STRENGTHENING THE TENSION OF SOCIO-SCIENTIFIC ISSUES BASED LEARNING TO PROMOTING DEMOCRATIC LIFE: A SYSTEMATIC REVIEW

Laras Firdaus¹, Hunaepi², Herdiyana Fitriani³, & Taufik Samsuri⁴

¹,²,³&⁴Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Pemuda Street Number 59A, Mataram, West Nusa Tenggara 83125, Indonesia
*Email: larasfirdaus@undikma.ac.id
Submit: 05-08-2023; Revised: 20-08-2023; Accepted: 21-08-2023; Published: 30-12-2023

ABSTRACT: Currently, Socio-Scientific Issues (SSI) are a learning approach that is widely used by educators, not only helping students to understand a topic but also improving students' scientific literacy skills, such as critical thinking, argumentation skills, and decision-making. Various studies related to SSI have been published but cannot provide specific recommendations for future SSI studies. Therefore, a research systematic review of literature related to SSI was carried out to identify and determine research trends related to SSI as a basis for conducting further SSI studies. In conducting this literature review, we collected SSI-related information from the Google Scholar publication database using socio-scientific issues as search keywords. In collecting and selecting it using PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis), 155 articles were found that met the predetermined criteria for further analysis using Vosviewer. From the results of the analysis that has been done, decision-making is an item that has been studied a lot related to SSI. Thus, this item (decision-making) is recommended for further study.

Keywords: Socio-Scientific Issues, PRISMA, Vosviewer.


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INTRODUCTION

Integrating controversial issues into learning is called socio-scientific issues (Cebesoy & Rundgren, 2021; Kutluca, 2021; Yapıcıoğlu & Kaptan, 2017), and recently, Socio-Scientific Issues (SSI) has been widely used by educators (Karpudewan & Roth, 2016), to help students master scientific literacy skills as the primary goal of education (Barrue & Albe, 2013; Cayci, 2020; Cebesoy, 2021; Jafari & Meisert, 2021; Lubis et al., 2022; Nida et al., 2021; Pitiporntrapin et al., 2018; Solli, 2021; Yapıcıoğlu & Kaptan, 2017), including motivation, critical thinking, and the nature of science (Sadler et al., 2016), actively involved in making decisions to solve problems, both personal problems and problems that occur in society (Vesterinen et al., 2016). In short, using SSI facilitated students to use their knowledge to solve societal problems to create a democratic life (Nida et al., 2021).
Many experts have explained SSI with various models and from multiple perspectives (Atabey & Arslan, 2020; Atabey & Topcu, 2017; Genel & Topçu, 2016; Sadler et al., 2016). Nonetheless, at least, SSI-based learning is context-dependent learning (Cebesoy, 2021; Saputri et al., 2022), that is, it deals with open-ended, ill-structured, controversial, and complex problems (Çalık et al., 2014; Chang et al., 2014; Karahan & Roehrig, 2017, 2019; Sağlam & Ergölu, 2022), debateable, requires various considerations, perspectives, and solutions (Cebesoy, 2021; Chang et al., 2014; Eş & Öztürk, 2021), usually involves emotions and moral judgment (Guler, 2013; Kutluca & Aydin, 2016), not only related to issues or problems that occur in life (Sadler et al., 2016), such as cloning (Cebesoy, 2021; Özden, 2015), Genetic Modification of Organisms (GMO) (Cebesoy, 2021; Herman et al., 2020), pharmacogenomics, nuclear power plant, stem cell (Cebesoy, 2021), and global warming (Herman, 2015), but also deals with controversial conceptual issues (Sadler et al., 2016), such as the theory of evolution and climate change. Because of this, SSI is also sometimes called Controversial Science Issues (CSI) (Beniermann et al., 2021).

Related to SSI as a learning approach, several research finding show that SSI can improve student learning outcomes (increase students' understanding of scientific knowledge) (Chen & Šo, 2017; Lorite et al., 2023; Estigarribia et al., 2022; Karpudewan & Roth, 2016; Kolarova et al., 2013; Owens et al., 2020; Sadler et al., 2016; Wahono, Chang, et al., 2021; Wahono et al., 2021), the development of students' attitudes and motivation towards science (Bossér & Lindahl, 2020; Chang et al., 2013; Lindahl & Folkesson, 2016; Yahaya et al., 2016), related to epistemological beliefs (Baytelman et al., 2020; Chang et al., 2020; Eryasar & Kilinc, 2022; Hsu et al., 2014; Leung, 2020; Lin et al., 2020; Muis et al., 2021; Öztürk & Yilmaz-Tuzun, 2016; Zeidler et al., 2013), increasing students' understanding of the nature of science itself (Bilican, 2018; Christenson & Walan, 2023; Karahan et al., 2017; Khishfe et al., 2017; Kutluca & Aydin, 2018), critical thinking (Gül & Akçay, 2020; Pratiwi et al., 2016; Solbes et al., 2018), argumentation (Anwar & Ali, 2020; Capkinoglu et al., 2020; Evagorou & Osborne, 2013; Grooms, 2020; Grooms et al., 2014; Jumadi et al., 2021; Khishfe, 2014; Kutluca & Aydin, 2016; Öçan & Balim, 2021; Robertshaw & Campbell, 2013; Torres & Cristancho, 2018; Türköz & Öztürk, 2019), related to metacognitive (Eggert et al., 2013; Hsu & Lin, 2017; Öztürk, 2017), informal reasoning (Cebesoy, 2021; Lorite et al., 2023; Karpudewan & Roth, 2016; Kolarova et al., 2013; Yapıcıoğlu & Aycan, 2018), socio-scientific reasoning (SSR) (Eggert et al., 2017; Kinslow et al., 2019; Owens et al., 2019, 2022; Romine et al., 2017), decision making (Grace et al., 2015; Gresch et al., 2013; Halim & Saat, 2017; Ladachart & Ladachart, 2021; Sakamoto et al., 2021; Zo‘bi, 2014).

From the description above, we know that SSI has been studied by many researchers using various methods. We do not deny all of this. However, we must understand that the results of studies conducted by researchers regarding SSI have yet to provide specific recommendations regarding topics or themes for further research related to SSI. Therefore, as part of the scientific culture, we need to
carry out a systematic analysis of the literature in our effort to find and determine future research topics related to SSI.

**METHOD**

This research is a systematic review of the literature that aims to identify research trends related to SSI. The research question to be answered is whether research themes are related to SSI, what items are trending related to SSI as a basis for further SSI studies. In the analysis, we collect articles related to socio-scientific issues from the Google Scholar publication database. In the collection and selection process, we use PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis), as shown in Picture 1. *First*, we collected data using Publish or Perish (PoP8) for Windows using socio-scientific issues as the search keywords. We will collect and analyze articles published in the last ten years (from 2013 to 2023). At this stage, we get 1000 publication data.

*Second*, from the 1000 data publications, we will choose only those in the form of articles. Alternatively, in this second stage, we eliminate publication data such as books, magazines or news, book chapters, research reports, and proceedings articles, and we also eliminate journal editorial statements. In this second phase, 769 articles were obtained (including articles published nationally and internationally). Furthermore, from these 769 articles, we selected articles related to SSI with several criteria. Among others, the article must be in the English language, not an article resulting from a theoretical review (literature analysis or meta-analysis). The article must be reputable. Finally, we obtained 155 articles related to SSI from this elimination process. Then, we visualize all these articles using Vosviewer for Windows version 1.6.19 to make the information more meaningful, including publication fluctuation, themes related to SSI, and author relationships.
RESULTS AND DISCUSSIONS

This study aims to identify and determine future research themes or topics related to SSI. Nonetheless, several points become the focus of discussion in this study, including publication fluctuations, trend items related to SSI, and relationships between authors.

Results

SSI is an essential part of education, providing opportunities for students to connect their knowledge with current issues, such as the use of technology, social issues (such as abortion) (Juntunen & Aksela, 2014). In short, SSI-based learning is believed to help students increase their motivation and scientific literacy skills (Sakamoto et al., 2021). From the screening results that have been carried out, fluctuations in the number of SSI-related article publications per year can be seen in Picture 2; namely, the highest publication occurred in 2016 (22 articles). Then, it decreased in 2017 (18 articles), 2018 and 2019 (15 articles) and increased again in 2020 (18 articles). Then, it decreases until 2023.

Picture 2. Number of Article Publications Related to SSI Screening Results in the Last 10 Years.

Picture 3 is a Vosviewer visualization network showing the relationships between items from the 155 articles analyzed, consisting of 87 items with 1354 links. The colour difference in each item indicates each cluster. From the 87 items, some items need to be visible. This is because each item overlaps between items and with every existing link. Then, Picture 4 shows items that are directly related to socio-scientific issues, including epistemic understanding, argumentation skill, complexity, attitude, tool, pre-service science teacher, lesson plan, informal reasoning, content knowledge, assessment, decision-making, responsibility, environmental issue, inquiry, training, respect, gmo, interest, science education, and other items.
Furthermore, Picture 5 (overlay visualization) shows items related to SSI that are being studied a lot, marked in yellow, where decision-making is the anchor item. Items in yellow, or related to them, are recommended for further study. In summary, the trend of items related to SSI can be seen in Picture 6, where decision making is related to scientific literacy, argumentation skills, debate, claim, training, multiple perspectives, nos understanding, critical thinking, perception, responsibility, environmental issues, epistemic understanding, and others.
Besides that, we can also visualize the relationship between authors in bibliometric analysis. In this process, we determined the criteria based on the number of documents for each author, namely, at least the author has 3 documents, and there are 21 authors. However, we take the top 10 authors (as shown in Table 1) and based on the relationship between authors (Picture 7), centred on Zeidler, Dana L; and Herman, Benjamin M (10 links). Then, Sadler, Troy D (6 links); Topcu, Mustafa M (5 links), Newton, Mark E (6 links), Atabey, Nejla; and Zangori, Laura (4 links each), Lee, Hyun-Ju; Rundgren, Shu-Nu Chang; Christenson, Nina; Karahan, Engin; and Roehrig, Gillian H (3 links each), and the Table 2 shows the top 10 most cited author.
Table 1. Top 10 Productive Authors.

<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Document</th>
<th>Affiliation</th>
<th>Country</th>
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<tbody>
<tr>
<td>1</td>
<td>Herman, Benjamin M</td>
<td>7</td>
<td>Department of Learning, Teaching and Curriculum, College of Education, University of Missouri.</td>
<td>Columbia, MO, USA</td>
</tr>
<tr>
<td>2</td>
<td>Zeidler, Dana L</td>
<td>7</td>
<td>Department of Teaching and Learning, University of South Florida.</td>
<td>Tampa, Florida, USA</td>
</tr>
<tr>
<td>3</td>
<td>Sadler, Troy D</td>
<td>7</td>
<td>The ReSTEM institute, University of Missouri.</td>
<td>Columbia, MO, USA</td>
</tr>
<tr>
<td>4</td>
<td>Topçu, Mustafa S</td>
<td>5</td>
<td>Department of Mathematics and Science Education, College of Education, Yıldız Technical University.</td>
<td>Istandbul, Turkey</td>
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<tr>
<td>5</td>
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<td>5</td>
<td>Department of Chemistry and Biomedical Sciences, Linnaeus University.</td>
<td>Sweden</td>
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<td>6</td>
<td>Lee, Hyun J</td>
<td>4</td>
<td>WCU Global Institute for STS Education, Ewha Womans University.</td>
<td>Seoul, Republic of Korea</td>
</tr>
<tr>
<td>7</td>
<td>Rundgren, Shu-Nu Chang</td>
<td>4</td>
<td>Faculty of Health, Science and Technology, Department of Engineering and Chemical Sciences, Karlstad University.</td>
<td>Karlstad, Sweden</td>
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<td>8</td>
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<td>4</td>
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<td>Holdrege, Lincoln, USA</td>
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<td>9</td>
<td>Dawson, Vaile</td>
<td>4</td>
<td>School of Education, University of Western Australia.</td>
<td>Perth, Australia</td>
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<td>10</td>
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<td>Faculty of Education, The University of Hong Kong.</td>
<td>Pokfulam, Hong Kong</td>
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</table>

Discussions

Publications Fluctuation

In this section, we will describe in general the results of our analysis. The research results related to SSI, which researchers have published, have inspired teachers, lecturers, and other researchers. Considering the number of SSI-related
publications in the last 10 years (as shown in Picture 2), 2016 was the year SSI-related articles were published (22 articles). The specified criteria and the database used strongly influence fluctuations in the number of published articles related to SSI.

Table 2. Top 10 Most Cited Author.

<table>
<thead>
<tr>
<th>No.</th>
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<th>Title</th>
<th>Source</th>
<th>Cited</th>
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<tr>
<td>2</td>
<td>Lee et al. (2013)</td>
<td>Socioscientific issues as a vehicle for promoting character and values for global citizens.</td>
<td>International Journal of Science Education.</td>
<td>92</td>
</tr>
<tr>
<td>3</td>
<td>Khishfe (2014)</td>
<td>Explicit nature of science and argumentation instruction in the context of socioscientific issues: An effect on student learning and transfer.</td>
<td>International Journal of Science Education.</td>
<td>88</td>
</tr>
<tr>
<td>5</td>
<td>Jho et al. (2013)</td>
<td>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.</td>
<td>Science &amp; Education.</td>
<td>72</td>
</tr>
<tr>
<td>6</td>
<td>Tidemand &amp; Nielsen (2017)</td>
<td>The role of socioscientific issues in biology teaching: From the perspective of teachers.</td>
<td>International Journal of Science Education.</td>
<td>69</td>
</tr>
<tr>
<td>9</td>
<td>Gresch et al. (2013)</td>
<td>Training in decision-making strategies: An approach to enhance students’ competence to deal with socio-scientific issues.</td>
<td>International Journal of Science Education.</td>
<td>58</td>
</tr>
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</table>
Quantitative Methods are the Most Widely Used to Study SSI in the Last 10 Years.

We do not analyze the method used to study SSI, but regarding this, we can photograph it through an overlay visualization, as shown in Picture 8, it can be said that the quantitative method is a method that is widely used to study SSI. The type of research is generally classified into quantitative, qualitative, and mixed research. As a research method, quantitative research is not only related to laboratories but is also widely used in social sciences, such as education or psychology (Rashid & Sipahi, 2021). In its process, quantitative research uses the rules of deductive logic to test, improve knowledge or solve problems by making systematic, standardized observations and then looking at the relationships between variables from a population. Because quantitative research works on populations, the findings are usually generalized to the entire population, which is one of the strengths of quantitative research. However, on the other hand, quantitative research cannot cover social phenomena (Rahman, 2016). But, in our view, all types of research have advantages and disadvantages. The choice of research method depends on the paradigm used by a researcher and the goals to be achieved (Daniel, 2016).

Researchers with a positivist view consider the world (reality) to be static, so quantitative research is chosen to explain a phenomenon, analyzing the data statistically (Rahman, 2016). Then, researchers who are of the view that humans socially construct reality and can be changed and understood subjectively will tend to choose qualitative methods (Daniel, 2016) to describe and provide a thorough interpretation of the phenomenon under study (Sousa, 2014), this can be done using various methods, such as phenomenology, grounded theory, hermeneutics, ethnography, content analysis, and phenomenography (Bengtsson, 2016). Meanwhile, researchers who think a phenomenon can be explained using two perspectives tend to use mixed methods (Dawadi et al., 2021; Walton, 2016; Warfa, 2016).

**Trend Items Related to SSI**

From the results of the analysis that has been done, as shown in Picture 6, decision-making is an item that has been studied a lot. As we know, SSI-based learning is context-dependent learning, using controversial issues that occur in
life, not an issue that is engineered to be controversial. The use of controversial issues, such as GMOs, cloning, and covid pandemic is expecting students to use their knowledge and participate (both personally and collectively) to solve and make decisions regarding these controversial issues (Gresch et al., 2015). Or in other word, helping students develop the ability to make decisions is a major element in educational goals (Cebeşoy & Rundgren, 2021; Fang et al., 2019).

Decision-making related to SSI is not simple, just relying on basic logic (cause and effect) (Sakamoto et al., 2021). However, this kind of process is an essential process in decision-making, looking at the pros and cons aspects of an issue before arriving at a final decision (Fang et al., 2019). In decision-making related to SSI, students must be able to see issues from multiple perspectives (Horin et al., 2023), ongoing inquiries, and exhibiting scepticism when presented potentially biased information (Ha et al., 2022).

Helping students make decisions regarding SSI is helping them not to make decisions intuitively but helping them to make decisions from various alternatives and points of view (Cebeşoy & Rundgren, 2021). In short, in making decisions related to SSI, students are not only required to use their knowledge including content knowledge (or conceptual knowledge) (Sakschewski et al., 2014), knowledge about ethics and morality (Steffen & Hößle, 2017), as an essential part of develop arguments and making decisions, they must be able to evaluate solutions critically (Sakamoto et al., 2021), but also in making decisions related to SSI, they are required to use their understanding of the nature of science (NOS), in which the NOS is a tool for obtaining knowledge, constructing arguments, and evaluating evidence (Bilican, 2018), improve students' personal qualities, and improve students' social-scientific skills (Yapıcıoğlu & Kaptan, 2017).

However, the NOS does not always provide assurance in making decisions regarding SSI because NOS is considered declarative knowledge. So, the students experience difficulty applying NOS as part of making decisions related to SSI (Leung, 2020). To solve open-ended or ill-structured problems, students need epistemic understanding (Öztürk & Tuzun, 2016), that is an understanding of knowledge is tentative, there are many methods to solve a problem (Carmona, 2021). Several studies have shown that epistemic understanding correlates with the quality of students' reasoning regarding SSI (Chang et al., 2020). Students who believe that knowledge is tentative are more readily accepting evidence that contradicts with their prior beliefs and knowledge (Leung et al., 2015). Therefore, expecting students to solve problems and make decisions related to SSI, it is recommended for teachers to provide epistemic understanding to students (Baytelman et al., 2020), this really helps students to be more productive in evaluating issues related to SSI from multiple perspectives (Leung, 2020).

**Relationship Between Authors**

If we pay attention to Table 1, the top 3 authors related to SSI are Sadler, Troy D; Herman, Benjamin M; and Zeidler, Dana L, with 7 documents each. Meanwhile, if we pay attention to Figure 7; Zeidler, Dana L collaborated with many authors. Of course, this provides distinct advantages for Zeidler and other authors. Meanwhile, there are (at least) two categories in this scientific
publication, namely single author or co-author, and of course, this benefits the
scientific community itself. However, published papers must be available in open
access to provide more benefits, allowing other authors to access or cite them
(Rodrigues et al., 2020).

Regarding scientific publications (especially articles), there has been a
significant increase in author collaboration (Abramo & D’Angelo, 2015; Eberle et
al., 2021; Estevez et al., 2022), caused by various factors, including the increasing
complexity and interdisciplinary nature of science, increasing production factor
costs in research projects, innovations in information and communication
technology. Various studies in scientometric literature offer empirical evidence
that co-authored publications achieve higher visibility and impact. In addition,
being part of the relevant scientific community and collaborating with other
researchers is very important for the scientific career development of an author (or
researcher) (Eberle et al., 2021).

Collaboration between authors can be understood in two aspects: different
authors but from the same country or institution (domestic collaboration) and
different authors (both from institutions and countries) or international
collaboration. Both forms of author collaboration (domestic and international)
positively impact authors. However, international collaboration is even more
important in increasing the citation rate far above domestic national collaboration
(Bote et al., 2013). Other benefits obtained in collaboration between authors are
improved quality of articles, gain much knowledge, authors can learn from
another author in the same article (Yeo & Lewis, 2019), increasing the number of
citations as they relate to scientific aspects and relevance, and have been used as
proxies for evaluating research in different scientific contexts, including
institutions (Estevez et al., 2022).

CONCLUSION

From the analysis that has been done, it is concluded that the most
published articles related to SSI were in 2016 (22 articles). There were top 10
authors, among which there were 3 most productive authors (Sadler, Troy D;
Herman, Benjamin M; and Zeidler, Dana L). In addition, the analysis results also
asked us to conclude that decision-making is a trend item related to SSI that has
been extensively explored quantitatively. However, it is necessary to understand
that SSI (in this case, decision-making as an SSI trend item) is not always studied
quantitatively but can also be studied qualitatively and in mixed methods, and
this, of course, depends on the paradigm used by the researcher.

SSI-based learning as learning that is synonymous with controversial
issues, ill-structured, involving various perspectives and solutions, such as GMOs,
cloning, and covid-19, is believed to be a means to prepare students to become
citizens who are actively involved in maintaining and shaping democratic life by
applying his knowledge to make decisions in solving problems that occur in life.

RECOMENDATIONS

A systematic literature review needs to be carried out in an effort to
identify and define research themes related to SSI in the future. From the results
of the analysis that has been done, future research is recommended to focus on decision-making. Suppose we pay attention to factors related to decision-making, such as content knowledge or conceptual understanding and epistemic understanding (including understanding of NOS). Then, the further studies can be carried out by looking at the relationship between these factors and the ability to make decisions related to SSI. It can also be done by increasing the ability to make decisions related to SSI. In addition, learning resources also have an impact on the quality of decision-making, so developing teaching materials related to SSI becomes something that can be recommended. Furthermore, regarding issues that can be used in further studies, we can use issues that are widely used (such as GMOs, cloning, weather changes, gene therapy, organ transplantation, and other conceptual issues), local issues, and ethical issues (such as abortion). In short, the selection and use of controversial issues are adjusted to the learning topic.

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