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A Systematic Review on Integrating SSI into Science Education: Its Impact on 21st Century Skills (2014-2024)

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Abstract

The Socio-Scientific Issues (SSI)-based learning approach has been recognized as an effective method in science education to develop students' essential skills. This study aims to explore the impact of SSI learning on six key skills: scientific literacy, critical thinking, problem-solving, social awareness and responsibility, argumentation, and collaborative and communicative skills. This research method uses the PRISMA guideline to review relevant literature. Articles were obtained from the Scopus database with the keywords "socio-scientific issues," "socioscientific issues," and "science education" which were limited to publications from 2014 to 2024. The results of the analysis of 46 articles showed that SSI-based learning can improve students' scientific literacy through the context of global issues, such as climate change and renewable energy, which provide a deeper scientific understanding. This learning also hones students' critical thinking skills by encouraging evaluation of evidence and analysis of multiple perspectives. In addition, the SSI approach encourages problem-solving skills by inviting students to find innovative solutions to environmental and health issues, as well as increasing their social awareness and responsibility. Students also develop argumentation skills through discussions and debates, as well as collaborative skills through SSI-based projects. In conclusion, SSI learning not only enriches students' scientific understanding but also prepares them with essential skills to face global challenges in the modern era.

Keywords: Socioscientific Issues, Science Education, 21st Century Skills.

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INTRODUCTION

Over the past decade, the integration of socioscientific issues into science education has become an increasingly important topic in efforts to improve students' scientific literacy, critical thinking skills, and social awareness (Zeidler et al., 2005; Sadler, 2011). SSIs involve issues that lie at the intersection of science, technology, and society, requiring ethical, environmental, and social considerations in decision-making. Examples of SSIs include climate change, biotechnology, renewable energy, and public health (Ratcliffe & Grace, 2003; Zeidler & Nichols, 2009). Because of their high relevance to everyday life, SSIs are believed to increase students' interest in science and motivate them to engage more deeply in learning (Lee et al., 2013). Science education often focuses on understanding abstract scientific concepts without much attention to their practical relevance and social context. As a result, students may have adequate scientific knowledge but lack understanding of how to apply this knowledge in everyday life and in dealing with complex social problems (Sadler & Zeidler, 2005; Kolstø, 2001). As an alternative, SSI provides a more holistic approach, which not only considers cognitive aspects but also affective ones, namely students' attitudes and values in scientific and social contexts (Zeidler et al., 2009; Zeidler & Nichols, 2009). Through SSI-based learning, students are invited to analyze and discuss real issues that are relevant to their lives, which in turn strengthens their argumentation skills and scientific literacy (Sadler & Donnelly, 2006). Various studies have shown that the implementation of SSI can strengthen students' critical thinking skills by encouraging them to consider multiple perspectives in the decision-making process (Albe, 2008; Klosterman & Sadler, 2010). Students involved in SSI discussions are expected to be able to examine information from various sources, identify biases, and evaluate the social and ethical implications of their decisions. This is particularly relevant in today's information age, where the ability to filter and evaluate information is critical (Zeidler et al., 2005; Sadler & Zeidler, 2009). Scientific literacy developed through the SSI approach includes a deep understanding of scientific concepts and a critical awareness of the social implications of technology and scientific developments (Evagorou et al., 2012; Chowning et al., 2012). However, the application of SSI in science education also faces a number of challenges. One of the main challenges is the readiness and competence of teachers in teaching with an SSI-based approach. Many teachers feel less confident in teaching controversial issues that require cross-disciplinary knowledge and skills in managing classroom discussions that may be full of differences of opinion (Lee & Witz, 2009; Levinson, 2006). Research shows that teachers often lack adequate resources and training to teach SSI effectively, and many feel that existing curricula are not flexible enough to accommodate issue-based learning (Presley et al., 2013; Reis & Galvão, 2004).

On the other hand, students themselves face difficulties in understanding SSI due to the complexity and interconnectedness of the scientific, ethical, and social aspects involved (Zeidler & Keefer, 2003; Sadler et al., 2007). These challenges are exacerbated by the lack of locally adapted teaching materials, which makes it difficult for students to relate SSI learning to their everyday experiences (Tal & Hoch, 2015). Therefore, the development of appropriate teaching materials and teaching strategies is urgently needed to help students understand and engage in SSI more effectively.

Several studies have shown that when SSI is presented in an interactive and discussion-based manner, students are better able to develop critical thinking skills and empathy for multiple perspectives (Albe, 2008; Tidemand & Nielsen, 2017). This approach can also help students understand that science is not a value-free activity, but rather a field that is closely tied to the needs and values of society. SSI facilitates learning that focuses not only on mastering scientific content but also on character building and developing critical scientific attitudes (Lee et al., 2013; Zeidler & Nichols, 2009). Given the growing interest in SSI, it is important to understand how this trend is evolving in science education across contexts and levels of

education. This article will review the literature published over the past decade (2014–2024) to identify trends, challenges, and impacts of SSI implementation in science education. Thus, it is expected to obtain comprehensive insights to advance science education that is more relevant and meaningful for students (Sadler et al., 2017; Evagorou et al., 2012). To explore this, the study will focus on the following questions:

a. How is the trend of SSI research publications in science education?
b. How are the most frequently studied SSI topics in science learning?
c. How is the impact of SSI in science learning on students' 21st century skills?

LITERATURE

The Importance of SSI in Science Education

In modern science education, the integration of Socio-Scientific Issues (SSI) has gained widespread attention as a learning approach that not only conveys scientific knowledge but also builds students' critical thinking skills, scientific literacy, and social awareness. SSI covers issues that are at the intersection of science, technology, and society, such as climate change, biotechnology, renewable energy, and antibiotic resistance (Zeidler et al., 2005; Sadler & Zeidler, 2005). These issues require students to consider not only scientific aspects but also social, ethical, and environmental dimensions in decision making (Ratcliffe & Grace, 2003; Sadler, 2011). According to Sadler and Donnelly (2006), this approach provides opportunities for students to understand the relevance of science in everyday life. SSI-based learning involves discussion, argumentation, and analysis of complex real issues, thus increasing students' motivation to learn science (Lee et al., 2013). In addition, SSI helps develop students' ability to think critically and construct arguments based on evidence, skills that are essential in today's information age.

Impact of SSI on Science Literacy

Scientific literacy is one of the key skills developed through SSI-based learning. Ratcliffe and Grace (2003) stated that scientific literacy includes not only understanding scientific concepts but also the ability to evaluate and interpret data in the context of global issues such as climate change or the greenhouse effect. Students who learn through an SSI approach are better able to relate scientific concepts to their daily lives, which ultimately increases their understanding of the impact of science on society. Evagorou et al. (2012) showed that SSI-based learning can deepen students' understanding of scientific concepts, especially through activities that encourage them to evaluate scientific evidence. For example, learning about renewable energy involves not only technical aspects such as energy efficiency but also examines the social and environmental implications of different types of energy sources.

Critical Thinking Skills in Development

Critical thinking skills are essential skills that result from SSI-based learning. Zeidler et al. (2009) explained that SSI provides a supportive environment for students to consider multiple perspectives before making decisions. In this context, students are trained to analyze data, evaluate sources of information, and consider the impact of each alternative solution.

According to Klosterman and Sadler (2010), SSI discussions often involve analyzing controversial issues such as genetically modified organisms (GMOs) or the use of nuclear energy. This process encourages students to ask critical questions, assess the evidence presented, and construct logical arguments. As a result, students are better able to make informed decisions, both in academic contexts and in everyday life.

The Role of SSI in Developing Social and Emotional Skills

Critical thinking skills are essential skills that result from SSI-based learning. Zeidler et al. (2009) explained that SSI provides a supportive environment for students to consider multiple perspectives before SSI not only focuses on cognitive aspects but also pays attention to the development of students' social and emotional skills. Lee et al. (2013) noted that SSI discussions can increase students' social awareness and responsibility for global issues such as climate change and food security. SSI-based projects are often designed to engage students in decision-making that considers social and ethical dimensions, thus forming an attitude of caring for the environment and society. Tidemand and Nielsen (2017) highlighted that SSI-based learning also strengthens students' collaboration skills. In group projects, students are invited to work together to find solutions to complex problems, listen to various views, and reach a common agreement. This experience not only improves students' communication skills but also builds their empathy for different perspectives.

METHOD

This study used a systematic review approach with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, which aims to identify, select, and synthesize research articles related to the integration of socioscientific issues in science education. PRISMA was chosen because it allows a transparent and structured review process at every stage of literature selection, from article identification to screening, final selection, and data analysis (Moher et al., 2009). The PRISMA protocol also helps ensure that this literature review is carried out to high-quality standards, providing reliable and replicable results.

Literature Research Procedure

The article search process was carried out through the Scopus database, one of the largest and most credible academic databases for research articles in various fields of science. The search used several main keywords related to this topic, namely "Socio-scientific Issues" OR "Socioscientific Issues" OR "SSI" AND "Science Education" OR "Science Teaching". The selection of these keywords aims to ensure the coverage of relevant and comprehensive articles on socio-scientific issues in the context of science learning. The article search was also limited to the years 2014-2024, with the type of research article document.

Inclusion and Exclusion Criteria

The article selection process was carried out based on inclusion and exclusion criteria to ensure the relevance and quality of the articles to be analyzed. The inclusion criteria in this study include articles that discuss socio-scientific issues in the context of science education, are written in English, and are available in open-access format. The exclusion criteria include articles that are not relevant to the topic of SSI in science education or are not written in English.

Data Analysis

Data from the selected articles were analyzed using a thematic synthesis approach to identify key trends, challenges, and strategies for SSI integration in science education. Through this analysis, the research findings were classified based on relevant categories, such as SSI-based learning methods, the impact of SSI on students' critical thinking skills, and the challenges faced by teachers in implementing SSI.

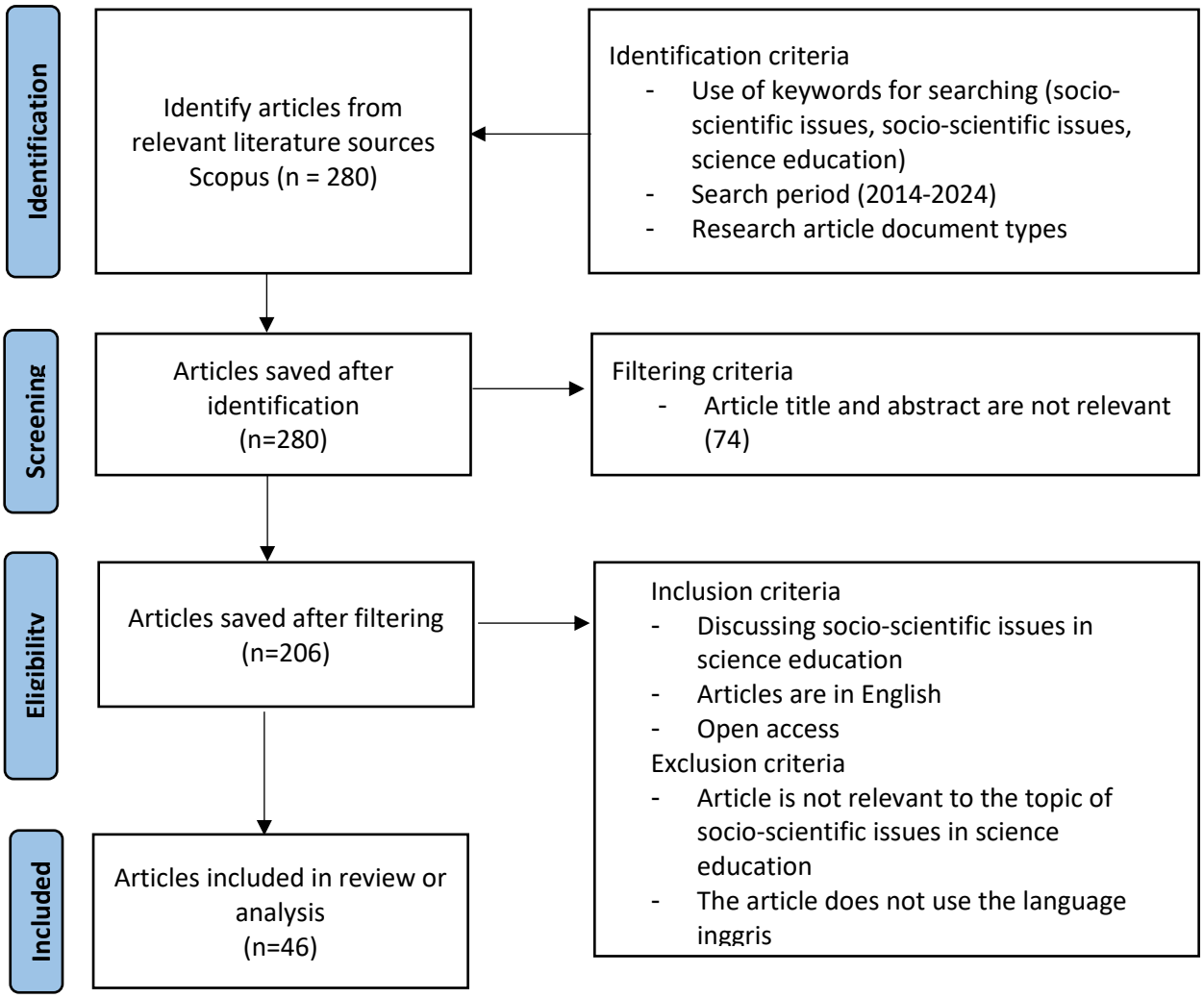

Figure 1. State Systematic Review

RESULTS

SSI Publications Trends in Science Education

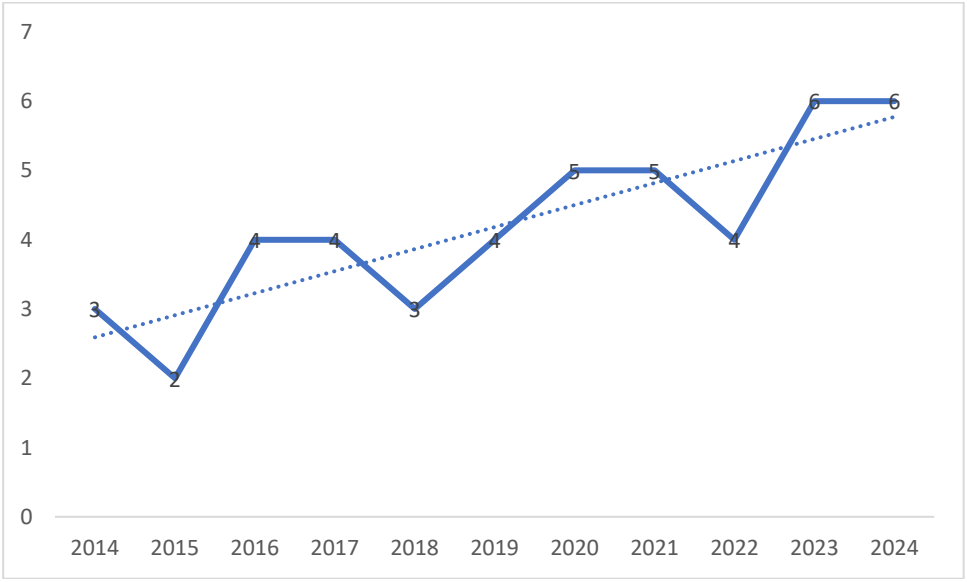

Figure 2. SSI research trends in science education

The graph shows the research trend related to Socio-Scientific Issues (SSI) in science education during the period 2014–2024. In general, there is a significant increase in the number of studies, as seen from the trend line that continues to climb. In 2014, the number of studies started with 3, but experienced a slight decrease in 2015 to 2. Then, the number of studies increased sharply to 4 in 2016 and remained until 2017. Although it dropped again to 3 in 2018, the trend rose again to 5 in 2020. After stabilizing at that number until 2021, the number of studies experienced a temporary decrease to 4 in 2022. However, the trend strengthened again with a significant increase to 6 in 2023 and remained stable until 2024. This pattern shows a growing interest in SSI research in science education, although accompanied by small fluctuations in certain years.

SSI Topics in Science Learning

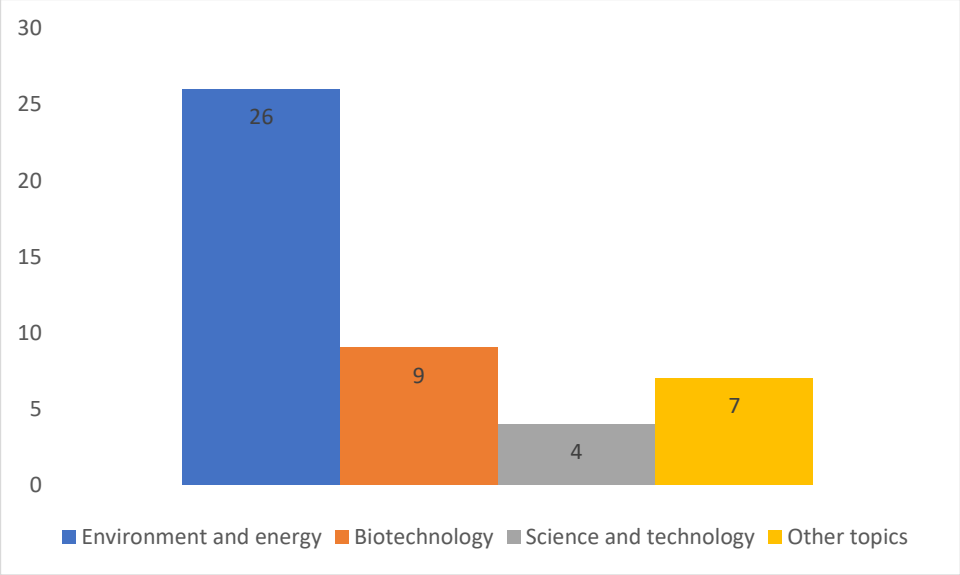

Figure 3. SSI topics in science learning

In SSI-based learning, the topics raised can be classified into four main groups: environment and energy, biotechnology, science and technology, and other topics. Environment and energy are the most dominant group with 26 articles, indicating the great attention to sustainability issues in science education. Overall, the SSI topics in science education divided into four main groups show how social issue-based learning can deepen students' understanding of scientific concepts while preparing them to face global challenges. By instilling critical thinking skills, ethical understanding, and scientific literacy, SSI learning offers a holistic approach that supports students' development as environmentally conscious and socially responsible citizens.

Impact of SSI in Science Learning on 21st Centiry Skills

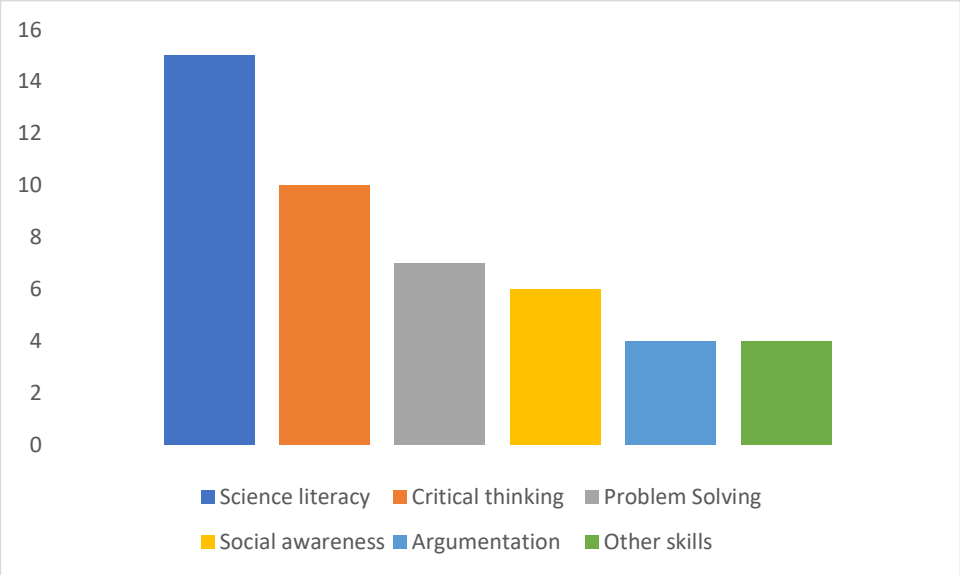

Figure 4. Impact of SSI in student skills

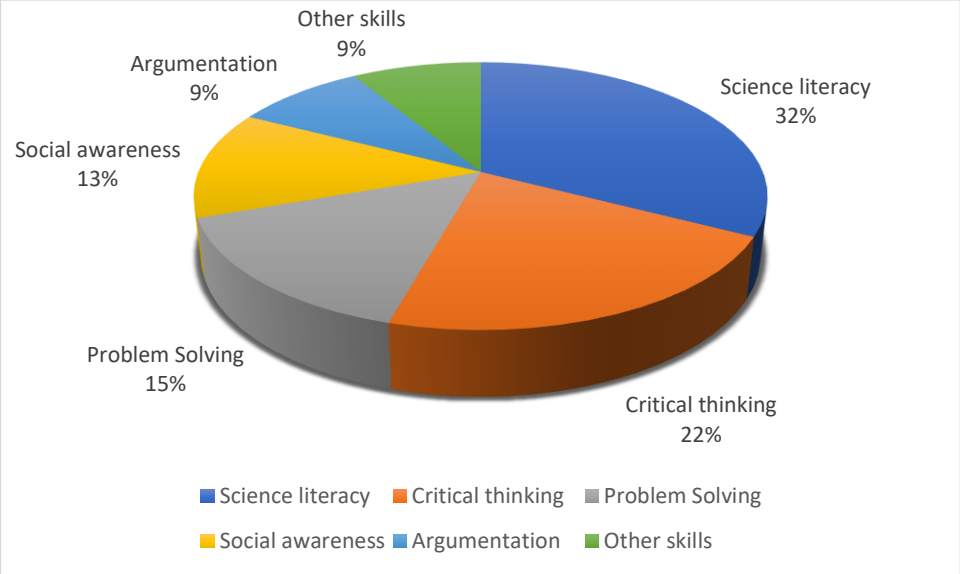

Figure 5. Percentage of student skills in SSI research

SSI-based learning in science education has a significant impact on the development of various important skills in students. One of the main skills developed through this approach is scientific literacy, where students are invited to understand scientific concepts in the context of real issues that are relevant to their lives. By connecting scientific theories to global issues such as climate change and energy sources, students learn to interpret scientific information critically and understand the role of science in solving social problems. This scientific literacy is not only important in the classroom, but also helps students become citizens who are able to understand and assess scientific information objectively in society.

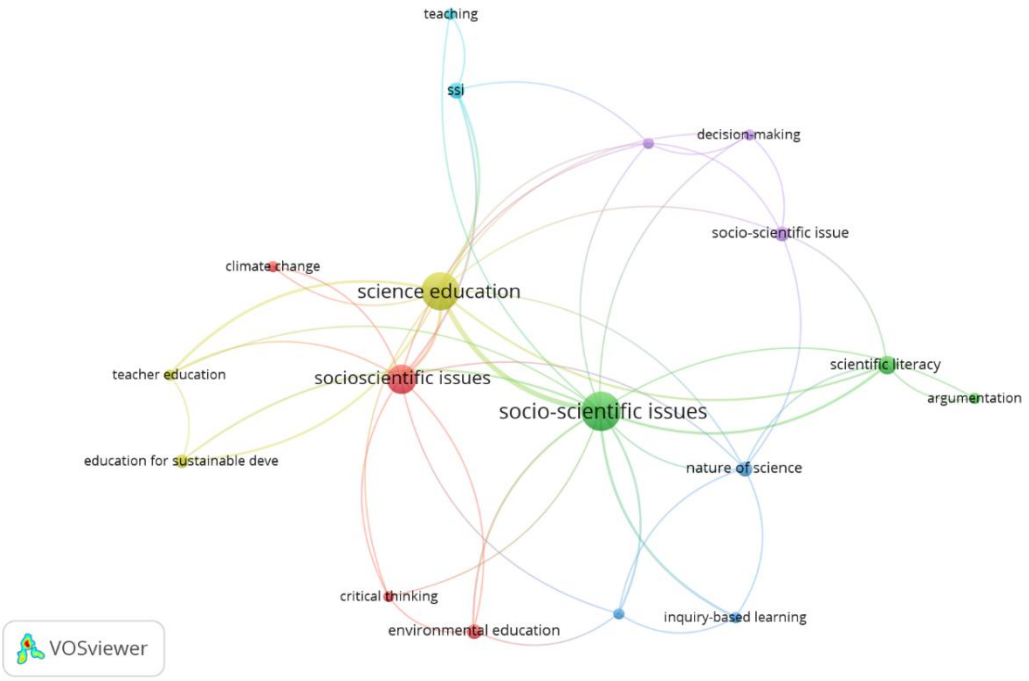

Figure 6. VOSviewer analysis

Visualization of the analysis results using VOSviewer software shows that SSI is a key concept that often appears in the literature related to science education. The main node of SSI has a strong relationship with keywords such as scientific literacy which is an important focus in the implementation of SSI. In addition, other clusters such as science education, teacher education, and education for sustainable development show the relationship between the development of teacher education and sustainability in science education. The relationship with keywords such as critical thinking, environmental education, and climate change reflects the role of SSI in improving critical thinking skills and awareness of environmental issues. This visualization provides a comprehensive picture of the strategic position of SSI in the science education literature, which can be a basis for further research.

Discussion

Overall, the publication trends of SSI research in science education indicate that while interest in SSI research in science education is not consistent across years, there are spikes in interest during certain periods. Factors such as developments in global social issues or educational policies may influence these fluctuations (Zeidler et al., 2005). Years with low publications may be due to shifts in research priorities or temporary changes in scientific focus. However, the increase in 2024 suggests a possible resurgence of interest in SSI, perhaps driven by the need to integrate scientific and social issues into science education amidst current global challenges.

Issues such as climate change, the greenhouse effect, and global warming are widely discussed to raise students' awareness of the impacts of human activities on the Earth's ecosystems. Lessons related to these topics often involve analysis of the carbon cycle and discussion of various energy sources, including comparisons between renewable and nuclear energy. In addition to imparting scientific knowledge, these topics also aim to develop students' decision-making skills in evaluating environmental policies and strategies that impact their daily lives.

The topic of biotechnology is also widely discussed, with 9 articles discussing developments in genetic technologies such as genetically modified organisms (GMOs), cloning, and gene therapy. These themes invite in-depth discussions on scientific ethics and the social impacts of biotechnology on society and ecosystems (Evagorou et al., (2012). In SSI learning, students are encouraged to evaluate the benefits of biotechnology in increasing food security or improving human health, while considering concerns about food safety, environmental sustainability, and potential threats to biodiversity. This topic trains students to think critically and argue by taking into account ethical aspects in the increasingly rapid scientific progress.

In the science and technology category, there are 4 articles that discuss the influence of technology such as artificial intelligence (AI) and space exploration. These issues teach students how science and technology play a major role in the advancement of human civilization and have a significant impact on various aspects of life. The discussion on AI, for example, not only covers its benefits in industrial automation but also invites students to consider ethical issues related to privacy and data security. Meanwhile, space exploration triggers discussions about the costs and benefits of space research, encouraging students to understand the limitations and potential that science offers in the fields of technology and innovation (Sadler & Zeidler, 2005).

The last group, other topics, includes 7 articles that focus on issues such as public health and scientific literacy, which although not as popular as the main topic, are still relevant in the context of SSI. The issue of antibiotic resistance is one of the important topics in this category, which educates students about the wise use of antibiotics and the dangers of resistance to medical treatment (Albe, 2008; Tidemand & Nielsen, 2017). In addition, scientific literacy raised in several articles aims to equip students with the ability to understand and evaluate scientific issues more objectively and critically. This group provides a broader learning framework, allowing students to relate science to social aspects, health, and public welfare. In addition to scientific literacy, critical thinking is an essential skill that students acquire through SSI learning. When faced with complex and controversial issues such as GMOs or nuclear energy, students are trained to evaluate various points of view, analyze evidence, and consider the impact of each decision taken. This process develops logical and structured thinking skills, where students learn to question information, analyze arguments, and draw conclusions reflectively. These critical thinking skills provide them with a strong foundation to face academic and everyday life challenges, where they are required to not only receive information but also understand it deeply.

Furthermore, SSI learning also strengthens students' problem-solving skills. When studying issues such as pollution or public health, students not only understand the problem but are also encouraged to find practical, impactful solutions. In this context, project-based learning is often implemented, which encourages students to develop innovative and sustainable solutions to environmental or health problems (Albe, 2008; Tidemand & Nielsen, 2017). This problem-solving process not only trains students' analytical skills but also encourages creativity and innovation, skills that are invaluable in facing real-world challenges that are often complex and require an evidence-based approach. In addition, SSI learning fosters social awareness and responsibility in students, as they are encouraged to consider the social and ethical impacts of the scientific issues they study. For example, when studying climate change, students not only understand the science behind the phenomenon but also realize the importance of their individual contributions to maintaining environmental sustainability. This awareness helps students become more sensitive to global challenges and fosters a sense of responsibility to participate in positive collective efforts. Thus, SSI learning shapes students into individuals who are not only knowledgeable but also have a social commitment to contribute to preserving nature (Ratcliffe & Grace, 2003).

Lee et al. (2013) explained that argumentation skills are also a significant impact of SSI learning, especially when students are involved in discussions on controversial topics such as renewable energy or biotechnology. In this discussion, students are trained to build arguments based on scientific evidence, formulate logical opinions, and communicate clearly and constructively. These argumentation skills are important not only to strengthen critical thinking skills but also to equip students to face situations where they have to debate or discuss in academic and professional environments. The evidence-based arguments they learn in science classes become the foundation for them in responding to different views in a respectful and constructive manner.

Finally, other skills such as collaboration, communication, and adaptability are also developed through SSI learning. Often, students work in groups to complete projects or present solutions related to the issues being studied. These skills are very relevant to the demands of the world of work that emphasizes collaborative skills and flexibility in solving problems Tidemand and Nielsen (2017). Overall, SSI-based learning offers a holistic approach that not only deepens students' scientific understanding, but also prepares them to become critical-thinking, socially responsible individuals with relevant skills to face challenges in the modern era.

CONCLUSION

This article concludes that the Socio-Scientific Issues (SSI)-based approach in science education makes a significant contribution to the development of 21st-century skills. This approach has been proven to be effective in improving students' scientific literacy, critical thinking, problem solving, social awareness and responsibility, evidence-based argumentation, and collaborative skills. Relevant topics such as climate change, renewable energy, biotechnology, and public health issues serve as learning frameworks that not only strengthen scientific understanding but also connect science to real life.

However, the implementation of SSI is not without challenges. Teacher readiness is a major obstacle, especially because many teachers feel less confident in discussing cross-disciplinary topics that are often controversial. The limitations of a rigid and inflexible curriculum also hinder the integration of SSI in science learning. In addition, the lack of contextual and relevant teaching materials to students' local environments makes SSI learning difficult to implement optimally.

Overall, this article shows that SSI-based learning not only enriches students' scientific understanding but also prepares them to face global challenges in the modern era. The development of more comprehensive teaching strategies and teacher training are important steps to optimize the potential of SSI in science education.

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