

Current research trends on socio-scientific issues and STEM education: a bibliometric analysis

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Abstract

Current research trends on socio-scientific issues and STEM education: a bibliometric analysis. STEM education aims to foster students' 21st-century skills. However, teaching STEM alone without integrating social and environmental real-world context remains a problem. To bridge this gap, integrating socio-scientific issues into STEM learning by integrating real-world context support the development of problem-solving, decision-making and argumentation skills. Research on SSI in STEM education has expanded rapidly over the past decade across various sub-disciplines. However, comprehensive quantitative bibliometric mapping that systematically traces the global research trajectory, intellectual structure, key contributors, and thematic clusters of SSI in STEM education remains lacking. This study aims to conduct a bibliometric analysis that offers an objective, data-driven methodology to visualize knowledge domain structures, author networks, and publication shifts over time. We collected documents from the Scopus database, resulting in 281 final documents related to the implementation of SSI in STEM education published from 2016 to 2026. Several tools were utilized, including Microsoft Excel, OpenRefine, RStudio, Biblioshiny, and VOS viewer. The findings show that while SSI is originally concentrated in the United States, other countries such as Indonesia now rank second among the most productive nations, with Universitas Negeri Malang leads the most productive institution with 10 publications within the timeframe. The thematic analysis and keyword co-occurrence analysis show that teaching, learning, teacher training, climate change education, and STEM education are the most used author keywords, indicating that the article mainly discusses these topics.

Keywords: Bibliometric Study; Socio-Scientific Issues; STEM Education; Thematic Analysis

Introduction

Today, real-world challenges faced by society, mostly related to climate change, energy crises, and public health-related problems, have become classroom discussion topics. In STEM-based learning, students are introduced to real-world problems in their social and environmental contexts to address (Bozkurt Altan et al., 2018). Introducing STEM learning aims to foster student competency, interdisciplinary problem-solving skills, and scientific literacy (Tytler, 2020). However, STEM education cannot be taught in isolation; it should integrate societal and environmental aspects to provide real-world contexts. To bridge this gap, integrating socio-scientific issues (SSI) connects science to real-world issues and improves students' understanding of science concepts and the nature of science (Johnson et al., 2023; Ke et al., 2021; Kruit et al., 2025). SSI integrates knowledge across science, technology, engineering, and mathematics subjects, as well as social and ethical perspectives (Howk et al., 2025; Wahono et al., 2021) by preparing students to address complex societal challenges through scientific inquiry and civic participation (Fensham & Montana, 2018; Johnson et al., 2023; Viehmann et al., 2024). SSI supports the development of skills such as problem-solving, decision-making, and argumentation (Altan et al., 2026; Ban & Mahmud, 2024; Wan, 2026) by engaging in dialogue, reasoning about controversial topics, evaluating ethical dimensions, and fostering critical and reflective thinking (Mukminati Nur et al., 2025; Viehmann et al., 2024), and preparing students to participate in societal decision-making and public discourse (Ban & Mahmud, 2024; Dauer et al., 2021).

Successful SSI implementation within STEM learning involves integrating subject matter, pedagogy, and understanding of complex societal issues like climate change (Bayram-Jacobs et al., 2019; Chang & Park, 2020; Lee, 2022), which can be developed through targeted curriculum materials, content representation (CoRe), and video-based reflection, especially when planning and reflecting on SSI or sustainable development topics (Forsler et al., 2024). Teachers should have high science efficacy when teaching SSI, as it

strengthens their belief in their ability to teach complex topics and directly influences their willingness and effectiveness in addressing SSI (Chen & Morris, 2026). Prior studies found that more knowledgeable teachers with higher self-efficacy are better prepared to teach SSIs (Ozturk & Yilmaz-Tuzun, 2022). Teachers' professional development programs that focus on SSI and STEM integration can enhance teachers' self-efficacy, influencing teachers' confidence level in facilitating discussions on complex societal issues (Krainara & Chatmaneerungcharoen, 2019; Nkundabakura et al., 2025). Previous studies found that high self-efficacy encourages teachers to adopt more innovative and effective classroom practices, such as SSI-based teaching with high confidence (Chen & Morris, 2026; Ngaoda et al., 2026), resulting in better student engagement and learning outcomes (Ozturk & Yilmaz-Tuzun, 2022).

Research on SSI in STEM education has expanded rapidly over the past decade across various sub-disciplines. For instance, Sadler et al. (2016) examined how SSI-based instruction and assessment support science learning. The results claim a positive effect on students' academic performance. Moreover, Kilinc et al. (2017) conducted a one-year longitudinal study to investigate pre-service science teachers' SSI teaching dialogic discourse. Despite the growing volume of empirical studies, existing scholarly literature in this domain has also focused on specific qualitative meta-analysis studies. For instance, Badeo & Duque (2022) conducted a meta-analysis study on the effect of SSI in science teaching. Kumar et al. (2024) conducted a systematic literature review on SSI and its role in developing scientific literacy in science education. Sanchez et al. (2024) conducted a meta-analytic review on SSI and climate change in science education. While these synthesis studies offer valuable insights, they have key limitations, such as not capturing global macro-level trends, collaborative networks, and the evolution of the SSI-STEM research landscape. Specifically, a comprehensive quantitative bibliometric mapping that systematically traces the global research trajectory, intellectual structure, key contributors, and thematic clusters of SSI in STEM education remains limited. To address this gap, this study presents a bibliometric analysis of the SSI-STEM research landscape by answering these research questions:

1. What are the high-output affiliations and contributing countries of SSI-STEM research over time?
2. What is the citation analysis of authors, journal sources, and documents for SSI-STEM research trajectories?
3. What is the intellectual structure of co-citation analysis in SSI-STEM research?
4. What are the primary thematic clusters and emerging research within the SSI-STEM research according to the results of the bibliography coupling network?

Method

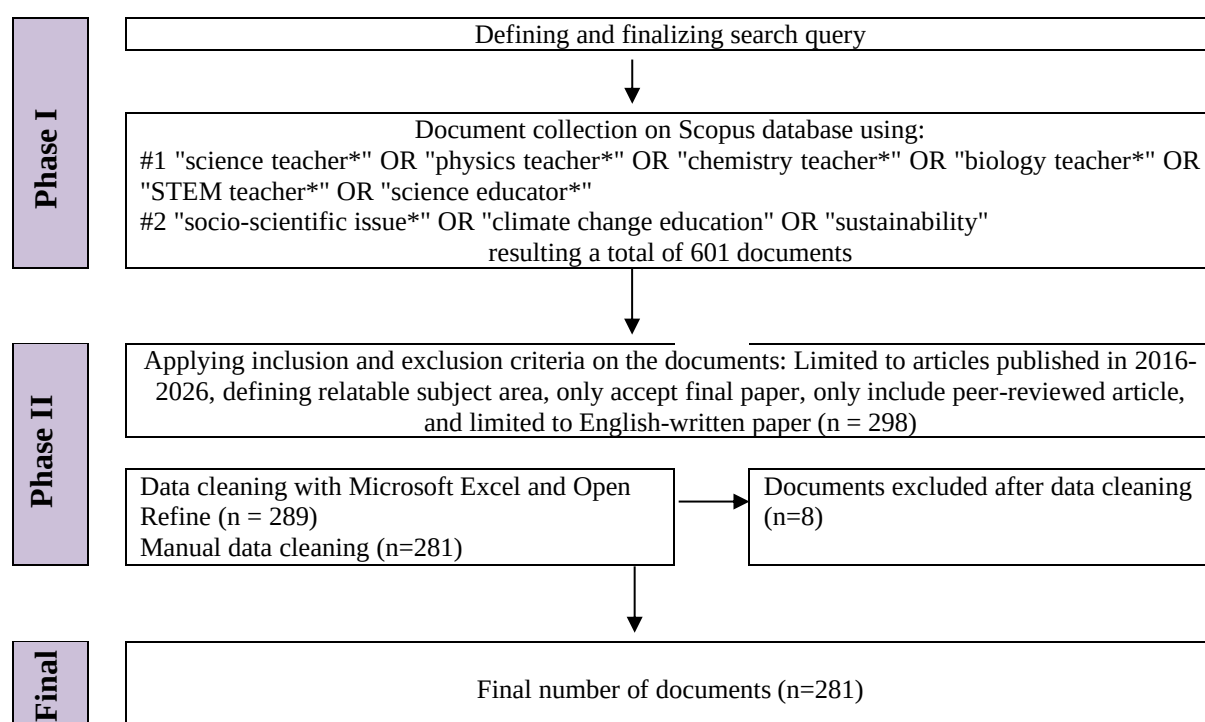
This study employs a bibliometric approach to quantitatively capture current research trends in how science teachers address socio-scientific issues. A bibliometric study is a quantitative methodology used to map and evaluate publication trends within a specific domain of study (Kumar et al., 2023). To assemble the dataset, we retrieved bibliographic records from the Scopus database on 29th August 2026 using a defined search query and applying the inclusion and exclusion criteria. Of the 601 documents retrieved in the first stage, a rigorous screening process yielded 281 articles for this study (see Figure 1, Table 1 and Table 2).

Table 1. Search Query

No.	Queries
#1	“science teacher*” OR “physics teacher*” OR “chemistry teacher*” OR “biology teacher*” OR “STEM teacher*” OR “science educator*”
#2	“socio-scientific issue*” OR “climate change education” OR “sustainability”
#3	#1 and #2

Table 2. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Empirical studies related to the field of Socio-scientific Issue within STEM education	Not empirical studies
Publications written in English	Publications written in other languages aside from English
Article published in peer-reviewed journal	Book chapters, magazines, conference proceedings, news, posters
Publications or journal issues related to the topic of Socio-scientific Issue within STEM education	The studies or journals' issues which does not align with the research's main topic

**Figure 1.** Document Collection Phases

Results and Discussion

To evaluate the scientific output of Scopus-indexed articles related to the implementation of socio-scientific issues by science teachers over the past decade (2016-2026), descriptive bibliometric metrics were generated using the R “bibliometrix” package, as seen in Table 1. A total of 281 relevant articles were retrieved from 118 journal sources, with a mean citation count of 11.15 per document. Moreover, of the 281 articles, 15,288 references were used, averaging 54.40 per publication. Authorship analysis indicated that 798 authors contributed to work on implementing socio-scientific issues by science teachers. A limited number of single-authored documents were found (n=37), while the majority (n=761) are co-authored, yielding an average co-authorship index of 3.17 authors per paper, as seen in Table 3.

Table 3. Descriptive Data of Document Analysis

No.	Description	Results
1.	Timespan	2016-2026
2.	Sources (Journals, Books, etc)	118
3.	Documents	281
4.	Average Citation per Doc	11.15
5.	References	15,288
6.	Author's Keywords	806
7.	Authors	798
8.	Authors of single-authored docs	37
9.	Co-authors per doc	3.17
10.	International co-authorship %	23.45%

4.1 Mapping High-Output Affiliations and Contributing Countries

To evaluate the distribution of research output, this section examines the primary institutional affiliations and top-producing countries driving literature on SSI science teacher implementation. Table 2 presents the top ten most productive affiliations from Southeast Asia, North America, the Middle East, Australia, and Europe, totaling 59 articles. First, three universities in Indonesia rank in the top three positions: Universitas Negeri Malang leads with 10 published articles on SSI in STEM education, followed by Universitas Pendidikan Indonesia with 8 published articles, and Universitas Negeri Surabaya in third with six published articles. Together, these three institutions account for 24 publications, nearly half of the top ten published articles in Table 2. This aligns with Indonesia's national research agenda, which emphasizes SSI as a pedagogical framework for fostering students' science literacy, reasoning, and critical thinking skills (Faisal et al., 2025). Similar to Universitas Negeri Surabaya, King Faisal University in Saudi Arabia and the University of Missouri in the US published six documents related to SSI in STEM education. Meanwhile, other affiliations published fewer than this number.

Table 4. Affiliation Production Number

No.	Affiliations	TP	No.	Affiliations	TP
1.	Universitas Negeri Malang	10	6.	Deakin University	5
2.	Universitas Pendidikan Indonesia	8	7.	University of Education	5
3.	Universitas Negeri Surabaya	6	8.	University of Texas at Dallas	5
4.	King Faisal University	6	9.	Akdeniz University	4
5.	University of Missouri	6	10.	Hacettepe University	4

In addition to the most productive affiliation, the study examines the most productive country for publishing scholarly literature on implementing SSI in STEM education, as shown in Table 3. The US leads global productivity, with 130 total documents published from 2016 to 2026. This may relate to the historical development of the SSI framework in US higher education institutions, especially in SSI decision-making, reasoning skills, and teacher pedagogical content knowledge (PCK) (Winarti et al., 2026). Moreover, Indonesia (TP = 77) and Turkey (TP = 71) ranked second and third, respectively. In Indonesia, SSI is reflected in the curriculum shift (Kurikulum Merdeka), which largely encourages contextual and inquiry-based learning by bringing real-life contexts into the classroom (Misel et al., 2025). Beyond Indonesia, Malaysia (TP = 22) and the Philippines (TP = 16) are also among the most productive countries in Southeast Asia.

Table 5. Country Production Number

No.	Country	TP	No.	Country	TP
1.	USA	130	6.	Malaysia	22
2.	Indonesia	77	7.	Chile	18
3.	Turkey	71	8.	Philippines	16
4.	Spain	23	9.	Saudi Arabia	15
5.	Israel	22	10.	South Africa	14

4.2 Citation analysis

To evaluate the scientific output of Scopus-indexed articles related to the implementation of socio-scientific issues by science teachers over the past decade (2016-2026), descriptive bibliometric metrics were generated using the R “bibliometrix” package, as seen in Table 1. A total of 281 relevant articles were retrieved from 118 journal sources, with a mean citation count of 11.15 per document. Moreover, of the 281 articles, 15,288 references were used, averaging 54.40 per publication. Authorship analysis indicated that 798 authors contributed to work on implementing socio-scientific issues by science teachers. A limited number of single-

authored documents were found (n=37), while the majority (n=761) are co-authored, yielding an average co-authorship index of 3.17 authors per paper, as seen in Table 3.

Citation analysis examined the h-index, total citations (TC), number of publications (NP), and publication year start (PY_start). As shown in Table 4, the results are ordered by total citations. First, Sadler, T. D., from the University of North Carolina, is among the most cited, the most productive author, and has the highest h-index. He began writing manuscripts on socio-scientific issues in 2016, reflecting a decade of dedication to the field. Second is Topçu, M. S., from Yildiz Technical University, with two documents cited 138 times (averaging 69 citations per paper). Interestingly, Omidiora, J. O., Oyelere, S. S., and Sanusi, I. T., in the third to the fifth position, have exactly similar h-index (1), total citations (125), and number of publications (1), with a similar year of first publication, which was in 2022. Despite only one publication in the field, these three authors have a high citation count, accounting for 125 citations.

Table 6. Citation Analysis on Author

No.	Author	h_index	TC	NP	PY_start
1.	Sadler, T. D.	5	228	7	2016
2.	Topçu, M.S.	2	138	2	2016
3.	Omidiora, J. O.	1	125	1	2022
4.	Oyelere, S. S.	1	125	1	2022
5.	Sanusi, I. T.	1	125	1	2022
6.	Feldman, A.	3	124	3	2017
7.	Romine, W. L.	1	116	1	2016
8.	Mouza, C.	2	108	2	2017
9.	Drewes, A.	2	96	2	2018
10.	Henderson, J.	1	93	1	2018

Besides the authors, citation analysis was also conducted on the journal sources, summarizing top journals that published articles on the SSI within STEM education. Table 5 shows the top ten most cited journals, along with their h-index, number of publications, and publication start year. As can be seen, the most cited (TC = 495), the most productive (NP = 32), and the highest h-index (h_index = 12) journal publishing articles related to the SSI within STEM education is Sustainability (Switzerland), which focuses mainly on themes such as education for sustainable development (ESD), environmental literacy, and socio-ecological decision-making. Second, the International Journal of Science Education (IJSE), published by Taylor & Francis, has 323 citations from 10 published articles, averaging 32 citations per article. Interestingly, this journal started publishing in the SSI in STEM education in 2016, making it older than Sustainability (Switzerland). The third and fourth positions have almost similar citation numbers, with TC = 188 for the Journal of Chemical Education and TC = 187 for the Journal of Research in Science Teaching (JRST). Although the citation counts differ by only one, the publication counts differ substantially. The Journal of Chemical Education published 15 articles with a total citation count of 188, averaging 12,5 citation for each article, while the Journal of Research in Science Teaching published only five documents with 187 total citations, meaning around 37,4 citation per document, which is three times the average citation count of the Journal of Chemical Education. IJSE and JRST are two flagship journals in science education; although both journals published fewer articles, they reflect a high average citations per document (32-37 citations/article). This suggests that foundational research on teacher SSI implementation remains anchored in top-tier specialized science journals.

Table 7. Citation Analysis on Journal Sources

No.	Jornal Source	h_index	TC	NP	PY_start
1.	Sustainability (Switzerland)	12	495	32	2019
2.	International Journal of Science Education	7	323	10	2016
3.	Journal of Chemical Education	9	188	15	2018

4.	Journal of Research in Science Teaching	4	187	5	2017
5.	International Journal of Science and Mathematics Education	6	154	6	2016
6.	Computers and Education Open	1	125	1	2022
7.	Journal of Science Teacher Education Open	4	119	11	2017
8.	Research in Science and Technological Education	4	119	5	2018
9.	Environmental Education Research	4	111	8	2017
10.	Eurasia Journal of Mathematics, Science and Technology Education	5	100	5	2017

Article citation analysis evaluates article impact and ranks articles by citation count. The article citation analysis discusses each document quantitatively and qualitatively by reading the abstract and full article. As presented in Table 8, we examined the top five most-cited articles based on Total Citations (TC).

Table 8. Document Citation Analysis

No.	Author	Title	Journal	TC
1.	Sanusi, I. T., Oyelere, S. S., & Omidiora, J. O.	Exploring teachers' preconceptions of teaching machine learning in high school: A preliminary insight from Africa	Computers and Education Open	125
2.	Sadler, T. D., Romine, W. L., & Topçu, M. S.	Learning science content through socio-scientific issues-based instruction: a multi-level assessment study	International Journal of Science Education	116
3.	Drewes, A., Henderson, J., & Mouza, C.	Professional development design considerations in climate change education: teacher enactment and student learning	International Journal of Science Education	93
4.	Herman, B. C., Feldman, A., & Vernaza-Hernandez, V.	Florida and Puerto Rico Secondary Science Teachers' Knowledge and Teaching of Climate Change Science	International Journal of Science and Mathematics Education	72
5.	Kilinc, A., Demiral, U., & Kartal, T.	Resistance to dialogic discourse in SSI teaching: The effects of an argumentation-based workshop, teaching practicum, and induction on a preservice science teacher	Journal of Research in Science Teaching	71

The most-cited article is authored by Sanusi et al. (TC=125), published in Computers & Education Open. This article examines teachers' conceptions about emerging technologies (specifically machine learning). Its high citation impact highlights a key thematic evolution within the SSI framework. SSI issues are increasingly expanding beyond science, biological and environmental topics into technological ethics, artificial intelligence, and digital literacy. Teachers' SSI implementation now includes how socio-technological innovations shape societal decision-making (Häyrynen et al., 2021). Second, Sadler et al. (TC=116), published in the International Journal of Science Education, addressed SSI concerns through multi-level assessment and provided empirical evidence that SSI-based instruction enhances students' conceptual understanding. Moreover, Climate change is one of the most prominent real-world socio-scientific contexts used by science teachers. Two top-cited papers explicitly address this topic. First, Drewes et al. (TC = 93) examine the design considerations of Professional Development (PD) programs needed to support teachers in enacting climate change curricula, and second, Herman et al. (TC = 72) explore secondary science teachers' subject matter knowledge and pedagogical practices surrounding climate science across different regional or cultural settings (Florida and Puerto Rico). Lastly, Kilinc et al. (TC = 71), published in the Journal of Research in Science

Teaching, provide deep qualitative insight into teacher preparation. It examines a pre-service science teacher's resistance to using dialogic discourse and argumentation during SSI instruction despite participating in specialized workshops and practicum. Overall, the most-cited documents show that research on science teachers implementing SSI centers on four interconnected pillars. First, modernizing SSI contexts to include emerging technology or AI ethics (Sanusi et al., 2022). Second, SSI teaching using a multi-level assessment. Third, targeted professional development programs to enhance teachers' pedagogical skills in SSI teaching (Drewes et al., 2018; Herman et al., 2017; Kilinc et al., 2017).

4.3 Co-Citation Analysis on Author and Journal Sources

The co-citation analysis examined author and journal sources to visualize connections among published articles on Socio-Scientific Issues (SSI) and STEM education. The analysis used VOSviewer and limited citations to at least five per document, as shown in Figure 2 and Figure 2. In particular, Figure 2 visualizes the author co-citation analysis, showing different color-coded thematic clusters with different node sizes. Larger nodes indicate higher citation counts (Kumar et al., 2023). Notably, Sadler, T.D. emerges as the most dominant node in the red cluster, establishing the SSI framework on socio-scientific reasoning and contextualized learning. Another distinct node is Eilks, I., reflecting strong co-citation analysis in the yellow clusters, specifically ties around chemistry education, sustainability, and societal decision-making in science learning. The green cluster also highlights scholars like Mouza, C., Bandura, A., and Ajzen, I., who authored articles on SSI in educational technology, self-efficacy, and behavioral theory. The interconnectedness density on the visualization reflects that the implementation of SSI within STEM education mainly discusses socio-scientific decision-making models, learning psychology, and STEM integration learning.

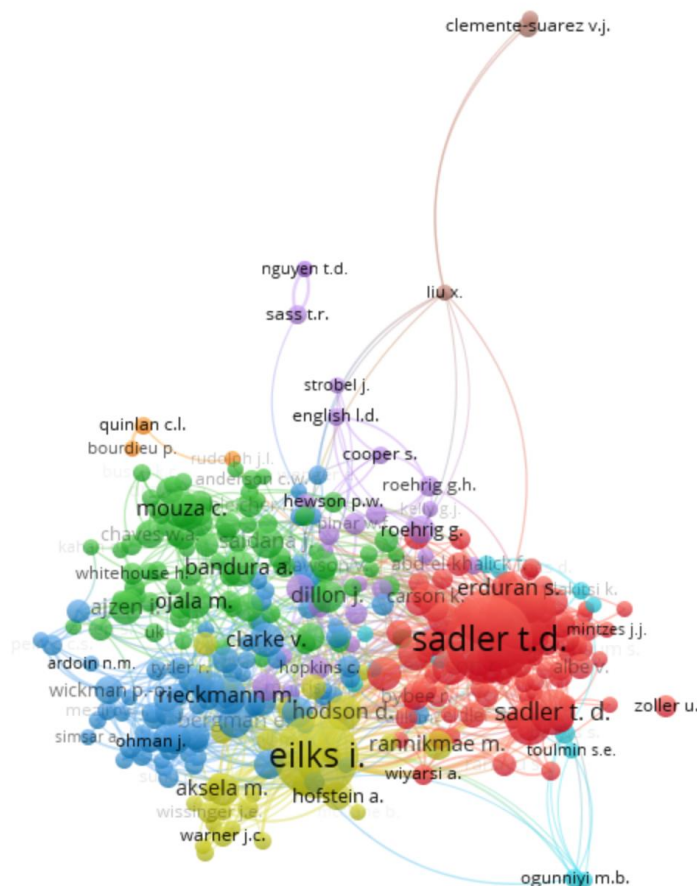


Figure 2. Analysis of Authors' Co-citation

Figure 3 depicts the co-citation analysis of the journal sources. The analysis was conducted using VOSviewer, limiting the citation count to at least five citations between journal sources. The visualization

At the core of the map, high-density hubs centered on teaching, learning, STEM education, socio-scientific issues, and education for sustainable development highlight the primary pedagogical drive to connect interdisciplinary STEM content with societal and environmental relevance. Moreover, in the sub-clusters, keywords related to teacher preparation and capacity building include teacher training, professional development, and teacher learning, reflecting the need for teacher skill-enhancement programs. Furthermore, keywords related to critical thinking competencies appear in terms like argumentation skills and decision-making, which are integral skills in SSI within STEM Education (Lu et al., 2025). Finally, specialized domain contexts are reflected in clusters such as climate change education, green chemistry, and chemistry education. Collectively, these keyword connections emphasize that implementing SSI in STEM education is driven by a dual focus. First, equipping teachers with professional pedagogical design skills while fostering students' higher-order reasoning and environmental literacy through real-world contextual topics.

4.5 Bibliographic Coupling Network

The bibliographic coupling network analysis examines authors who independently cite one or more common reference publications in their respective works, indicating that they draw from a shared theoretical background and operate within similar active research themes (Kumar et al., 2023).

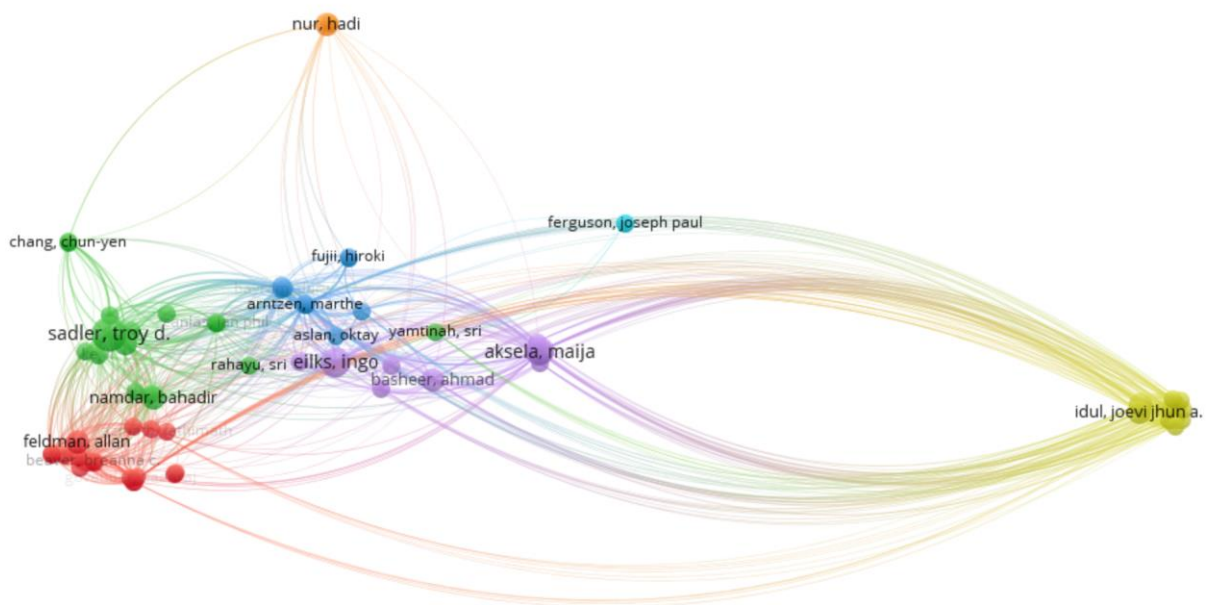


Figure 5. Bibliographic Coupling Network of Authors

Figure 5 presents the bibliographic coupling network results, highlighting current intellectual overlap among active researchers implementing Socio-Scientific Issues (SSI) in STEM education. The tight, highly interconnected central cluster, such as Sadler, Eilks, Hiroki Fujii, Chun-yen Chang, and Sri Rahayu, demonstrates a strong consensus in the foundational literature used across contemporary SSI-STEM studies, bridging global perspectives on socio-scientific reasoning, sustainability, and chemistry education. In contrast, yellow and orange clusters shared different references from the red, blue, green, and purple clusters. In summary, Figure 5 illustrates authors who shared similar references and conceptual frameworks in SSI-STEM research.

Conclusion

This bibliometric study provides a quantitative analysis of research trends in implementing Socio-Scientific Issues (SSI) within STEM education. The documents were collected from the Scopus database and published between 2016 and 2026, following some inclusion and exclusion criteria, yielding 281 Scopus-indexed articles for this study. Three main findings emerge regarding the current and future research direction of SSI-STEM education. First, global publication and citation trajectories show a shift from a Western-centric

research base to a globalized ecosystem, as shown by heavily concentrated publications from Southeast Asian and North American institutions. Second, citation analysis reflects strong representation of highly cited scholars and top-tier science education journals. Furthermore, cross-national co-authorship networks highlight an expanding international commitment within the research on SSI in STEM education. Third, thematic co-occurrence mapping reveals a detailed research shift from fundamental conceptualization of SSI toward practical classroom implementation, teacher self-efficacy, professional development, and climate change education. Despite these contributions, the study has limitations because it drew on only the Scopus database; future bibliometric studies may incorporate multiple databases, such as Web of Science (WOS) and Google Scholar, to enable a more comprehensive analysis.

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