JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

Bibliometric Analysis of Physics Learning Research Trends using Socio-scientific Issues in the Last 10 Years

Novita Wulandari[1,*], Jumadi Jumadi[2], Silvia Laeli[3], Heru Kuswanto[4]

Department of Physics Education, Universitas Negeri Yogyakarta, Indonesia
*Email novitawulandari.2023@student.uny.ac.id

ARTICLE INFO

Keywords:
Bibliometric
Physics
Learning
Socio-scientific Issues

ABSTRACT

Purpose-Contextual learning approaches play an important role in supporting the needs of 21st-century Education. Socioscientific issues (SSI) orientation is one form of contextual approach that is relevant to physics learning. This study aims to see research trends on socioscientific issues in the period 2014 to 2023. The main focus of this study is to understand the role of SSI in supporting the development of 21st-century skills.

Methodology-This type of research includes literature using bibliometric analysis methods. The data analysis process used VOSviewer software to obtain a network visualization that states the relationship between keywords.

Findings-The synthesis results refer to the distribution of articles per year, research themes, countries of affiliation, and authors. One hundred articles were successfully identified through the Scopus database, showing that research on socioscientific issues fluctuates yearly. Based on bibliometric analysis, the keyword "socioscientific issues" is closely related to students' scientific literacy attitudes and abilities. This relationship highlights the importance of socioscientific issues in learning, especially in helping students understand scientific issues relevant to everyday life.

Significance-Research also shows that integrating sociocultural issues in learning plays an important role in supporting the development of 21st-century skills. Therefore, the relevance of Socioscientific Issues can be applied by teachers in physics learning.

Received 9 December 2024; Received in revised form 13 December 2024; Accepted 15 February 2024
Jurnal Eduscience (JES) Volume 12 No. 1 (2025)
Available online xx February 2025

INTRODUCTION

The 21st-century Education demands fundamental changes in learning approaches to face increasingly complex global challenges. 21st-century skills, such as critical thinking, creativity, communication, collaboration, and digital literacy, are core competencies that students must master (Purwanto et al., 2023). Mastery these skills is necessary so students can adapt to increasingly complex global dynamics. In addition, students also need to be able to solve real problems and contribute to a changing society (Ariza et al., 2021).

Socioscientific Issues (SSI) approach contributes significantly to developing 21st-century skills (Zeidler et al., 2019). Integrating real issues relevant to life can encourage students to think critically, creatively, and collaboratively (Benek & Akcay, 2022). This is driven by the need for individuals who can adapt, solve problems, and innovate amidst rapid changes in technology and social roles. Socioscientific Issues (SSI) in 21st-century Education equips students with theoretical knowledge and practical skills that can be applied in real life.

There is a close relationship between Socioscientific issues and scientific problems. For example, in a discussion about the use of renewable energy, students not only learn about the technology used but also consider its impact on local communities, local culture, and the sustainability of the ecosystem. An increasingly close relationship between society and science has emerged due to advances in technology and science that have greatly influenced people's lives. One of the main focuses of Education is instilling problem-solving skills (Ulger, 2018). The aim of Education is not only to provide theoretical knowledge to students but also to give them the ability to relate it to real-world situations (Simeon et al., 2022). To achieve this goal, a relevant and contextual learning approach is needed. This will help students understand the relationship between science and the problems facing society.

One practical approach to realizing contextual learning is socioscientific problem-based learning (Putri et al., 2018). Socioscientific Issues (SSI) is a learning approach that uses science-related social issues as a context for exploring scientific concepts (Cebesoy & Rundgren, 2023). This approach offers a framework that allows students to explore fundamental science-related issues in a social context. Students can be trained to be critical, analytical, and think critically, which makes learning more meaningful (Maksum et al., 2021; Dewi & Primayana, 2019). This can help students develop higher-order thinking skills critical for solving complex problems. In addition, this method meets the needs of modern society, where people need to be able to participate in discussions and decision-making on significant scientific issues (Smith et al., 2022). As a result, socioscientific problem-based learning improves students' understanding of science and helps them overcome real-life problems.

The social-scientific issue approach is an innovation in science education related to the world's problems today. Socioscientific Issues are based on the idea that science interacts with many social, cultural, and moral aspects of society (Li & Guo, 2021). The theories underlying Socioscientific Issues are usually complex, multidisciplinary, and controversial. This is relevant to physics learning, which presents fundamental phenomena and real observations (Diani et al., 2023). Socioscientific Issues can present a real physics context that can develop understanding and train critical thinking and problem-solving skills (Jariah & Aminatun, 2022; Anisa et al., 2020). Students are directed to learn how science can be used in the real world, which is full of changes and problems (Uus et al., 2022). Students can connect deeper physics learning to complex environments with socioscientific issues (Amos et al., 2020). This process helps students understand that science has social and moral implications.

Socioscientific is applied in learning by interpreting social issues in society that are related to science in a social aspect (Troy D. Sadler et al., 2016). Socioscientific Issues emphasize local, national, and global social phenomena (Tal & Ginosar, 2024). The research results show that learning based on sociocultural issues can improve student learning outcomes (Genisa, 2020). Socioscientific learning allows students to make direct observations of social and environmental problems. The influence of scientific background analysis provides students with a complex picture of local, social, and global issues.

Analyzing trends in research publications can help identify gaps in current literature. The novelty of the analysis of the development of Socioscientific Issues in this study can guide future studies in physics learning. Bibliometrics is a set of tools that researchers can use to analyze published data and research fields that apply mathematical and statistical techniques to study publication patterns in the distribution of information (Lyu et al., 2023). Bibliometrics effectively provides data sets that can be used to improve the quality of research (Baas et al., 2020). This study uses bibliometric mapping to determine research trends on Socioscientific Issues in physics learning. The research questions in this study are described as follows:

1. How has the distribution of research publications in physics learning that use "Socioscientific Issues" been distributed over the past ten years?

2. How has the number of documents distributed based on country affiliation on "Socioscientific Issues" in the past ten years been?
3. How has the accumulation of author citations in the "Socioscientific Issues" field been distributed in the past ten years?
4. What is the role of "Socioscientific Issues" on physics learning practices and learning outcomes?

METHODOLOGY

This type of research is library research using bibliometric analysis methods. Bibliometric analysis was chosen because of its ability to analyze and visualize scientific publication patterns quantitatively, thus providing a broad picture of research trends, collaborations between authors, and the influence of journals or institutions in a field. Bibliometric analysis is carried out by looking at the distribution of publications to evaluate the contribution of articles to the advancement of knowledge in various literatures using a statistical approach. It can provide a broader understanding of the entire scientific discipline. In general, the bibliometric analysis stages are presented in Figure 1.

Figure 1. Bibliometric Analysis Stages

The data collection technique in this study used secondary data in the form of articles. The defined keyword stage begins with data collection using "social scientific issues" in physics learning with the categories of articles, titles, and keywords from 2014-2023. Data collection was carried out using Publish or Perish (PoP) because it can set search parameters according to the inclusion criteria that have been set. The stage of getting initial search results obtained 100 articles that met the criteria. The search results were stored in Research Information System (RIS) format. Then, the data was imported into Mendeley desktop software to continue sorting the search results. The sorted data was re-checked for metadata one by one. The collecting data information stage carried out metadata analysis that needed to be completed, including article identity such as abstract, keywords, year, volume, and publication issue. RIS format data edited by Mendeley desktop was further analyzed using VOSviewer software. The selection of VOSviewer was based on the reason that the software has a feature that can create a visualization map of the relationship between keywords, authors, or institutions based on bibliometric data. This is suitable for analyzing trends in this study.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion (IN)	Exclusion (EX)
Research relevance	IN1: Relevant research includes “Socioscientific Issues" in the title, keywords, and abstract	EX1: Do not include "socioscientific issue" in the title, keywords, and abstract
Publication period	IN2: Articles published from the 2014-2023 period	EX2: Publication under 2014
Language	IN3: Article reviews are in English	EX3: The article review is not in English
Document Type	IN4: The type of publication is an article	EX4: Type of non-article publication (conference, book, etc.)
Document Access	IN5: The article is open access	EX5: The article is not open-access

Article data that met the criteria is exported in RIS format and inputted into VOSviewer. The analysis process is carried out using the VOSviewer application because the software can visualize and explore the results of bibliometric studies. The data analysis technique in this study refers to the results of bibliometric mapping from the VOSviewer application, which applies co-occurrence calculations. Co-occurrence analysis

reveals research topics statistically, with the provision that the more frequent the pairing between two keywords, the closer the relationship between the keywords. Analysis using VOSviewer extracts the title and abstract of the article obtained using the binary counting method so that each word found interpreting the relationship with the topic will be considered the same. The minimum number of occurrences is five terms, meaning that the words that will be displayed are words that have a relationship of 5. The results of the bibliometric analysis obtained are then interpreted to answer the objectives of this study.

FINDINGS

Based on data collection using Publish or Perish, 100 articles meet the criteria for analysis in this study. These criteria include research relevance, publication period, language, document type, and access. Table 2 presents the results of the top twenty-five samples selected based on the most citations.

Table 2. Results of Data Collection

No.	Author, Publication Country	Title	Journal
1.	(Lederman, 2014) United States	Nature of Science, Scientific Inquiry, and Socioscientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry	Science and Education
2.	(T D Sadler, 2016) United States	Learning science content through Socioscientific Issues-based instruction: A multi-level assessment study	International Journal of Science Education
3.	(Zangori, 2017) United States	Student development of model-based reasoning about carbon cycling and climate change in a Socioscientific Issues unit	Journal of Research in Science Teaching
4.	(Jho, 2014) South Korea	The Relationship of Science Knowledge, Attitude and Decision Making on Socioscientific Issues: The Case Study of Students' Debates on a Nuclear Power Plant in Korea	Science and Education
5.	(Ke, 2021) United States	Developing and Using Multiple Models to Promote Scientific Literacy in the Context of Socioscientific Issues	Science and Education
6.	(Hancock, 2019) United States	Selecting Socioscientific Issues for Teaching: A Grounded Theory Study of How Science Teachers Collaboratively Design SSI-Based Curricula	Science and Education
7.	(Tsai, 2018) Taiwan	The effect of online argumentation of Socioscientific Issues on students' scientific competencies and sustainability attitudes	Computers and Education
8.	(Iordanou, 2014) Turkey	Developing pre-service teachers' evidence-based argumentation skills on Socioscientific Issues	Learning and Instruction
9.	(Khishfe, 2017) Lebanon	Students' understanding of the nature of science and their arguments in the context of four Socioscientific Issues	International Journal of Science Education
10.	(Ke, 2020) United States	Students' perceptions of socioscientific issue-based learning and their appropriation of epistemic tools for systems thinking	International Journal of Science Education
11.	(Chang, 2016) Taiwan	A comparison study of augmented reality versus interactive simulation technology to support student learning of a socioscientific issue	Interactive Learning Environments

No.	Author, Publication Country	Title	Journal
12.	(Byrne, 2014) Swedia	Climate Change and Everyday Life: Repertoires children use to negotiate a socioscientific issue	International Journal of Science Education
13.	(Karpudewan, 2018) Malaysia	Changes in Primary Students' Informal Reasoning During an Environment-Related Curriculum on Socioscientific Issues	International Journal of Science and Mathematics Education
14.	(Martín-Gámez, 2018) Spain	Understanding argumentation about Socioscientific Issues on energy: a quantitative study with primary pre-service teachers in Spain	Research in Science and Technological Education
15.	(Lund, 2019) Norwegia	Direct and indirect effects of textual and individual factors on source-content integration when reading about a socioscientific issue	Reading and Writing
16.	(Christenson, 2015) Swedia	A framework for teachers' assessment of socioscientific argumentation: An example using the GMO issue	Journal of Biological Education
17.	(Kammerer, 2021) Germany	The Role of Internet-Specific Justification Beliefs in Source Evaluation and Corroboration During Web Search on an Unsettled Socioscientific Issue	Journal of Educational Computing Research
18.	(Gutierez, 2015) Philipina	Integrating Socioscientific Issues to enhance the bioethical decision-making skills of high school students	International Education Studies
19.	(Muis, 2021) Canada	Epistemic Emotions and Epistemic Cognition Predict Critical Thinking About Socioscientific Issues	Frontiers in Education
20.	(Nam, 2017) South Korea	Promoting argumentative practice in Socioscientific Issues through a science inquiry activity	Eurasia Journal of Mathematics, Science and Technology Education
21.	(Bryce, 2014) United Kingdom	Skepticism and doubt in science and science education: the complexity of global warming as a socioscientific issue	Cultural Studies of Science Education
22.	(Fensham, 2014) Australia	Skepticism and trust: Two counterpoint essentials in science education for complex Socioscientific Issues	Cultural Studies of Science Education
23.	(Stenseth, 2016) Norwegia	Investigating interest and knowledge as predictors of students' attitudes towards Socioscientific Issues	Learning and Individual Differences
24.	(Wiyarsi, 2019) Indonesia	Revisiting the scientific habits of mind scale for Socioscientific Issues in the Indonesian context	International Journal of Science Education
25.	(Wang, 2017) Taiwan	A longitudinal study of a cooperation-driven, socioscientific issue intervention on promoting students' critical thinking and self-regulation in learning science	International Journal of Science Education

This research is based on an article that examines the application of Socioscientific Issues in physics learning. Based on the analysis, 100 articles met the criteria in this research. The results were interpreted based on the results of network visualization and density. Figure 2 shows research publications on Socioscientific Issues from 2014 to 2023.

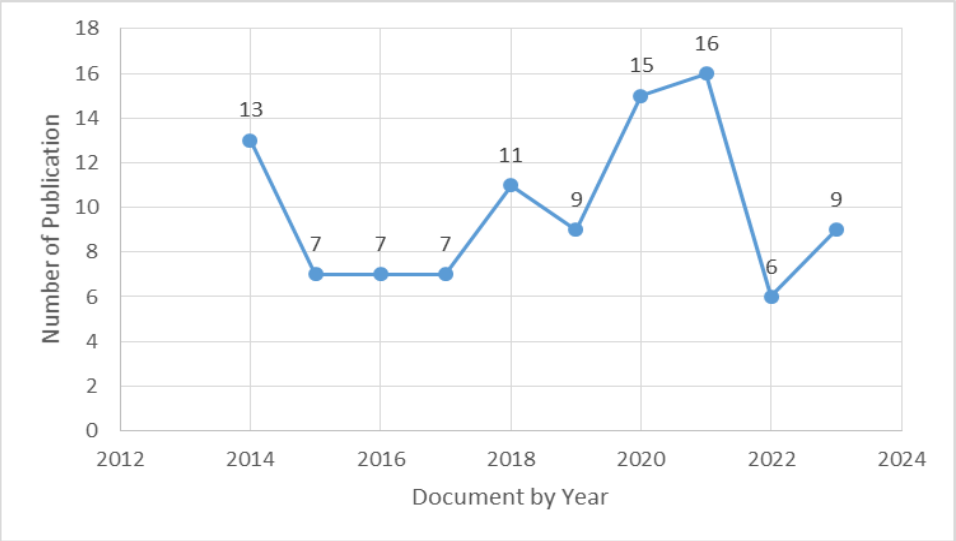

Figure 2. Article Distribution by Year

The trend of publishing articles on Socioscientific Issues changes every year. From 2015 to 2018, related research tends not to experience developments that can be seen as a horizontal line on the graph. Most articles containing Socioscientific Issues in Physics learning were published between 2020 and 2021. However, it experienced a significant decline in 2022 and is currently still experiencing growth. This explanation shows that integrating Socioscientific Issues in physics learning still has the potential for further research.

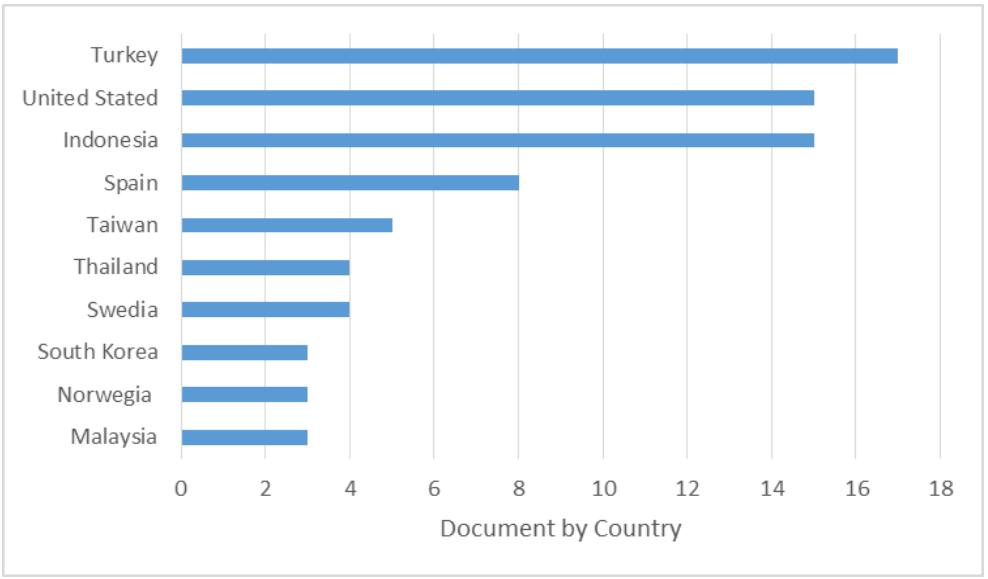

Figure 3. Top Ten Country Publications on Socioscientific Issues

Figure 3 shows that the documents analyzed according to affiliated countries are limited to a minimum of 3 documents published in the Scopus database. The results of the analysis show that Turkey has the most productive research in the field, with 17 documents identified, followed by the United States and Indonesia, with 15 documents each. This means that the development of research on socioscientific issues in Indonesia also contributes to improving the contextual quality of learning.

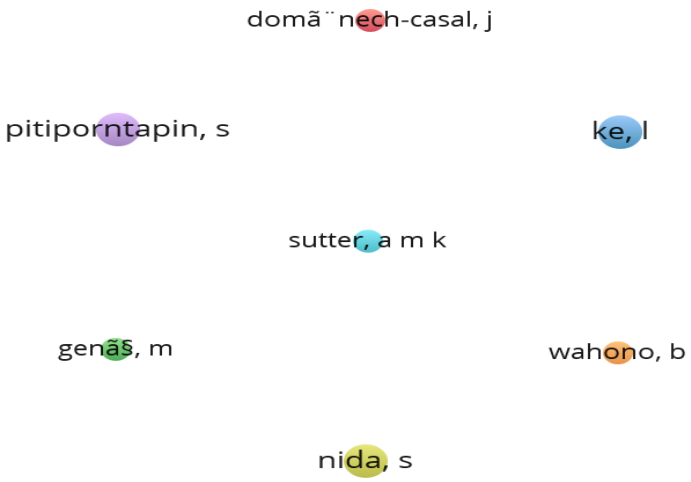

Figure 4. Author with Publication in Socioscientific Issues

The results of the analysis of the best authors in the field of study are determined based on having at least two publications on Socioscientific Issues, as presented in Figure 4. These results are also supported by document analysis based on Scopus citations, as seen in Table 2. Lederman (2014) published an article on Socioscientific Issues in the Journal of Science and Education with 169 citations.

Table 3. Top Five Most Cited Articles

No.	Author	Journal	Number of Citations
1.	(Lederman, 2014)	Science and Education	169
2.	(T D Sadler, 2016)	International Journal of Science Education	89
3.	(Zangori, 2017)	Journal of Research in Science Teaching	86
4.	(Jho, 2014)	Science and Education	75
5.	(Ke, 2021)	Science and Education	72

The bibliometric analysis results were reviewed based on the title, abstract, and keywords obtained from VOSviewer. Overall, the analysis results are presented in Figure 5 as a visualization of research trend density.

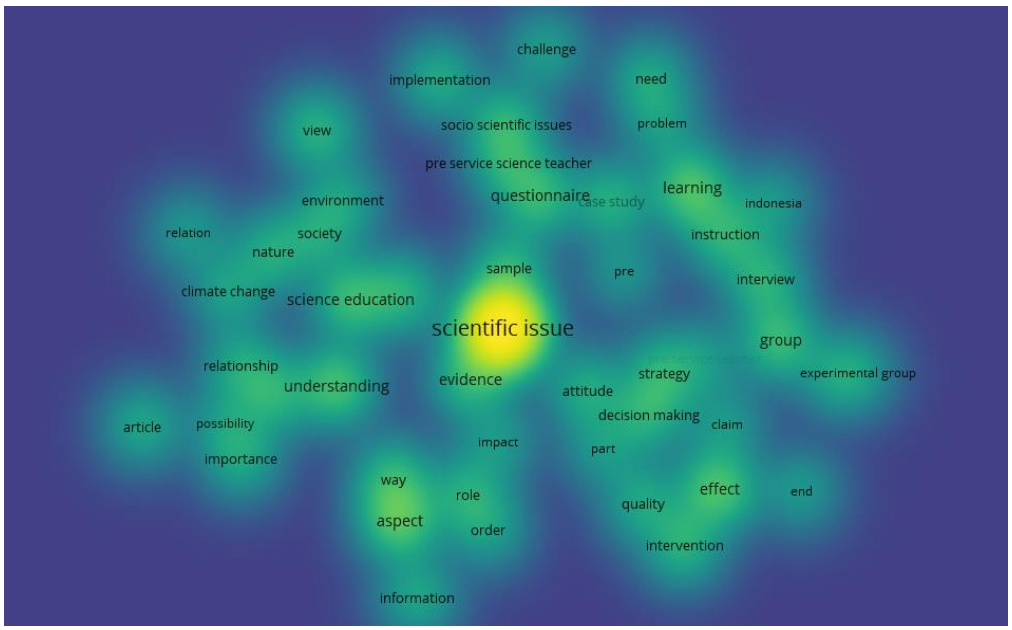

Figure 5. Visualization of Research Density on Socioscientific Issues

Based on the search results, the keyword scientific issues most often appear in several research articles. This shows that social scientific issues often appear in the title, abstract, and keywords in several scientific research articles. This means that there is a relationship between scientific studies and community life. Research on social scientific issues is developed based on the potential of local wisdom and culture in community life. However, the distribution of social scientific research may be the center of attention for researchers who want to create sustainable learning. The development of Socioscientific Issues (SSI) in Education in the future must be directed to answer the challenges of 21st-century skills.

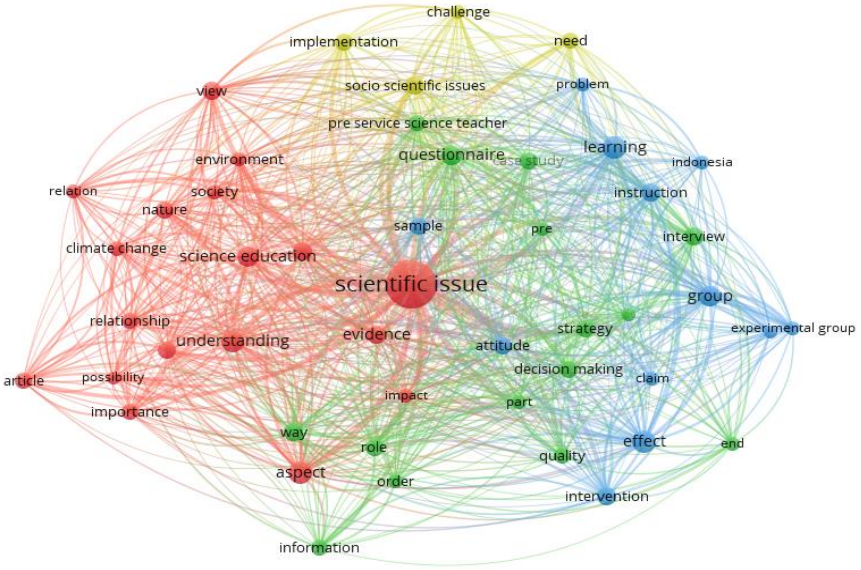

Figure 6. Visualization of Research Networks on Socioscientific Issues

After being analyzed using VOSviewer, the network visualization is shown in Figure 6. There are 4 clusters (red, green, blue, and yellow) indicate a relationship between one topic and another. The group in red shows keywords closer to the scientific issue. Groups in green indicate groups that are closer to the word learning strategy. Groups in blue indicate groups that are closer to the word effect on learning. The yellow group shows keywords closer to the words implementation of Socioscientific Issues.

If you focus more on mapping more specific relationships, you can find the research trends presented in Figure 7. Socioscientific issue research content was more dominant in science from 2014 to 2023, especially related to climate change. The reciprocal relationship between Socioscientific Issues (SSI) and climate change reflects how scientific phenomena impact society and how social responses shape scientific solutions.

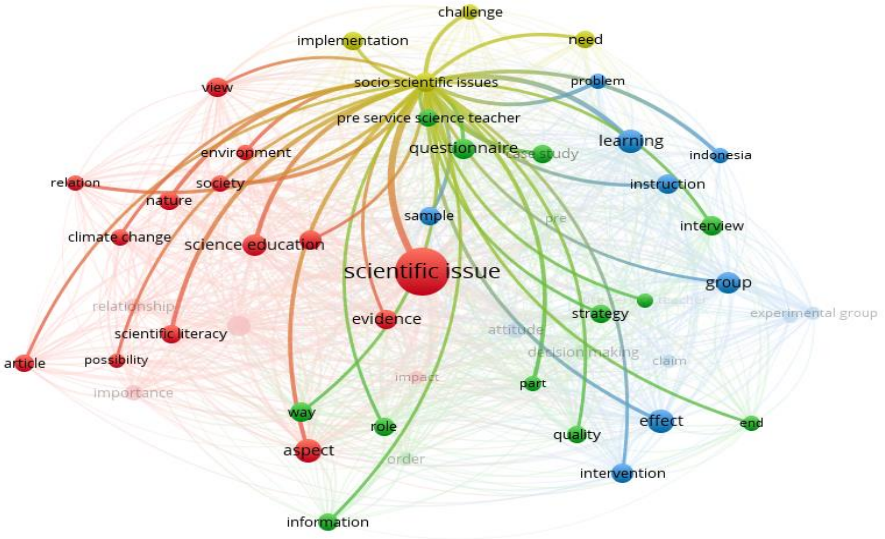

Figure 7. Interrelationship of Socioscientific Issues

Socioscientific Issues (SSI) are closely related to attitude variables, as shown in the network visualization results in Figure 8. In Socioscientific Issues, attitude variables include individual responses to scientific issues with social, cultural, and moral dimensions, such as climate change, genetic technology, or renewable energy.

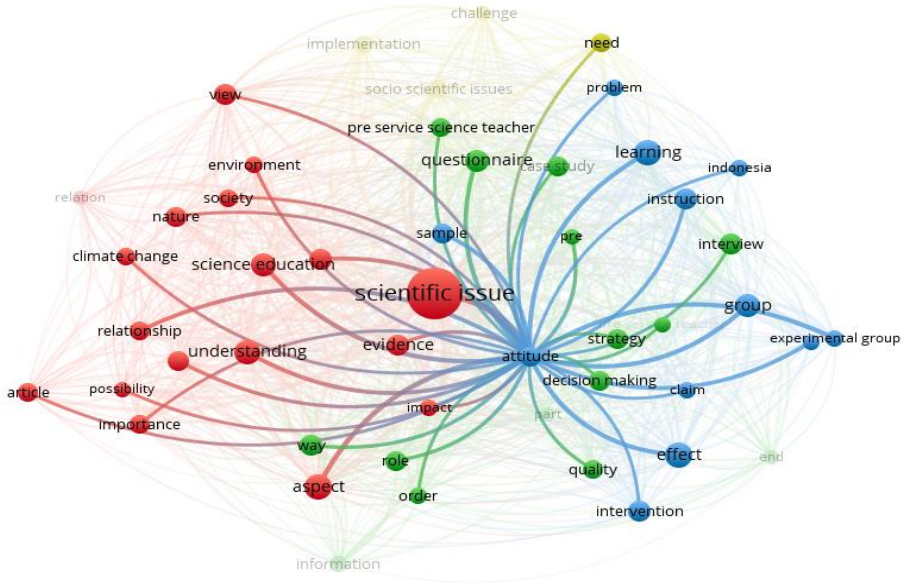

Figure 8. The relationship between Socioscientific Issues and attitude

The results of the bibliometric network visualization show that attitude is one of the central themes closely related to various topics, such as science learning topics. In the context of Socioscientific Issues (SSI) Education, attitudes reflect emotional responses to scientific issues and include openness to learning, willingness to understand different perspectives, and willingness to act based on scientific understanding.

DISCUSSION

The integration of socioscientific issues into learning can develop student character. The results of the analysis presented in Figure 8 show that there is a link between the implementation of learning and integrating sociocultural issues towards attitude. In addition, there is a visible network relationship in that the attitudes formed during learning are closely related to the problem-solving process. In Socioscientific Issues (SSI) based learning, student attitudes, such as openness to different views, social responsibility, and empathy, develop along with the process of discussion and exploration of solutions. When students are exposed to real, controversial issues, they are trained to understand the problem from a scientific perspective and to evaluate each solution's ethical, social, and environmental impacts. This kind of discussion and exploration of solutions also encourages students to think creatively in finding solutions to complex problems. Creative thinking emerges when students are invited to formulate alternative solutions they may not have considered before or combine various existing approaches. In this process, students learn to work together, respect their peers' ideas, and develop evidence-based arguments. The network relationship between attitudes and problem-solving abilities is visible when students demonstrate openness to new ideas and the courage to explore different possibilities, ultimately resulting in more innovative solutions.

Research on sociocultural issues in learning also increases scientific literacy so students can connect theory with real life. This approach helps students see the relevance of science in solving everyday problems. This scientific literacy is critical to equip students with critical thinking skills in evaluating information, making evidence-based decisions, and contributing to society responsibly. Apart from increasing scientific literacy, the socioscientific issue approach also helps students see the relevance of science in life, which can increase their interest and involvement in learning. When students face issues that directly impact them or their communities, they tend to be more motivated to learn and find solutions.

In general, learning based on Sociocultural issues focuses on mastering subject matter and character building and developing high-level thinking skills needed to face real challenges in the world. The complexity of the challenges presented in Socioscientific Issues-based learning reflects situations often occurring in society, where solutions are rarely single or straightforward. Therefore, students are trained to face uncertainty, collaborate with others, and think strategically when solving problems. This approach trains students to understand complex issues, such as climate change, biotechnology, or resource management, which require interdisciplinary understanding. SSI-based learning facilitates the development of analysis, evaluation, and decision-making skills so that students can see the relationship between theories learned in class and everyday situations. In this way, students become more literate in science and have greater social awareness.

CONCLUSION

The distribution of articles on Socioscientific Issues experienced fluctuating developments from 2014 to 2023. The research trend on Socioscientific Issues experienced a significant increase in 2021 based on 100 papers from the Scopus database. Turkey, as the most productive country, produces articles on Socioscientific Issues. Based on the results of the bibliometric analysis, it can be concluded that articles with the keyword socioscientific issues in the 2014-2023 period have a close relationship with the attitude variable. Integrating Socioscientific Issues (SSI) in learning significantly supports the development of positive attitudes toward science, scientific literacy, and 21st-century skills. These findings suggest SSI is relevant in physics learning to build connections between science and social contexts, strengthening students' motivation and engagement. The implications of this study emphasize the importance of the socioscientific issue approach in building a generation that not only understands physics concepts but also has a responsible attitude toward global challenges.

REFERENCES

Amos, R., Knippels, M. C., & Levinson, R. (2020). Socioscientific Inquiry-Based Learning: Possibilities and Challenges for Teacher Education. In *Contemporary Trends and Issues in Science Education* (Vol. 52). https://doi.org/10.1007/978-3-030-40229-7_4

Anisa, A., Widodo, A., Riandi, R., & Muslim, M. (2020). Analyzing socioscientific issues through an algorithm. *Journal of Physics: Conference Series*, *1469*(1). https://doi.org/10.1088/1742-6596/1469/1/012084

Ariza, M. R., Christodoulou, A., van Harskamp, M., Knippels, M. C. P. J., Kyza, E. A., Levinson, R., & Agesilaou, A. (2021). Socioscientific inquiry-based learning as a means toward environmental citizenship. *Sustainability (Switzerland)*, *13*(20). https://doi.org/10.3390/su132011509

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus is a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1). https://doi.org/10.1162/qss_a_00019

Benek, I., & Akcay, B. (2022). The effects of socioscientific STEM activities on 21st-century skills of middle school students. *Participatory Educational Research*, *9*(2). https://doi.org/10.17275/PER.22.27.9.2

Bryce, T. G. K. (2014). Skepticism and doubt in science and science education: the complexity of global warming as a socioscientific issue. *Cultural Studies of Science Education*, *9*(3), 599–632. https://doi.org/10.1007/s11422-013-9500-0

Byrne, J. (2014). Climate Change and Everyday Life: Repertoires children use to negotiate a socioscientific issue. *International Journal of Science Education*, *36*(9), 1491–1509. https://doi.org/10.1080/09500693.2014.891159

Cebesoy, U. B., & Rundgren, S.-N. C. (2023). Embracing socioscientific issues-based teaching and decision-making in teacher professional development. *Educational Review*, *75*(3). https://doi.org/10.1080/00131911.2021.1931037

Chang, H. (2016). A comparison study of augmented reality versus interactive simulation technology to support student learning of a socioscientific issue. *Interactive Learning Environments*, *24*(6), 1148–1161. https://doi.org/10.1080/10494820.2014.961486

Christenson, N. (2015). A framework for teachers assessment of socioscientific argumentation: An example using the GMO issue. *Journal of Biological Education*, *49*(2), 204–212. https://doi.org/10.1080/00219266.2014.923486

Dewi, P. Y. A., & Primayana, K. H. (2019). Effect of Learning Module with Setting Contextual Teaching and Learning to Increase the Understanding of Concepts. *International Journal of Education and Learning*, *1*(1). https://doi.org/10.31763/ijele.v1i1.26

Diani, R., Anggoro, B. S., & Suryani, E. R. (2023). Enhancing problem-solving and collaborative skills through RICOSRE learning model: A socioscientific approach in physics education. *Journal of Advanced Sciences and Mathematics Education*, *3*(2). https://doi.org/10.58524/jasme.v3i2.252

Fensham, P. J. (2014). Skepticism and trust: two counterpoint essentials in science education for complex socioscientific issues. *Cultural Studies of Science Education*, *9*(3), 649–661. https://doi.org/10.1007/s11422-013-9560-1

Genisa, M. U. (2020). Socioscientific issues implementation as science learning material. *International Journal of Evaluation and Research in Education*, *9*(2), 311–317. https://doi.org/10.11591/ijere.v9i2.20530

Gutierez, S. B. (2015). Integrating socioscientific issues to enhance the bioethical decision-making skills of high school students. *International Education Studies*, *8*(1), 142–151. https://doi.org/10.5539/ies.v8n1p142

Hancock, T. S. (2019). Selecting Socioscientific Issues for Teaching: A Grounded Theory Study of How Science Teachers Collaboratively Design SSI-Based Curricula. *Science and Education*, *28*(6), 639–667. https://doi.org/10.1007/s11191-019-00065-x

Iordanou, K. (2014). Developing pre-service teachers' evidence-based argumentation skills on socioscientific issues. *Learning and Instruction*, *34*, 42–57. https://doi.org/10.1016/j.learninstruc.2014.07.004

Jariah, S. A., & Aminatun, T. (2022). Implementation of the Socioscientific Issues Approach with the Investigative Group Learning Model to Improve Students' Critical Thinking Skills on Environmental Change Materials. *Jurnal Penelitian Pendidikan IPA*, *8*(3). https://doi.org/10.29303/jppipa.v8i3.1197

Jho, H. (2014). The Relationship of Science Knowledge, Attitude and Decision Making on Socioscientific Issues: The Case Study of Students' Debates on a Nuclear Power Plant in Korea. *Science and Education*, *23*(5), 1131–1151. https://doi.org/10.1007/s11191-013-9652-z

Kammerer, Y. (2021). The Role of Internet-Specific Justification Beliefs in Source Evaluation and Corroboration During Web Search on an Unsettled Socioscientific Issue. *Journal of Educational Computing Research*, *59*(2), 342–378. https://doi.org/10.1177/0735633120952731

Karpudewan, M. (2018). Changes in Primary Students' Informal Reasoning During an Environment-Related Curriculum on Socioscientific Issues. *International Journal of Science and Mathematics Education*, *16*(3), 401–419. https://doi.org/10.1007/s10763-016-9787-x

Ke, L. (2020). Students' perceptions of socioscientific issue-based learning and their appropriation of epistemic tools for systems thinking. *International Journal of Science Education*, *42*(8), 1339–1361. https://doi.org/10.1080/09500693.2020.1759843

Ke, L. (2021). Developing and Using Multiple Models to Promote Scientific Literacy in the Context of Socioscientific Issues. *Science and Education*, *30*(3), 589–607. https://doi.org/10.1007/s11191-021-00206-1

Khishfe, R. (2017). Students' understanding of the nature of science and their arguments in the context of four socioscientific issues. *International Journal of Science Education*, *39*(3), 299–334. https://doi.org/10.1080/09500693.2017.1280741

Lederman, N. G. (2014). Nature of Science, Scientific Inquiry, and Socioscientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry. *Science and Education*, *23*(2), 285–302. https://doi.org/10.1007/s11191-012-9503-3

Li, Y., & Guo, M. (2021). Scientific Literacy in Communicating Science and Socioscientific Issues: Prospects and Challenges. In *Frontiers in Psychology* (Vol. 12). https://doi.org/10.3389/fpsyg.2021.758000

Lund, E. S. (2019). Direct and indirect effects of textual and individual factors on source-content integration when reading about a socioscientific issue. *Reading and Writing*, *32*(2), 335–356. https://doi.org/10.1007/s11145-018-9868-z

Lyu, P., Liu, X., & Yao, T. (2023). A bibliometric analysis of literature on bibliometrics in recent half-century. *Journal of Information Science*. https://doi.org/10.1177/01655515231191233

Maksum, A., Wayan Widiana, I., & Marini, A. (2021). Path analysis of self-regulation, social skills, critical thinking, and problem-solving ability on social studies learning outcomes. In *International Journal of Instruction* (Vol. 14, Issue 3). https://doi.org/10.29333/iji.2021.14336a

Martín-Gámez, C. (2018). Understanding argumentation about socioscientific issues on energy: a quantitative study with primary pre-service teachers in Spain. *Research in Science and Technological Education*, *36*(4), 463–483. https://doi.org/10.1080/02635143.2018.1427568

Muis, K. R. (2021). Epistemic Emotions and Epistemic Cognition Predict Critical Thinking About Socioscientific Issues. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.669908

Nam, Y. (2017). Promoting argumentative practice in socioscientific issues through a science inquiry activity. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3431–3461. https://doi.org/10.12973/eurasia.2017.00737a

Purwanto, M. B., Hartono, R., & Wahyuni, S. (2023). Essential Skills Challenges for the 21st-century Graduates: Creating A Generation of High-Level Competence in The Industrial Revolution 4.0 Era. *Asian Journal of Applied Education (AJAE)*, *2*(3). https://doi.org/10.55927/ajae.v2i3.3972

Putri, P. D., Tukiran, T., & Nasrudin, H. (2018). The Effectiveness of Problem-Based Learning (PBL) Models Based on Socioscientific Issues (SSI) To Improve The Ability of Science Literacy on Climate Change Materials. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *7*(2). https://doi.org/10.26740/jpps.v7n2.p1519-1524

Sadler, T D. (2016). Learning science content through socioscientific issues-based instruction: a multi-level assessment study. *International Journal of Science Education*, *38*(10), 1622–1635. https://doi.org/10.1080/09500693.2016.1204481

Sadler, Troy D., Foulk, J. A., & Friedrichsen, P. J. (2016). Evolution of a Model for Socioscientific Issue Teaching and Learning. *International Journal of Education in Mathematics, Science and Technology*, *5*(1). https://doi.org/10.18404/ijemst.55999

Simeon, M. I., Samsudin, M. A., & Yakob, N. (2022). Effect of design thinking approach on students' achievement in some selected physics concepts in the context of STEM learning. *International Journal of Technology and Design Education*, *32*(1). https://doi.org/10.1007/s10798-020-09601-1

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of Problem-Based Learning (PBL) in STEM Education: Using Expert Wisdom and Research to Frame Educational Practice. *Education Sciences*, *12*(10). https://doi.org/10.3390/educsci12100728

Stenseth, T. (2016). Investigating interest and knowledge as predictors of students' attitudes towards socioscientific issues. *Learning and Individual Differences*, *47*, 274–280. https://doi.org/10.1016/j.lindif.2016.02.005

Tal, T., & Ginosar, A. (2024). Wild boars in the streets: Applying a socioscientific issue framework to analyze news items. *International Journal of Science Education, Part B: Communication and Public Engagement*, *14*(3). https://doi.org/10.1080/21548455.2023.2279518

Tsai, C. Y. (2018). The effect of online argumentation of socioscientific issues on students' scientific competencies and sustainability attitudes. *Computers and Education*, *116*, 14–27. https://doi.org/10.1016/j.compedu.2017.08.009

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1). https://doi.org/10.7771/1541-5015.1649

Uus, Õ., Mettis, K., & Väljataga, T. (2022). Self-directed learning: A case study of school students scientific knowledge construction outdoors. *Cogent Education*, *9*(1). https://doi.org/10.1080/2331186X.2022.2074342

Wang, H. H. (2017). Longitudinal study of a cooperation-driven, socioscientific issue intervention on promoting students' critical thinking and self-regulation in learning science. *International Journal of Science Education*, *39*(15), 2002–2026. https://doi.org/10.1080/09500693.2017.1357087

Wiyarsi, A. (2019). Revisiting the scientific habits of mind scale for socioscientific issues in the Indonesian context. *International Journal of Science Education*, *41*(17), 2430–2447. https://doi.org/10.1080/09500693.2019.1683912

Zangori, L. (2017). Student development of model-based reasoning about carbon cycling and climate change in a socioscientific issues unit. *Journal of Research in Science Teaching*, *54*(10), 1249–1273. https://doi.org/10.1002/tea.21404

Zeidler, D. L., Herman, B. C., & Sadler, T. D. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1). https://doi.org/10.1186/s43031-019-0008-7