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Socio-scientific Issues (SSI) research trends: A systematic literature review of publications 2011 – 2022

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ABSTRACT
This study aimed to investigate research trends related to socio-scientific issues (SSI). The SSI articles analysed were from highest-rating five science education journals with the highest impact ratings, published between 2011 and 2022, including Science Education [SE], Journal of Research in Science Teaching [JRST], Science and Education [S&E], International Journal of Science Education [IJSE], and Research in Science Education [RSE]. A total of 87 selected relevant SSI articles were analysed to determine research types, research topics, research sample groups, research sites, and authors with the most citations. According to the research findings, IJSE articles are the most widely published articles compared to other articles of similar journals. It is revealed that the most discussed issues in those articles of IJSE are argumentation and decision-making, followed by the nature of science. Pupils in middle and high schools constitute the largest sample groups. The continent that has been widely selected as research sites is European continent. Meanwhile, the country with the most research sites is the United States. The data collection tool most frequently used in the research is interview. S&E's Nature of Science, Scientific Inquiry, and Socio-Scientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry articles are the most cited articles. Challenges such as addressing efficacy, emotion, and attitude remain noticeably unexplored in SSI studies. Furthermore, exploratory studies on SSI for early childhood education.

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Introduction

Scientific publication activities rely heavily on information about research trends. This article, in addition to disseminating research, serves to validate and legitimise ideas and outcomes (Milne et al., 2015). Research reviews serve as the foundation for scientific development (Zheng, 2017). Publications in the form of reviews, particularly in the field of science education, have been carried

out extensively recently, including mobile gamification in science education (Kalogiannakis et al., 2021; Ullah et al., 2022), the correlation between mathematics and science (Monferrer et al., 2022), STEM (Li et al., 2020; Sırakaya & Alsancak Sırakaya, 2022), human rights and science (Schuck & Feser, 2022), and the association between culture and science education (Kolovou, 2022).

Socio-scientific Issues, as a context for science education, connect science and society (Barrue & Albe, 2013; Herman et al., 2019). SSIs arise from the implementation of science to various societal and everyday life problems from the perspectives of social, moral, economic, regulatory, and political issues (Zeidler, 2014; Hsu & Lin, 2017; Cian, 2020). SSIs allow students to study science conceptually as well as practically in terms of the controversy investigated (Sadler et al., 2007; Zeidler, D. L., & Kahn, 2014). This controversy requires students to collect data and assess issues from various perspectives before making decision (Paul et al., 2019; Lin, 2020).

Various issues have been identified within the domain of various SSI studies. Notably, science teachers often encounter challenges when assessing SSI argumentation (Christenson et al., 2017). They are lacking a of suitable SSI materials, coupled with limited preparation time (Tidemand, 2017). Similarly, learners find it difficult to obtain evidence during SSI debates in classroom activities (Xiao, 2018). Both teachers and pupils frequently grapple with making appropriate decisions concerning real-world issues related to scientific and technological advancements (Lee, 2020). The implementation of SSI in classroom settings is often faced with resistance due to the emerging controversial aspects from school to university educational levels (Yahaya et al., 2016). Proficiency in SSI learning demands readiness on the part of both teachers and learners (Christenson et al., 2017; Macalalag et al., 2019).

SSI studies make substantial contributions to science education. SSI provides a platform that effectively examines issues that can be scientifically explained and may significantly transform pupils' attitudes towards controversial issues (Yahaya et al., 2016), fosters empathy and moral reasoning through collaborative exploration (Lee, 2020). Collaborative discussion was found to promote moral reasoning in both cultures, leading to more consideration of principles such as honesty, empathy, and trustworthiness. SSI also establishes a foundation for learners' understanding of science and the Nature of Science (NOS), evoking interest, motivation, argumentation, and critical thinking (Dawson, 2015). SSI promotes comprehension and application of scientific explanations and NOS in real-world contexts (Herman et al., 2019), establishes connections between attitude and science learning (Xiao & Sandoval, 2017), and holds potential for developing Emotional Competence (EC) to contribute to scientific learning and student character development (Gao et al., 2019). Students with positive attitudes towards science tend to have better understanding of scientific concepts. Meanwhile, students with scientific attitudes are more likely to develop critical thinking skills and engage in inquiry-based learning. Various contributions of SSI in science education involve attitude, empathy, moral reasoning, critical thinking skills, and an emphasis on contextualised learning. SSI research trends serves as an invaluable guide for both practical applications and theoretical advancements (Chen & Xiao, 2021). The correlation between SSI discussion activities and attitudes of primary school teacher candidates about life science teaching is evident in the study by Karakaş (2022) which showed that these discussion activities significantly influence attitudes, with changes in sub-dimensions such as liking, valuing, and caring showing notable significance. Examining the belief system of Turkish preservice science teachers (PSTs) regarding the teaching of a socio-scientific issue (GM Foods) reveals that PSTs possess relatively strong knowledge, hold substantial risk perceptions, and uphold certain moral and religious beliefs regarding GM Foods (Kilinç et al., 2014).

The findings of SSI studies in science education, along with unexplored research focus. Professional teacher education programmes that are aimed at fostering students' SSI argumentation skills are supposed to be adjusted to each individual teacher’s characteristics. However, these efforts often lack a strong connection between argumentation and conceptual science understanding (Dawson V. M., & Venville, 2010). Decision-making processes are facilitated through dialogic activities in pre-service training, yet a comprehensive understanding of the efficacy of argumentation schemes and critical questioning in improving the quality of students' dialogic argumentation remains an area to be fully examined (Kim et al., 2014). There has been a study addressing students' attitudes towards

controversial socio-scientific issues, particularly focusing on topics of a sexual nature, disregarding the roles of gender and participant backgrounds (Yahaya et al., 2016). Also, a study on perceptions regarding critical thinking and self-regulation in science learning through SSI has been explored, but it is not specific yet to examine how self-regulation and critical thinking can be developed in science teaching and learning (Wang et al., 2017). The use of multiple representations that mediate SSI argumentation in different forms and for different purposes. It did not examine the impact of peer influence on the use of diverse representations and students' argumentation processes (Wang et al., 2017). The integration of scientific argumentation within SSI serves as an indispensable scheme for fostering critical thinking skills, aiming to actively engage learners (Barrue & Albe, 2013; Khishfe, 2020). Some areas of SSI studies that have yet to be extensively explored include critical argumentation schemes in SSI, self-regulation, critical thinking, and students' multiple representations.

Systematic literature reviews are an essential component of educational research (Vojíř & Rusek, 2019). SLR, particularly in the field of science education, explicitly responded to various published scientific articles, including systematic maps of research and other relevant researches in numerous fields of science education (Bennett; et al., 2005). This study aims to look at how SSI studies are studied in the leading academic journals of *Science Education* [SE], *Journal of Research in Science Teaching* [JRST], *Science and Education* [S&E], *International Journal of Science Education* [IJSE] and *Research in Science Education* [RSE]). The rationale for the choice of these five journals SE, JRST, S&E, IJSE and RSE from 2004 to 2015 is that they are the major journals that have high impact factors in science education research (Tekin et al., 2016). This assessment encompasses the evolution of discussed topics, connections between different research themes, emerging patterns in methodological approaches, and a detailed exploration of the countries that have emerged as significant contributors in this research field. The inclusion of these five selected journals is also in alignment with the methodology applied in the study by Luo et al. (2023), wherein they utilised JRST, IJSE, RSE, SE, and S&E from 2017 to 2021, as well as the content analysis of publications in selected journals (Tsai & Lydia Wen, 2005; Lin et al., 2014). It is worth noting that high quality journals do not only provide a robust platform for scholarly discourse but also serve as catalysts for the advancement and development of the science education research (Lin et al., 2012). The identification result of the citation score for the aforementioned selected journals, as determined through the Scopus database, reveals SE (9.3), JRST (8.2), S&E (4.5), IJSE (4.7) RSE (5.4).

Comprehensive review studies of SSIs have previously been conducted, specifically focusing on content analysis studies covering the period from 2004 to 2015, originating from a selection of selected journals. This study delved into the domain of research methodologies employed, topic explorations, and sample demographics. However, it is noteworthy that the analysis remained confined to these dimensions and did not extend to encompass the complicated aspects of authors' identities, author specifications, and the extent of content knowledge underpinning the SSIs addressed in the examined articles (Tekin et al., 2016). However, this study does not explicitly examine the impact of the relationship between SSI issues and complex reasoning, sophisticated argumentation, and a deep understanding of science (Sadler, 2004). Several articles have been reviewed to contextualise the connection between SSI and the Nature of Science. This study has focused on reviewing 7 articles spanning from 2002 to 2014 (Karisan & Zeidler, 2016). Reviews on decision-making within the context of SSIs (Jho, 2015; Fang et al., 2019), SSIs and technology in problem-based learning (Hernández-Ramos et al., 2021), SSIs in science education in Turkey from 2002 to 2012 (Topçu et al., 2014) as well as review on SSIs for chemistry education (Çalık & Wiyarsi, 2021)

Despite the increasing number of research publications on SSIs each year, the underlying trends within this research domain remain unclear. This current study complements a range of previous review articles, offering a comprehensive evaluation of SSI research trends from the past 11 years (2011 – 2022).

To obtain the objective of this study, authors formulate the research questions as follows:

a. How were the research topic trends of the selected articles in these five journals from

2011 to 2022?

b. What methods were mostly employed in the selected articles in these five journals from 2011 to 2022?

c. How did the research types of the selected articles in these five journals change from 2011 to 2022?

d. Which country contributed the most to the SSI research publication in these five journals from 2011 to 2022?

e. What are the most cited articles regarding SSI in these five journals from 2011 to 2022?

Methods

This study comprehensively presents various SSI studies in science education. A Systematic Literature Review (SLR) was systematically carried out to identify, select, and collect all relevant research materials directly related to SSI and associated with the research questions (Kitchenham et al., 2010). The process and methodology in this study employed a systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model (Moher et al., 2009). The stages specifically adhered to the steps outlined by Kitchenham (2004) as follows:

a. Specifying research questions
b. Conducting database searches
c. Determining Inclusion/Exclusion criteria
d. Selecting relevant studies
e. Analysing and extracting data
f. Summarizing and interpreting findings
g. Writing the review report

Journal Research Methodology

A systematic review serves as a comprehensive exploration across specific electronic databases and web search engines to access scholarly literature and academic resources (Kalogiannakis et al., 2021). At this initial stage, the search for articles from various journal sources was open, allowing the search for articles as well as a broader description (Lee et al., 2009; Chang et al., 2010; Teo et al., 2014). Specific criteria were determined to facilitate the screening of diverse studies, selecting, and limiting the scope to encompass those directly relevant to the research topic while excluding studies deemed unnecessary. The inclusion and exclusion criteria were defined as follows:

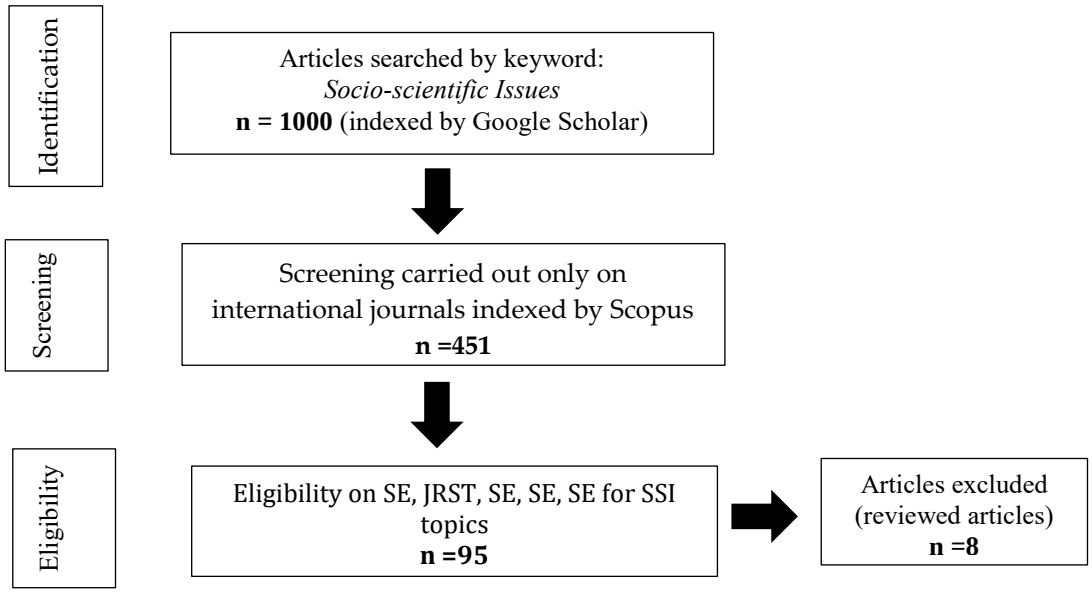
Inclusion	Exclusion
1. The studies must involve empirical research methods (quantitative, qualitative, and mixed methods)	1. The studies are not written in English.
2. The studies must be implemented at specified educational levels (kindergarten, primary, secondary, and higher education)	2. The studies are in the form of books or theses.
3. The SSI studies must be related to science education (chemistry, physics, biology, health, and natural science)	3. The studies are in the form of review articles.
4. The selected articles must be peer-reviewed.	4. The studies only publish abstracts
5. The selected articles must be sourced from five reputable and Scopus-indexed science education journals, such as Science Education (SE), Journal of Research in Science Teaching (JRST), Science & Education (S&E), International Journal of Science	5. The studies do not specifically examine SSI.

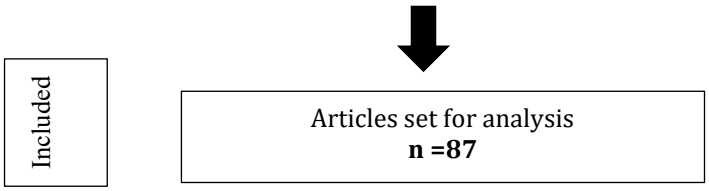
Education (IJSE), and Research in Science Education (RSE), which were published between 2011 and 2022.

Referring to the results of the initial search, 1000 articles indexed by Google Scholar were gathered. Google Scholar was selected due to its standing as a comprehensive academic search engine at present (Gusenbauer, 2019). the '*publish or perish software*' search engine on October 12, 2022 was applied to '*socio-scientific issues*' OR 'socioscientific' AND 'science education' keywords, with publication periods ranging from 2011 to 2022. The criteria for Scopus-indexed international journals were then applied, leaving 451 journal articles. Only articles from reputable international journals indexed by Scopus in Science Education [SE] journals, Journal of Research in Science Teaching [JRST], Science and Education [S&E], International Journal of Science Education [IJSE], and Research in Science Education [RSE]) (Tekin et al., 2016; Luo et al., 2023). This screening process resulted in the identification of 87 of 451 articles that warranted further investigation, following the exclusion of 8 articles due to their nature as literature reviews (Figure 1). The thematic analysis procedure employed in this review referred to the framework proposed by Braun & Clarke (2006). Each author independently engaged in the thorough reading and an in-depth examination of each article, aiming to acquire a comprehensive understanding of their content, methodologies, procedures, and research findings. Each identified theme was systematically documented in a Microsoft Excel table, facilitating subsequent comparison and discussion. A systematic keyword searching was employed to gather data. To ensure accuracy and cohesiveness in the findings of this study, a comprehensive document analysis was conducted. The following essential information was derived from each article: (a) methods; (b) research topic; (c) research sample; (d) research location; (e) data collection tools; and (f) most cited articles. The study's focal points were identified and grouped into different clusters. The density mapping of the co-authoring network of researchers was executed through the utilisation of the VOS Viewer software (Kamdem et al., 2019; Karimi Takalo et al., 2021). Finally, the finding indicates that the ensuing cartographic representation revealed that the distribution of analysed articles was as follows: Science Education (SE) 7 (8.04%), Journal of Research in Science Teaching (JRST) 15 (17.24%), Science & Education (S&E) 12 (13.79%), International Journal of Science Education (IJSE) 36 (41.37%), and Research in Science Education (RSE) 17 (19.54%). An overview of the stages involved in the article search is succinctly depicted in Figure 1.

Figure 1

Flow Chart of the Article Search Stages





Findings and Discussion

Research Types and Data Collection Tools

Research types are presented in Table 1. Qualitative research had the highest percentage (56,3%). IJSE contributed the most in qualitative research too. It also made the greatest contribution to quantitative research (63,15%), and 47,4% to mixed-research methods. The prevalence of qualitative methods highlights the complexity and multidimensionality inherent in SSI studies. This tendency for qualitative methodologies arises from the recognition that SSI investigations were complex and often defy straightforward experimental settings (Tetnowski & Damico, 2001). Qualitative studies in the realm of SSI result in a more comprehensive insight into the subject matter (Kolstø et al., 2006). Notably, most SSI studies use qualitative methods including SSI argumentation (Lee et al., 2020; Cebrián-Robles et al., 2021; Khishfe, 2021; Christenson & Walan, 2022) and decision-making (Lee et al., 2020; Cebrián-Robles et al., 2021; Ladachart & Ladachart, 2022) being particularly prominent examples. Certain SSI studies necessitate the application of quantitative methodologies to facilitate generalisation, such as the development of SSI instruments (Çalik & Coll, 2012; Sakschewski et al., 2014;) and the examination of SSI reasoning (Romine et al., 2020; Cian, 2020). The Nature of Science (NOS) within SSI emerged dominantly through mixed methods approaches (Khishfe et al., 2017; Herman et al., 2019). The combination of quantitative and qualitative elements within mixed methods studies enriches understanding by bridging micro and macro domains, culminating in holistic conclusions (Azorin, J.M., & Cameron, 2010).

Table 1

Research Types

Research types	Number of Articles	Percentage (%)
Qualitative	49	56,4
Quantitative	19	21,8
Mixed-Methods	19	21,8

The collected data reveal similarities among various data collection procedures. The percentage of articles reviewed using data collection tools is shown in Table 2. Based on this finding, it was determined that interviews (12,6%), open-ended questions (11,5%), and questionnaires (11,5%) were the most popular methods for collecting data on the SSI topics. The majority of the articles (25.3%) employed multiple data collection methods. Interviews, open-ended questions, audio and video transcription were the primary tools employed for data collection in qualitative and mixed methods approaches. Conversely, tests and questionnaires served as the primary data collection instruments in quantitative methodologies. Several studies employed multiple data collection tools, both qualitative (Gardner & Jones, 2011; Barrue & Albe, 2013; Karahan & Roehrig, 2017; Lee & Yang, 2019; Christodoulou et al., 2021) and quantitative (Bayram-Jacobs, 2019). Researchers opted for the utilisation of two to three data collection tools to improve the strength of their findings. This study also figured out the integration of technology in SSI data collection through computer log (Zhang &

Hsu, 2021).

Table 2

Data Collection Tools

Data Collection Tools	Number of Articles	Percentage (%)
Interview	11	12.6
Open Ended Question	10	11.5
Questionnaire	10	11.5
Audio Transcription	8	9.2
Documents	5	5.7
Video Recorded	5	5.7
Survey	4	4.6
Test	3	3.4
Research Report	2	2.3
Essay	1	1.1
Short answer questions	1	1.1
Computer Log	1	1.1
Annotation	1	1.1
Narrative Notes	1	1.1
Observation	1	1.1
Multiple Choice	1	1.1
Multiple Data Collection	22	25.3

Research Topics

In the following stage, a total of 87 articles were processed to be manually analysed by identifying titles, abstracts, and keyword lists, as in the study conducted by Erduran et al., (2015). Table 3 reveals that the topics with the highest percentage are argumentation (20,7%), decision-making (17,2%), nature of science (8%), and reasoning (8%). The categorisation of the article topics in this study was based on the studies conducted by Dewi et al., (2021) and Kalogiannakis et al., (2021).

Numerous studies have been conducted concerning argumentation in the context of SSI. Argumentation in SSI involving both science and language teachers in a collaborative project has been explored (Christenson et al., 2017). Argumentation through discussion activities has also been investigated (Nielsen, 2012). The correlation between argumentation, opinions, and decision-making in dialogues has been examined (Kim et al., 2014). Cultural perspectives have also been considered in SSI argumentation (Balgopal et al., 2017; Lee et al., 2020), as well as the use of teachers' PCK (Pedagogical Content Knowledge) for scientific SSI argumentation (Kutluca, 2021). The intersection of NOS and argumentation in the context of both SSI and non-SSI has also been explored (Khishfe, 2022). Additionally, the use of multiple representations in scientific argumentation has been explored (Namdar & Shen, 2016). It has been found that increased issue familiarity with SSI topics can enhance the diversity of discipline-related arguments among school students (Garrecht et al., 2021). The implementation of group-based discussions has been shown to stimulate students' argumentation, with shifts in their perspectives observed following group-based negotiation (Jafari & Meisert, 2022). Studies have evaluated SSI argumentation in a persuasive manner, encompassing the assessment of argumentative structures such as 'elements of argument', 'content of argument', 'rhetoric of argument', 'characteristics of arguer', and 'argumentative relationship with SSI' (Capkinoglu et al., 2021). The findings in the realm of SSI argumentation studies include the construction of arguments through dialogues and discussions, the enrichment of argumentative structures, and the utilisation of multiple representations in argumentation. This study reinforces the strong correlation between SSI and the

development of argumentation.

Numerous studies on decision-making within SSI domain have also been carried out. Noteworthy investigations have revolved around encouraging pupil engagement in decision-making processes in classroom activities. The study related to the issues in particular, focuses on student positioning and teacher-pupil interactions as pivotal elements shaping the dynamics of decision-making (Bossér & Lindahl, 2019). Additionally, the correlation between debate, decision-making, and fostering democratic participation in SSI has been explored (Ottander & Simon, 2021). The implementation of local SSI, drawing from domains such as media literacy and the Nature of Technology (NOT), has been strategically leveraged to facilitate pupil decision-making processes (Menke et al., 2022). The effect of NOS comprehension on decision-making in the SSI context has also been examined (Adal & Cakiroglu, 2022). Furthermore, the pedagogical proposition of embedding local cultural-based SSI into science learning has received attention, emphasising the alignment with the characteristics of global citizens through decision-making and informal reasoning frameworks (Ladachart & Ladachart, 2021). The unprecedented challenges posed by the Covid-19 pandemic have led to the exploration of decision-making facilitation through thinking and action (Herman et al., 2022) and collective decision-making within collaborative environments (Zhang & Hsu, 2021). It's noteworthy that studies on decision-making are often intricately intertwined with complementary skills and competencies, such as the understanding of the Nature of Science (NOS), reasoning, debate, and scientific argumentation. The essential core of SSI, characterised by unstructured and multifaceted topics, naturally lends itself as a fertile ground for the cultivation of decision-making competencies (Zamakhsyari, 2020; Christodoulou et al., 2021).

Table 3

Research Topics in Selected Articles

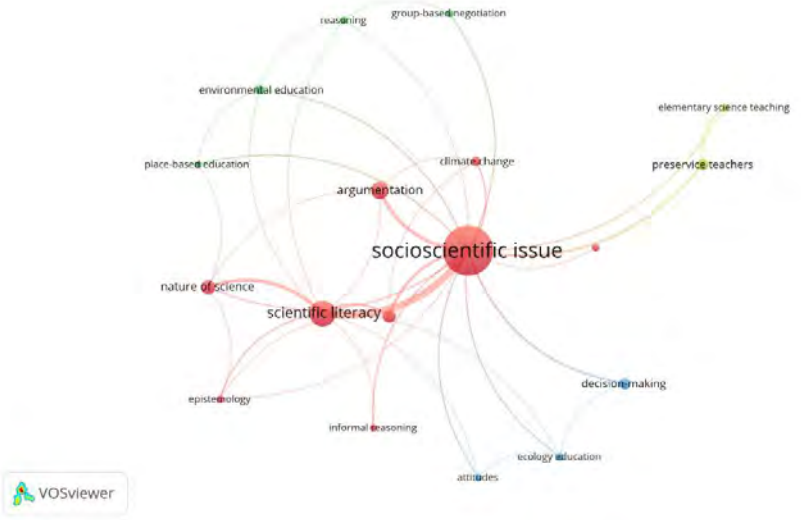
Topics	Total	Percentage (%)
Argumentation	18	20.7
Decision Making	15	17.2
Nature of science	7	8.0
Reasoning	7	8.0
Classroom practices	4	4.6
Attitudes	3	3.4
Discussion	3	3.4
Epistemological view	3	3.4
Character and Value	2	2.3
Conceptual studies	2	2.3
Critical Thinking	2	2.3
Curriculum	2	2.3
Efficacy	2	2.3
Instrument Development	2	2.3
Sustainability	2	2.3
Citizenship	1	1.1
Contemporary SSI	1	1.1
Debates	1	1.1
Emotions	1	1.1
Ethics	1	1.1
Informal reasoning	1	1.1
Narrative Text	1	1.1
Opinion	1	1.1
Pedagogical Content Knowledge	1	1.1
Perspective	1	1.1

Place Based Understanding	1	1.1
Scientific Inquiry	1	1.1
Textbooks	1	1.1

In addition to manual identification, co-occurrence or co-word analysis was employed to determine the article topics based on the relationship of keywords in titles, abstracts, or keyword lists. If the same keywords frequently appear interrelated, it indicates that the discussion in the article is sufficiently close (Zupic & Čater, 2015). The articles' co-word analysis contained a total of 168 co-occurring keywords, as shown in Figure 3. The closest co-occurring keywords directly related to SSI were scientific literacy, argumentation, and nature of science. On overlay visualisation, new keywords appeared on articles in 2021 and 2022, including place-based education, environmental education, group-based negotiation, as shown in Figure 2.

Figure 2

Keywords of Network Map Co-occurrence



A number of popular SSI topics related to argumentation included multidisciplinary argumentation (Garrecht et al., 2021), measurement of argumentation quality related to local socio-scientific issues (Capkinoglu et al., 2020), pedagogical content knowledge in teacher SSI argumentation (Kutluca, 2021), the relationship between students' disciplinary backgrounds and their SSI argumentation (Christenson et al., 2014), developing prospective teachers' competences in assessing SSI argumentation (Christenson & Walan, 2022), the relationship between the nature of science and scientific argumentation (Khishfe, 2022), argumentation and reasoning in group negotiations in the SSI context (Jafari & Meisert, 2022) as well as studies on the combination of debate and reflection activity in developing student argumentation (Bächtold & Pallarès, 2022).

Several other related studies comprised of scientific thinking and learner decision-making in learning (Menke et al., 2022), democratic citizen participation in decision-making and debate in the SSI context (K. Ottander & Simon, 2021), understanding the nature of science and deep decision-making through a referendum simulation in the SSI context (Adal & Cakiroglu, 2022), decision-making and informal reasoning in SSI agriculture (Ladachart & Ladachart, 2022), and the measurement of collective decision-making In students (Zhang & Hsu, 2021).

Several new topics in 2020 included SSI-based exhibitions with characteristics of critical reflection, contextualised information, and opinion sharing (Yun et al., 2022), compensatory weighting as the preferred strategy for decisions in SSIs, the cartography of controversy approach

was used to analyse the complexity controversy over SSI (Jafari & Meisert, 2022) as well as studies on the effect of SSIs on self-efficacy of science teaching (Kinskey & Callahan, 2021). Cartography of Controversy (CoC) approach in enabling students to understand and communicate about socioscientific issues. The method was used to explore and represent complex socioscientific issues. It involved mapping out the different perspectives, knowledge types, and uncertainties surrounding a controversy.

Research Samples

According to Table 4, the largest research sample groups were middle and high school (42,5%) pupils with contributions to IJSE, totalling 18.4%. A total of 16 studies at this level employed a qualitative approach (Balgopal et al., 2017; Herman et al., 2021; Kutluca, 2021). Among these, review of scientific argumentation has garnered significant interest from researchers, particularly in classroom settings (Evagorou & Osborne, 2013; Rudsberg et al., 2013; Capkinoglu et al., 2020; Bächtold & Pallarès, 2022). Studies focusing on character and value aspects of SSI within this level are limited (Lee et al., 2013), offering a substantial potential avenue for future studies. The reinforcement of character and values is crucial for imparting to pupils, emphasising the significance of this endeavour (Lee et al., 2012). The second-ranked group of samples is comprised of pre-service teachers, making up 27.6% of the total, with the International Journal of Science Education (IJSE) contributing the most (17.2%). Studies involving this sample category predominantly examined topics related to argumentation (Balgopal et al., 2017; Baytelman, 2020; Capkinoglu et al., 2021) and decision-making (Ladachart & Ladachart, 2022; Adal & Cakiroglu, 2022). Although studies exploring scientific inquiry within pre-service teacher training have been conducted (Eastwood et al., 2013), the scope of such investigations remains relatively limited, indicating a promising avenue for future studies in this domain. There were no pre-school group research samples. Providing a scientific environment stimulation from an early age is imperative (Tu, 2006). Thereby, conducting SSI studies at the pre-school level holds significant potential for future studies.

Table 4

Number of Articles Based on the Research Sample Groups

Research Samples	Total	Percentage
Middle and High School	37	42.5
Preservice Teacher	24	27.6
Primary School	10	11.5
Teacher	8	9.2
Undergraduate Students	5	5.7
Lecturer	1	1.1
None	2	2.3
Total	87	100

Research Sites Discussing SSIs

Upon analysing 87 articles, only 82 articles were acquired that specified the location of the research. Table 5 shows that countries in the European continent featured the most, followed by Asia. Studies conducted in Europe reveal that the topic of SSI argumentation has garnered significant attention, maintaining its popularity even in 2022 (Bächtold & Pallarès, 2022; Jafari & Meisert, 2022; Christenson & Walan, 2022). This emphasis on argumentation remains prominent, particularly concerning middle and high school students as well as pre-service teachers. However, few studies examined attitudes (Klaver & Molen, 2021); ethics (Saunders & Rennie, 2013), and

scientific inquiry (Eastwood et al., 2013). The development of science education in Europe is also influenced by biodiversity citizen science initiatives, which contribute to shaping pedagogical approaches (Jenkins, 2001; Van der Wende, 2011; Kelemen-Finan et al., 2018). Meanwhile, few countries on the American and Australian continents have studied this topic. The location of the author's affiliation does not always fit that of the research, as one carried out by Dewi et al. (2021). Researchers from 14 European countries participated in the studies. Meanwhile, the United States has studied SSI the most, with 22 articles (25,3%), followed by Sweden with 7 articles (8%). Popular studies in science education in the USA are decision making (Herman et al., 2022; Menke et al., 2022) and scientific argumentation (Namdar & Shen, 2016; Balgopal et al., 2017).

Table 5

Continental Locations of Different Countries

Continents	Countries
Asia	China, India, South Korea, Malaysia, Lebanon, Taiwan, and Thailand.
Europe	Denmark, Cyprus, Sweden, Turkey, UK, France, Netherlands, England, Germany, Portugal, and Greece.
America	USA and Canada
Australia/Oceania	Australia, New Zealand

Table 6

Distribution of the Number of Articles by Countries

Countries	Number of Articles	Percentage (%)
USA	22	25.3
Sweden	7	8.0
Turkey	7	8.0
South Korea	6	6.9
UK	6	6.9
Taiwan	4	4.6
Germany	4	4.6
Lebanon	3	3.4
France	3	3.4
New Zealand	3	3.4
Thailand	2	2.3
Denmark	2	2.3
Cyprus	2	2.3
Canada	2	2.3
Australia	2	2.3
China	2	2.3
India	1	1.1
Malaysia	1	1.1
Netherlands	1	1.1
Portugal	1	1.1
Greece	1	1.1
Not Detected	5	5.7

Most Cited Articles

Table 7 displays the 10 most cited articles from the 168 articles analysed, with a total of less than 100 citations. It is obvious that the article by Lederman et al. (2014) is the most frequently cited by other articles. This article investigates how teachers employ current socio-scientific issues to teach science materials. This study is also relevant to Eastwood et al. (2012)'s, which examines the explicit-

reflective contextualisation of SSIs in science learning.

This SSI study also mentioned characters and values (Lee et al., 2012; Lee et al., 2013), ethics (Saunders & Rennie, 2013), and the relationship between attitude and decision-making (Jho et al., 2014). These studies look at how a teacher fosters pupils' understanding of SSI contexts, as well as characters, ethics, and attitude in learners.

Table 7

The Most Cited Articles

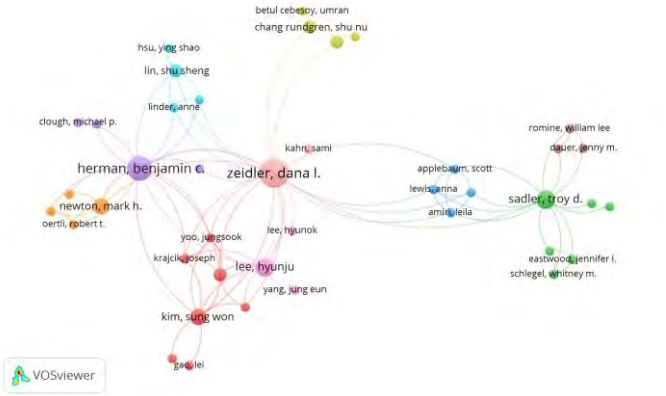
Authors	Article Titles	Number of Citations	Year	Journals
(Lederman et al., 2014)	Nature of Science, Scientific Inquiry, and Socio-Scientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry	364	2014	SE
(Evagorou & Osborne, 2013)	Exploring young students' collaborative argumentation within a socioscientific issue	272	2013	JRST
(Eastwood et al., 2012)	Contextualizing Nature of Science Instruction in Socioscientific Issues	267	2012	IJSE
(Lee et al., 2012)	Developing Character and Values for Global Citizens: Analysis of pre-service science teachers' Moral reasoning on socioscientific issues	215	2012	IJSE
(Lee et al., 2013)	Socioscientific Issues as a Vehicle for Promoting Character and Values for Global Citizens	210	2013	IJSE
(Khishfe, 2014)	Explicit Nature of Science and Argumentation Instruction in the Context of Socioscientific Issues: An Effect on Student Learning and Transfer	173	2014	IJSE
(Ottander & Ekborg, 2012)	Teachers' Experience of Working with Socio-scientific Issues:	166	2012	RSE

	A Large Scale and in Depth Study			
(Saunders & Rennie, 2013)	A Pedagogical Model for Ethical Inquiry into Socio-scientific Issues in Science	162	2013	RSE
(Bencze et al., 2012)	Students' Research-Informed Socio-scientific Activism: Re/Visions for a Sustainable Future	148	2011	RSE
(Jho et al., 2014)	The Relationship of Science Knowledge, Attitude and Decision Making on Socio-scientific Issues: The Case Study of Students' Debates on a Nuclear Power Plant in Korea	143	2013	S&E

Through author co-citation analysis in Figure 5, 210 authors meet the determined criteria. There are 10 cluster maps in the author co-citation map that can be recognised and indicated though different colours. Dana L. Zeidler of the Department of Teaching and Learning, College of Education, University of South Florida has the highest total link strength, with 29 out of 10 documents. Benjamin C. Herman of the Department of Learning, Teaching and Curriculum, College of Education, University of Missouri, Columbia, is another researcher with a second total link strength of 20. Benjamin, serving as the first author, co-authored with Dana L. Zeidler on several related papers. The third researcher with a total link strength of 13 is Hyunju Lee from WCU Global Institute for STS Education, Ewha Womans University, with 4 article documents.

Figure 5

Author Co-citation Map



Conclusion and Implications

An analysis of 87 articles from top-tier journals in the field of science education reveals that IJSE had the most published SSI articles, with 36 in numbers. With a 56,3% contribution, qualitative research methods are the most commonly employed in research. While argumentation, decision-making, and nature of science are the most frequently discussed topics in SSIs. Middle and high

school students make up the majority of the sample groups (42.4%). The European continent is widely used as research sites (14 countries), but the United States has the most articles about research sites (22 articles). Interview (12,6%) is the most commonly used data collection tool. The most cited articles in 2014 by S&E were Nature of Science, Scientific Inquiry, and Socio-Scientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry, which received 364 citations. These findings suggest that the SSI studies have been improved year after year. The following are several points of recommendations for researchers regarding SSI studies:

- The scope of research topics relevant to SSI remains broad, and areas such as efficacy, emotion, and attitude have received limited attention.
- Further exploration is needed in investigating SSI studies in the context of early childhood education.
- There is a potential to conduct cross-country studies in the domain of SSI, particularly by focusing on biodiversity-related issues that are unique and distinct to various regions. Currently, a majority of SSI studies are confined to samples from a single country, limiting the broader perspective that international collaboration can provide.

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