interactive web using the PjBL model to improve scientific attitude is expected to continue to develop in the next few years. This can be done by developing new combination of PjBL model with technology or other things like web interactive to facilitate students' scientific attitude, especially in modern physics (Almulla, 2020; Bereczki & Kárpáti, 2021; Rizaldi & Ziadatul Fatimah, 2023).

Conclusion

Research on trends in the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude has urgency high because of its potential to provide various benefits to 21st century education. The research trend on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude indexed by Google Scholar from 2015 to 2024 has experienced a fluctuating

increase. Where the research trend is with an increase in the number of publications every year, namely from 2015 to 2023. However, in 2024 the research trend on the modern physics learning media based on interactive web using the PjBL model to improve scientific attitude has decreased. There are many documents in the form of articles, proceedings, book chapters, edited, preprint and monograph books that discuss research about modern physics learning media based on interactive web using the PjBL model to improve scientific attitude. Key words that are often used in research of scientific attitude are critical thinking, scientific literacy, scientific approach, creativity, etc.

Acknowledgments
Acknowledgments are expressed by the researchers to the team so that researchers can complete research in the form of journal publications.

Author Contributions
Conceptualization, A. D.; methodology, S. ; validation, A. H.; formal analysis, S. A.; investigation, M. I.; resources, N. R. A.; data curation, S. H.: writing—original draft preparation, A. D.; writing—review and editing, S., A. H.: visualization, M. I., N. R. A., S. H. All authors have read and agreed to the published version of the manuscript. All authors contributed to writing this article.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

References

Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. *Sage Open*, *10*(3), 2158244020938702. https://doi.org/10.1177/2158244020938702

Amaliyah, N. I., Aznam, N., & Dewi, S. S. (2024). Analysis of Students' Scientific Attitude Through Experience Practicum Activities in Chemistry Learning. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 19–27. https://doi.org/10.29303/jppipa.v10i1.6068

Bahtiar, B., Yusuf, Y., Doyan, A., & Ibrahim, I. (2023). Trend of Technology Pedagogical Content Knowledge (TPACK) Research in 2012-2022: Contribution to Science Learning of 21st Century. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 39–47. https://doi.org/10.29303/jppipa.v9i5.3685

Bereczki, E. O., & Kárpáti, A. (2021). Technology-enhanced creativity: A multiple case study of digital technology-integration expert teachers' beliefs and practices. *Thinking Skills and Creativity*, *39*, 100791. https://doi.org/10.1016/j.tsc.2021.100791

Burns, C. S. (2023). The Issues with Journal Issues: Let Journals Be Digital Libraries. *Publications*, *11*(1), 7. https://doi.org/10.3390/publications11010007

Cacciamani, S., Cesareni, D., Fiorilli, C., & Ligorio, M. B. (2022). Teachers' Work Engagement, Burnout, and Interest toward ICT Training: School Level Differences. *Education Sciences*, *12*(7), 493. https://doi.org/10.3390/educsci12070493

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dewi Muliani, N. K., & Citra Wibawa, I. M. (2019). Pengaruh Model Pembelajaran Inkuiri Terbimbing Berbantuan Video Terhadap Hasil Belajar IPA. *Jurnal Ilmiah Sekolah Dasar*, *3*(1), 107. https://doi.org/10.23887/jisd.v3i1.17664

DiCerbo, K. (2014). Assessment and teaching of 21st century skills. *Assessment in Education: Principles, Policy & Practice*, *21*(4), 502–505. https://doi.org/10.1080/0969594X.2014.931836

Doyan, A., Susilawati, Purwoko, A. A., Ibrahim, Ahzan, S., Gummah, S., Bahtiar, & Ikhsan, M. (2023). Trend Synthesis Thin Film Research as Electronic Device (A Review). *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1155–1164. https://doi.org/10.29303/jppipa.v9i11.5764

Fitriansyah, R., Werdhiana, I. K., & Saehana, S. (2021). Pengaruh Pendekatan STEM dalam Model Inkuiri Terbimbing Terhadap Sikap Ilmiah dan Kerja Ilmiah Materi IPA. *Jurnal Ilmiah Pendidikan Fisika*, *5*(2), 225. https://doi.org/10.20527/jipf.v5i2.3598

Fry, S., & Seely, S. (2011). Enhancing Preservice Elementary Teachers' 21st-Century Information and Media Literacy Skills. *Action in Teacher Education*, *33*(2), 206–218. https://doi.org/10.1080/01626620.2011.569468

Geisinger, K. F. (2016). 21st Century Skills: What Are They and How Do We Assess Them? *Applied Measurement in Education*, *29*(4), 245–249. https://doi.org/10.1080/08957347.2016.1209207

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. *Sustainability*, *14*(3), 1493. https://doi.org/10.3390/su14031493

Griffin, P. (2017). Assessing and Teaching 21st Century Skills: Collaborative Problem Solving as a Case Study. In *Innovative Assessment of Collaboration* (pp.

113–134). Springer International Publishing. https://doi.org/10.1007/978-3-319-33261-1_8

Hallinger, P., & Chatpinyakoop, C. (2019). A Bibliometric Review of Research on Higher Education for Sustainable Development, 1998–2018. *Sustainability*, *11*(8), 2401. https://doi.org/10.3390/su11082401

Hallinger, P., & Nguyen, V.-T. (2020). Mapping the Landscape and Structure of Research on Education for Sustainable Development: A Bibliometric Review. *Sustainability*, *12*(5), 1947. https://doi.org/10.3390/su12051947

Harvey, L. (2022). Editorial: Lee Harvey Future for printed journals. *Quality in Higher Education*, *28*(3), 261–264. https://doi.org/10.1080/13538322.2022.2051233

Hikmah, N., & Jauhariyah, M. N. R. (2021). Meta-Analysis of Students' Critical Thinking Skills Improvement on Physics Learning. *Berkala Ilmiah Pendidikan Fisika*, *9*(2), 155. https://doi.org/10.20527/bipf.v9i2.10585

Hikmawati, H., Suastra, I. W., Suma, K., Sudiatmika, A. A. I. A. R., & Rohani, R. (2021). Effect of Problem-Based Learning Integrated Local Wisdom on Student Hots and Scientific Attitude. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 233–239. https://doi.org/10.29303/jppipa.v7iSpecialIssue.1118

Izzati, N., Tambunan, L. R., Susanti, S., & Siregar, N. A. R. (2019). Pengenalan Pendekatan STEM sebagai Inovasi Pembelajaran Era Revolusi Industri 4.0. *Jurnal Anugerah*, *1*(2), 83–89. https://doi.org/10.31629/anugerah.v1i2.1776

Jang, H. (2016). Identifying 21st Century STEM Competencies Using Workplace Data. *Journal of Science Education and Technology*, *25*(2), 284–301. https://doi.org/10.1007/s10956-015-9593-1

Kaufman, K. J. (2013). 21 Ways to 21st Century Skills: Why Students Need Them and Ideas for Practical Implementation. *Kappa Delta Pi Record*, *49*(2), 78–83. https://doi.org/10.1080/00228958.2013.786594

Knecht, A., Skawran, A., & Vogiatzi, S. M. (2020). Study of nuclear properties with muonic atoms. *The European Physical Journal Plus*, *135*(10), 777. https://doi.org/10.1140/epjp/s13360-020-00777-y

Lambert, J., & Gong, Y. (2010). 21st Century Paradigms for Pre-Service Teacher Technology Preparation. *Computers in the Schools*, *27*(1), 54–70. https://doi.org/10.1080/07380560903536272

Larson, L. C., & Miller, T. N. (2011). 21st Century Skills: Prepare Students for the Future. *Kappa Delta Pi Record*, *47*(3), 121–123. https://doi.org/10.1080/00228958.2011.10516575

Mahulae, P. S., Makahinda, T., Silangen, P. M., & Rampengan, A. M. (2023). Effectiveness of Project Based Learning Model in Learning Evaluation Course in Physics Education Study Programme. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 1077–1082. https://doi.org/10.29303/jppipa.v9iSpecialIssue.5891

Mynbayeva, A., Vishnevskaya, A., & Sadvakassova, Z. (2015). Diagnosis of Students Intellectual Potential on Pedagogical Specialties. *Procedia - Social and Behavioral Sciences*, *171*, 776–781. https://doi.org/10.1016/j.sbspro.2015.01.191

Ogundiwin, O. A., Adewumi, G. S., Olabisi, O. L., & Asaaju, O. A. (2024). The Effect of Active Review Strategy on Student's Attitude to Basic Science in Oyo State. *Indonesian Values and Character Education Journal*, *7*(1), 25–34. https://doi.org/10.23887/ivcej.v7i1.78201

Oltarzhevskyi, D. O. (2019). Typology of contemporary corporate communication channels. *Corporate Communications: An International Journal*, *24*(4), 608–622. https://doi.org/10.1108/CCIJ-04-2019-0046

Ospankulova, E., Maxutov, S., Lathrop, R., Anuarova, L., & Balta, N. (2025). Science students' attitudes, learning, critical thinking and engagement in project-based learning. *Cogent Education*, *12*(1), 2445358. https://doi.org/10.1080/2331186X.2024.2445358

Pelowski, M., Spee, B. T. M., Arato, J., Dörflinger, F., Ishizu, T., & Richard, A. (2022). Can we really 'read' art to see the changing brain? A review and empirical assessment of clinical case reports and published artworks for systematic evidence of quality and style changes linked to damage or neurodegenerative disease. *Physics of Life Reviews*, *43*, 32–95. https://doi.org/10.1016/j.plrev.2022.07.005

Ploj Virtič, M. (2022). Teaching science & technology: Components of scientific literacy and insight into the steps of research. *International Journal of Science Education*, *44*(12), 1916–1931. https://doi.org/10.1080/09500693.2022.2105414

Purwaningsih, S., Dani, R., & Yuversa, E. (2024). Designing a Virtual Lab-based Learning Module Integrated with Project-based Learning for Modern Physics. *AL-ISHLAH: Jurnal Pendidikan*, *16*(1), 406–415. https://doi.org/10.35445/alishlah.v16i1.4495

Queiruga-Dios, M. Á., López-Iñesta, E., Diez-Ojeda, M., Sáiz-Manzanares, M. C., & Vázquez Dorrío, J. B. (2020). Citizen Science for Scientific Literacy and the Attainment of Sustainable Development Goals

in Formal Education. *Sustainability*, *12*(10), 4283. https://doi.org/10.3390/su12104283

Risnawati, Amir, Z., & Sari, N. (2018). The development of learning media based on visual, auditory, and kinesthetic (VAK) approach to facilitate students' mathematical understanding ability. *Journal of Physics: Conference Series*, *1028*, 012129. https://doi.org/10.1088/1742-6596/1028/1/012129

Rizaldi, D. R. & Fatimah, Z.. (2023). Efforts to Create an Interesting and Meaningful Physics Learning Environment with a Project-Based Learning Model. *AMPLITUDO : Journal of Science and Technology Inovation*, *2*(1), 7–13. https://doi.org/10.56566/amplitudo.v2i1.11

Rossouw, M., & Steenkamp, G. (2025). Developing the critical thinking skills of first year accounting students with an active learning intervention. *The International Journal of Management Education*, *23*(1), 101086. https://doi.org/10.1016/j.ijme.2024.101086

Sakliressy, M. T., Sunarno, W., & Nurosyid, F. (2021). Students Scientific Attitude in Learning Physics using Problem Based Learning Model with Experimental and Project Methods. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *10*(1), 59. https://doi.org/10.24042/jipfalbiruni.v10i1.8347

Santosa, T. A., Razak, A., Lufri, L., Zulyusri, Z., Fradila, E., & Arsih, F. (2021). Meta-Analisis: Pengaruh Bahan Ajar Berbasis Pendekatan STEM Pada Pembelajaran Ekologi. *Journal of Digital Learning and Education*, *1*(01), 1–9. https://doi.org/10.52562/jdle.v1i01.24

Savelsbergh, E. R., Prins, G. T., Rietbergen, C., Fechner, S., Vaessen, B. E., Draijer, J. M., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review*, *19*, 158–172. https://doi.org/10.1016/j.edurev.2016.07.003

Sibille, K., Greene, A., & Bush, J. P. (2010). Preparing Physicians for the 21st Century: Targeting Communication Skills and the Promotion of Health Behavior Change. *Annals of Behavioral Science and Medical Education*, *16*(1), 7–13. https://doi.org/10.1007/BF03355111

Stamou, L. (2022). Cartography and Art: A Comparative Study Based on Color. *Geographies*, *2*(1), 87–110. https://doi.org/10.3390/geographies2010007

Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student 21st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education*, *6*(1), 39. https://doi.org/10.1186/s40594-019-0192-1

Suseno, B. A., & Fauziah, E. (2020). Improving Penginyongan Literacy in Digital Era Through E-Paper Magazine of Ancas Banyumasan. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3807680

Susilawati, Doyan, A., Rokhmat, J., & Muliyadi, L. (2023). Analysis Validation of Modern Physics Learning Media Based on Smartphone Integrated Project Based Learning to Improve Students' Creativity and Scientific Literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7888–7892. https://doi.org/10.29303/jppipa.v9i10.5404

Susilawati, Harjono, A., & Firdaus, F. (2024). Improving Students' Science Process Skills Through Project Based Learning Models: A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, *10*(10), 711–720. https://doi.org/10.29303/jppipa.v10i10.9381

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J.-M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. *Journal of Intelligence*, *11*(3), 54. https://doi.org/10.3390/jintelligence11030054

Wahyudiati, D. (2022). Critical Thinking Skills and Scientific Attitudes of Pre-Service Chemistry Teachers Through the Implementation of Problem-Based Learning Model. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 216–221. https://doi.org/10.29303/jppipa.v8i1.1278

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0