Jurnal Cakrawala Pendas
Vol. 11 No. 3, July 2025
DOI: http://dx.doi.org/10.31949/jcp.v11i3.13396

p-ISSN: 2442-7470
e-ISSN: 2579-4442

INTEGRATING SOCIO-SCIENTIFIC ISSUES (SSI) APPROACH BASED ON SDGS FOR GENERATION ALPHA IN ELEMENTARY SCHOOLS

Annas Solihin[1*], Suryanti[2], Enny Susiyawati[3], Julianto[4], Endang Susantini[5], Ari Metalin Ika Puspita[6]

[1,2,3,4,5,6]State University of Surabaya, Indonesia
[1]24010855015@mhs.unesa.ac.id

Abstract
Socio-Scientific Issues (SSI)-based learning has become increasingly significant in addressing global challenges, particularly for Generation Alpha, who are growing up in the digital era. This study aims to analyze the effectiveness of the SSI-based learning approach within the context of the Sustainable Development Goals (SDGs) at the elementary school level. A qualitative research approach with a case study design was employed, involving observations, interviews, and document analysis of educators and students from several elementary schools. The findings indicate that implementing SSI-based learning contributes to enhancing students' understanding of global issues while simultaneously strengthening critical thinking, problem-solving, and collaboration skills. Educators play a central role in designing interactive and technology-based learning strategies to increase student engagement. However, challenges remain in implementing this approach, including teachers' readiness and limited learning resources. Therefore, integrating SSI-based learning within the SDG framework in elementary education can be an effective strategy for improving students' scientific literacy and social awareness. Further research is needed to develop training strategies for educators and expand the implementation of this method across various educational contexts. In conclusion, integrating the SSI approach based on SDGs into science education in elementary schools has great potential to enhance scientific literacy, social awareness, and 21st-century skills among students.
Keywords: *Socio-Scientific Issues; Sustainable Development Goals; Generation Alpha; Elementary School; Learning*

Abstrak
Pembelajaran berbasis Socio-Scientific Issues (SSI) memiliki signifikansi yang semakin tinggi dalam menghadapi tantangan global, terutama bagi Generasi Alpha yang tumbuh di era digital. Penelitian ini bertujuan untuk menganalisis efektivitas pendekatan pembelajaran berbasis SSI dalam konteks Sustainable Development Goals (SDGs) di jenjang sekolah dasar. Metode penelitian yang digunakan adalah pendekatan kualitatif dengan desain studi kasus, mencakup observasi, wawancara, dan analisis dokumen terhadap pendidik serta peserta didik di beberapa sekolah dasar. Hasil penelitian menunjukkan bahwa penerapan pembelajaran berbasis SSI berkontribusi terhadap peningkatan pemahaman peserta didik mengenai isu-isu global, sekaligus memperkuat keterampilan berpikir kritis, pemecahan masalah, dan kolaborasi. Pendidik memiliki peran sentral dalam merancang strategi pembelajaran yang interaktif serta berbasis teknologi guna meningkatkan keterlibatan peserta didik. Namun, implementasi pendekatan ini masih menghadapi tantangan, di antaranya kesiapan pendidik dan keterbatasan sumber daya pembelajaran. Oleh karena itu, integrasi pembelajaran berbasis SSI dalam kerangka SDGs di pendidikan dasar dapat menjadi strategi yang efektif dalam meningkatkan literasi sains serta kesadaran sosial peserta didik. Penelitian lebih lanjut diperlukan guna mengembangkan strategi pelatihan bagi pendidik serta memperluas implementasi metode ini dalam berbagai konteks pendidikan. Kesimpulannya, integrasi pendekatan SSI berbasis SDGs dalam pembelajaran sains di sekolah dasar memiliki potensi besar untuk meningkatkan literasi sains, kesadaran sosial, serta keterampilan abad ke-21 pada peserta didik.
Kata Kunci: Socio-Scientific Issues; Sustainable Development Goals; Generasi Alpha; Sekolah Dasar; Pembelajaran

Received	: 2025-03-26	Approved	: 2025-07-24
Reviesed	: 2025-07-21	Published	: 2025-07-31

Introduction

Science education in elementary schools continues to evolve in response to changing times and global challenges. One approach that is increasingly being used in science education is the Socio-Scientific Issues (SSI) approach, which integrates social and scientific issues into learning to enhance students' scientific literacy and critical thinking skills (Widodo & Yermiandhoko, 2021). In Indonesia, the 2019 PISA survey showed that the average science literacy score for Indonesian students was 396, far below the OECD average of 489, indicating the urgent need for contextual and innovative approaches at all levels, including elementary education (OECD, 2019). This approach aims to help students understand the relationship between science and real life while fostering evidence-based thinking in decision-making. The relevance of SSI is further strengthened by its alignment with the Sustainable Development Goals (SDGs), which serve as a global framework for addressing issues such as climate change, renewable energy, and quality education until 2030.

Currently, the education system is facing Generation Alpha, a group of individuals born after 2010 who are growing up in an environment heavily influenced by digital technology (Jukić & Škojo, 2021). This generation's characteristics early technological exposure, broad access to information, and a preference for interactive learning demand that teachers move away from rote learning and adopt contextual strategies such as SSI that can link science concepts to students' daily lives and global realities (Ziatdinov & Cilliers, 2022). Indonesia faces various complex national issues including climate change impacts, environmental degradation, and public health crises that directly affect communities. SSI-based learning can serve as a bridge, introducing these issues within science lessons so that students not only gain theoretical knowledge but also understand its practical application and social consequences (Genc, 2023; Kumari, 2024). For instance, topics such as plastic waste pollution, air quality, or renewable energy alternatives can be linked to SDG targets like SDG 4 (Quality Education) and SDG 13 (Climate Action) to foster a sense of responsibility and social participation among students (Mehmood, 2021; Priatna & Khan, 2024).

To meet the needs of Generation Alpha, SSI implementation must consider the use of relevant digital media and technology-enhanced learning tools, including e-learning platforms, augmented reality (AR), and educational games that stimulate student engagement and interactivity (Höfrová et al., 2024). Therefore, the development of SSI-based learning materials should consider the use of appropriate media, such as e-learning platforms, augmented reality (AR), and educational games that allow interactive exploration of socio-scientific issues. Additionally, educators must present information from multiple perspectives to help students develop critical thinking and evidence-based argumentation skills (Demircioglu et al., 2023). However, the successful implementation of SSI cannot be separated from teacher readiness, which includes the ability to design learning scenarios, manage class discussions, and align socio-scientific content with the existing curriculum structure (Liang, 2023; Soysal, 2021). In Indonesia, adapting the SSI approach to the elementary school context remains challenging because teachers often lack specific training and learning resources to support this method. Moreover, the national curriculum still emphasizes content mastery over issue-based learning, which limits opportunities to integrate real-world problems into science classes (H.-C. Lee & Liu, 2025).

Despite extensive research highlighting SSI's impact on students' scientific literacy, argumentation, and problem-solving skills at the secondary and tertiary levels (Suwono et al., 2023). Previous studies have shown that SSI-based learning enhances students' argumentation skills, problem-solving abilities, and ethical and social awareness (Dewi et al., 2023). Globally,

the SSI approach has been widely used to teach environmental, health, and technology-related issues, particularly at the secondary and higher education levels (H. Lee et al., 2024). Therefore, this study seeks to fill that gap by exploring how SSI topics can be contextualized for young learners and linked with the SDGs to create meaningful learning experiences. Specifically, this research aims to: (1) identify socio-scientific issues relevant to Indonesian elementary students, (2) analyze how these topics relate to the SDGs, (3) determine appropriate digital media and methods for Generation Alpha's learning preferences, and (4) formulate recommendations for teachers to effectively implement SSI in elementary school classrooms. The results are expected to contribute to more innovative, engaging, and context-based science education practices, which in turn can help improve Indonesia's science literacy indicators at the global level. By focusing on the unique characteristics of Generation Alpha, aligning learning with the SDGs, and proposing digital solutions, this study provides new insights that can serve as a foundation for curriculum innovation, teacher professional development, and evidence-based policy making to prepare students as informed and responsible global citizens.

Research Methods

This study employs a qualitative descriptive approach using a multiple case study design, focusing on an in-depth exploration of the integration of Socio-Scientific Issues (SSI) into Indonesian elementary schools based on the Sustainable Development Goals (SDGs). A qualitative design is appropriate for exploring complex educational phenomena in their natural context, in line with the guidance of (Suryanti et al., 2021). The multiple case study design enables comparison across diverse school environments to obtain broader insights into strategies, obstacles, and contextual variations. The research was conducted for six months, from September 2024 to February 2025, in four elementary schools: two in Surabaya and two in Yogyakarta, Indonesia. These sites were selected purposively to capture variations in urban education dynamics and local curriculum adaptations. This diversity is important for understanding how socio-economic and cultural factors shape SSI implementation in science education.

Participants in this study consisted of 20 elementary school teachers, 5 education experts specializing in curriculum and SSI, and 3 educational media developers. Teachers were selected because they directly implement SSI in classroom practice. Education experts provide theoretical and practical perspectives on aligning SSI with the national curriculum, while media developers contribute insights into digital content suitable for Generation Alpha's characteristics. Purposive sampling was employed to ensure that all participants have relevant experience and are directly involved in SSI and SDG-based education. This research obtained ethical approval (Ethical Clearance No: 158/EC/UNESA/2024) issued by the Research Ethics Committee of Universitas Negeri Surabaya, ensuring that all research procedures comply with ethical standards for studies involving human participants, such as informed consent, confidentiality, and voluntary participation. The research process consists of four main stages: First, document analysis. Second, semi-structured interviews. Third, slassroom observations and last, digital media review.

In the first stage, national curriculum documents, lesson plans, and science textbooks are analyzed to identify how SSI and SDG elements are embedded in existing materials. In the second stage, semi-structured interviews are conducted with the teachers, experts, and media developers to explore their perceptions, practices, and challenges in integrating SSI. In the third stage, direct observations are carried out in selected classrooms to understand real

teaching practices, interaction patterns, and how digital media are utilized. The fourth stage involves analyzing digital educational platforms and media commonly accessed by Generation Alpha, such as YouTube Kids, interactive science applications, and AR-based learning tools.

Data were collected using validated research instruments: interview guides, observation sheets, and a document analysis protocol. Interview questions were constructed based on key SSI and SDG indicators adapted from recent studies (Wahyutami et al., 2023). Observations focus on classroom activities, teacher-student interactions, and media use. Document analysis investigates the depth of SSI integration in the curriculum and teaching materials. Data analysis followed the thematic analysis approach described by Braun & Clarke (2021). First, data reduction was conducted to extract relevant information. Second, thematic categorization grouped data into core themes: SSI topic relevance, curriculum integration, Generation Alpha-oriented media, and SDG alignment. Third, interpretation was carried out to connect empirical findings with theoretical perspectives on SSI-based learning and the Indonesian elementary curriculum context. To ensure the validity and reliability of findings, the study applied source triangulation by cross-checking data from interviews, document analyses, and classroom observations, following the recommendation of (Balluerka et al., 2024). Member checks were also conducted by asking some participants to validate summarized findings. Figure 1 presents the procedural flow of this study to provide a clear roadmap for readers and future researchers.

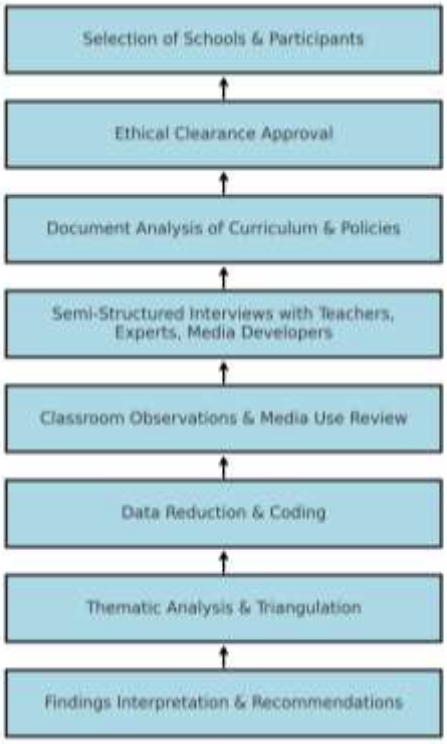

Figure 1. Research Procedure Flow

This rigorous methodological framework is expected to generate trustworthy insights and practical recommendations for integrating SSI into elementary science education, ensuring that learning is aligned with the SDGs and responsive to the unique characteristics of Generation Alpha.

Results and Discussion

Jurnal Cakrawala Pendas Vol. 11, No. 3, July 2025, pp. 763-774

This study focuses on identifying and analyzing Socio-Scientific Issues (SSI) that are relevant to Generation Alpha in elementary schools and their alignment with the Sustainable Development Goals (SDGs). Through content analysis of educational documents, expert interviews, and a review of popular media, the study identifies ten core SSI themes essential for integration into elementary education. Findings confirm that Generation Alpha, growing up in a digital and fast-changing era, demands interactive, contextual, and tech-supported learning models. As stated by one participating teacher, "*Children today are more motivated when real-world issues are directly linked to their daily activities and they can see the impact around them*" (Interview with Elementary Teacher, Surabaya, January 2025). Table 1 presents the SSI Themes, SDG Alignment, and Concrete Classroom Examples, while Table 2 outlines Recommended Media and Practical Implementation Strategies.

Table 1. SSI Themes, SDG Alignment, and Concrete Classroom Examples

No	SSI Theme	SDG Alignment	Concrete Classroom Example
1	Food Security & Nutrition	SDG 2, SDG 3	Students create a "Healthy Meal Diary" and collaborate to plan balanced lunch menus using local food ingredients.
2	Climate Crisis & Weather Changes	SDG 13, SDG 15	Students monitor schoolyard temperature changes daily, then present solutions to reduce heat with greenery projects.
3	Plastic Waste & Environment	SDG 12, SDG 14	Students bring plastic waste from home, sort it, and create eco-bricks or art installations displayed at school.
4	Clean Water Crisis & Sanitation	SDG 6, SDG 11	Students build simple water filters from gravel and sand, test water cleanliness, and present posters on water-saving tips.
5	Renewable Energy & Technology	SDG 7, SDG 9	Students assemble mini solar-powered fans or lamps as part of science fair projects.
6	Digital Literacy & Misinformation	SDG 4, SDG 16	Students analyze viral news headlines, discuss their credibility, and write a short fact-checking report.
7	Forest & Wildlife Management	SDG 15, SDG 13	Students adopt a tree seedling at school and monitor its growth, connecting this to lessons on deforestation impacts.
8	Poverty & Social Inequality	SDG 1, SDG 10	Students organize charity drives for underprivileged peers and simulate micro-business ideas through role-play.
9	Children's & Teen Mental Health	SDG 3, SDG 4	Students keep weekly well-being journals and join guided peer-sharing circles for stress management.
10	Technology Revolution & Education	SDG 8, SDG 4	Students participate in beginner coding tasks using block-based programming apps.

Table 2. Learning Media and Practical Implementation Strategies

No	SSI Theme	Recommended Learning Media	Practical Implementation Strategy
1	Food Security & Nutrition	Infographics, Animated Videos	Cooking demo with parents, healthy recipe contests

2	Climate Crisis & Weather Changes	AR, Educational Films	Community tree planting, weather station mini-project
3	Plastic Waste & Environment	Interactive Games, Documentaries	School waste bank, inter-class plastic-free competitions
4	Clean Water Crisis & Sanitation	Online Simulations, Field Visits	Field trip to local water treatment plant
5	Renewable Energy & Technology	VR, DIY Kits	Solar lamp-making workshops, energy-saving campaigns
6	Digital Literacy & Misinformation	Podcasts, AI Simulations	Mock news broadcasts, online safety poster projects
7	Forest & Wildlife Management	Animations, Field Trips	Visit to local forest conservation site
8	Poverty & Social Inequality	Storytelling Videos, Discussions	Role-play as community leaders solving social problems
9	Children's & Teen Mental Health	Interactive E-books, Forums	Class mindfulness exercises, stress-buster activities
10	Technology Revolution & Education	Coding Workshops, Gamified Apps	Monthly 'Tech Day' to showcase student projects

One education expert emphasized, "*Integrating SSI should not stop at theory; we must provide opportunities for students to act and reflect. Small-scale projects make them feel responsible for real changes.*" (Interview with Education Expert, Yogyakarta, February 2025). This comprehensive approach provides a foundation for aligning classroom practices with the SDGs, encouraging both awareness and action among Generation Alpha students.

The findings highlight the importance of integrating relevant and engaging SSI topics into the elementary school curriculum. The study focuses on identifying and analyzing Socio-Scientific Issues (SSI) relevant to Generation Alpha in elementary schools and their alignment with the Sustainable Development Goals (SDGs). By employing document content analysis, expert interviews, and popular media reviews, ten key topics have been identified as crucial for integration into elementary education. The findings indicate that Generation Alpha exhibits unique characteristics in understanding and responding to socio-scientific issues. Growing up in the digital era grants them rapid access to information but simultaneously demands a more interactive, technology-based, and contextual learning approach. The selection of SSI topics considers their relevance to daily life, impact on the environment and society, and alignment with SDGs.

Food security and nutrition remain significant concerns, particularly in the context of child stunting and unhealthy eating habits. Research by Wells et al. (2021) highlights that malnutrition remains a critical issue in many developing countries, emphasizing the need for improved dietary awareness. To address this, interactive learning media such as infographics, animated videos, and digital simulations are effective tools for educating students on the importance of balanced nutrition. This approach aligns with SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being), promoting critical thinking about how nutrition influences overall health. The implementation of hands-on projects, such as designing healthy meal plans, enables students to internalize healthy eating habits from an early age.

Climate change poses an increasing global challenge, manifesting in extreme weather patterns, rising sea levels, and worsening air pollution. Studies by Myers et al. (2021), confirm the scientific consensus on anthropogenic climate change, underscoring the necessity of environmental education from an early age. Generation Alpha needs to comprehend the connection between human activities and climate change, particularly concerning fossil fuel

consumption and deforestation. Augmented Reality (AR), educational films, and simple scientific experiments provide effective avenues for students to visualize the greenhouse effect and understand global warming. SDG 13 (Climate Action) and SDG 15 (Life on Land) emphasize the urgency of addressing environmental degradation. Engaging students in simulations, debates, and direct observation fosters analytical skills, enabling them to propose viable climate solutions.

Plastic waste pollution has become a pressing environmental issue, particularly in countries with high consumption and low recycling rates. According to Mathis et al. (2022), Indonesia ranks among the top contributors to marine plastic pollution. This necessitates early interventions to instill responsible consumption habits among students (Solihin et al., 2025). Interactive learning tools such as games, documentaries, and infographics allow students to grasp the life cycle of plastic waste and its environmental consequences. SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water) provide a framework for sustainable waste management practices. Implementing school-based recycling projects and plastic-free campaigns fosters students' environmental awareness and responsibility, equipping them with the knowledge to adopt sustainable behaviors.

Access to clean water and sanitation remains a critical issue in many urban and rural areas. Research by Saxena (2025) highlights that water scarcity is exacerbated by urbanization, industrial pollution, and climate change. Understanding the importance of clean water can be enhanced through online simulations, field visits, and simple water purification experiments. The integration of SDG 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities and Communities) into the curriculum helps students connect theoretical knowledge with real-world applications. Activities such as water filtration experiments and community observation exercises instill a sense of responsibility toward water conservation and sanitation practices.

The transition from fossil fuels to renewable energy sources is crucial in mitigating climate change. Studies by Mudaliyar et al. (2022) emphasize that renewable energy adoption can significantly reduce greenhouse gas emissions. Generation Alpha should be introduced to alternative energy solutions such as solar, wind, and bioenergy through interactive learning methods, including Virtual Reality (VR), hands-on DIY projects, and interactive comics. SDG 7 (Affordable and Clean Energy) and SDG 9 (Industry, Innovation, and Infrastructure) provide a foundation for sustainable energy discussions. Encouraging students to explore clean energy technologies through science projects enhances their understanding of energy sustainability and efficiency.

The rise of digital technology has brought both opportunities and challenges, particularly concerning cybersecurity and misinformation. Research by Purnama et al. (2021) highlights that children are increasingly vulnerable to online risks, necessitating early education on digital literacy. To promote responsible internet usage, students can engage in educational podcasts, interactive games, and AI-driven simulations. SDG 4 (Quality Education) and SDG 16 (Peace, Justice, and Strong Institutions) emphasize the importance of fostering critical thinking skills in digital spaces. Classroom exercises on fact-checking, role-playing as journalists, and cybersecurity awareness campaigns equip students with the tools to navigate the digital landscape safely and responsibly.

Mental health issues among children have gained increasing attention due to academic pressures, social influences, and excessive digital exposure. Studies by Mundy et al. (2021) indicate a correlation between social media usage and increased anxiety among adolescents, highlighting the need for early mental health interventions. Using educational videos,

interactive books, and discussion forums, students can learn about stress management, self-care, and emotional resilience. SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education) underscore the importance of mental health awareness. Implementing mindfulness activities, journaling exercises, and classroom discussions helps students develop emotional intelligence and coping strategies.

Air pollution, particularly in urban areas, remains a major public health concern. Research by Bouza et al. (2022) associates air pollution with severe respiratory diseases, emphasizing the need for environmental education. Students can explore pollution sources and mitigation strategies through hands-on experiments, air quality mapping, and interactive infographics. SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) stress the importance of sustainable urban planning. Encouraging students to propose solutions such as eco-friendly transportation campaigns and tree-planting initiatives fosters environmental consciousness and proactive engagement.

Biodiversity conservation is crucial in maintaining ecological balance, yet habitat destruction and illegal wildlife trade pose serious threats. Studies by Singh (2025) highlight the alarming rate of species decline due to human activities. Interactive ecosystem simulations, field trips, and documentary screenings provide immersive learning experiences for students. SDG 14 (Life Below Water) and SDG 15 (Life on Land) advocate for the preservation of biodiversity. School-based conservation projects, such as tree adoption programs and wildlife protection campaigns, empower students to take an active role in environmental stewardship.

Social inclusion and gender equality remain pivotal in fostering a fair and just society. Research by Fuentes et al. (2021) underscores the importance of early education in promoting equity and diversity. Storytelling, classroom dramas, and role-playing exercises offer effective ways to introduce these concepts to students. SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities) emphasize the need for inclusive education. Initiatives such as equality awareness campaigns and collaborative class discussions help students develop empathy and respect for diversity.

The findings demonstrate that SSI topics must be contextually relevant to students' daily lives to facilitate meaningful learning experiences. Technology-enhanced learning methods, such as AR, VR, and digital games, have proven effective in engaging Generation Alpha and improving their comprehension of complex issues. Integrating SSI with SDGs allows students to connect scientific knowledge with real-world problem-solving. Project-based and exploratory learning approaches foster critical thinking skills and decision-making abilities, preparing students to become informed and responsible global citizens. The integration of these interdisciplinary topics into elementary education plays a crucial role in shaping environmentally conscious, socially responsible, and technologically adept future generations.

The findings of this study indicate that integrating socio-scientific issues (SSI) into elementary schools is an effective approach to enhancing students' critical thinking, scientific literacy, and social awareness. By contextualizing learning within real-world challenges such as climate change, food security, digital citizenship, and biodiversity conservation, students develop a deeper understanding of the interconnectedness between science, society, and sustainable development. The use of digital learning tools, interactive media, and project-based methods proves to be highly engaging for Generation Alpha, aligning with their digital-native characteristics and fostering more meaningful learning experiences. Furthermore, the incorporation of the Sustainable Development Goals (SDGs) framework enables students to connect their knowledge with practical solutions, encouraging active participation in addressing global issues from an early age. These results align with previous research (H. Lee et al., 2024;

Rundgren & Chang Rundgren, 2024), which emphasizes the role of SSI in promoting scientific inquiry and ethical reasoning in education. Moving forward, further research should explore the long-term impact of SSI-based learning on students' decision-making skills and civic engagement, as well as the development of teacher training programs to support the effective implementation of this approach in elementary school.

Conclusion

The research results indicate that integrating Socio-Scientific Issues (SSI) into elementary school plays a crucial role in developing scientific literacy, critical thinking, and social awareness among Generation Alpha. By connecting learning with real-world issues such as climate change, cybersecurity, food security, and biodiversity, students not only grasp scientific concepts but also relate them to sustainable solutions. The use of technology-based learning media, such as digital simulations, augmented reality, and project-based learning, has been proven to enhance student engagement and comprehension, aligning with their digital-native characteristics. Additionally, implementing an SDG-based approach helps students understand the relevance of science in addressing global challenges. However, this study has several limitations, including the limited number of schools and participants involved, as well as the relatively short research period of six months, which may affect the scope of generalization. Future research could focus on the long-term impact of SSI-based learning on students' critical thinking and decision-making skills. Moreover, further development of teacher training programs is needed to optimize the implementation of the SSI approach in elementary school curricula, ensuring that education remains relevant to students' lives and future challenges.

References

Balluerka, N., Gorostiaga, A., Sampietro, H. M., González-Pinto, A., & Aliri, J. (2024). Cross-cultural adaptation and psychometric validation of a Spanish version of the Maryland Assessment of Recovery Scale (MARS-12). *PLOS ONE*, *19*(2), e0298554. https://doi.org/10.1371/journal.pone.0298554

Bouza, E., Vargas, F., Alcázar, B., Álvarez, T., Asensio, Á., Cruceta, G., Gracia, D., Guinea, J., Gil, M. A., Linares, C., Muñoz, P., Olier, E., Pastor, P., Pedro-Botet, M. L., Querol, X., Tovar, J., Urrutia, I., Villar, F., & Palomo, E. (2022). Air pollution and health prevention: A document of reflection. *Revista Española de Quimioterapia*, *35*(4), 307–332. https://doi.org/10.37201/req/171.2021

Demircioglu, T., Karakus, M., & Ucar, S. (2023). Developing Students' Critical Thinking Skills and Argumentation Abilities Through Augmented Reality–Based Argumentation Activities in Science Classes. *Science & Education*, *32*(4), 1165–1195. https://doi.org/10.1007/s11191-022-00369-5

Dewi, A. I. K., Suyono, S., & Erman, E. (2023). Effectiveness of Socioscientific Issues (SSI) Based Learning to Improve Argumentation Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 279–283. https://doi.org/10.29303/jppipa.v9i1.2866

Fuentes, M. A., Zelaya, D. G., & Madsen, J. W. (2021). Rethinking the course syllabus: Considerations for promoting equity, diversity, and inclusion. *Teaching of Psychology*, *48*(1), 69–79. https://doi.org/10.1177/0098628320959979

Genc, H. N. (2023). Global issues within the scope of sustainable development in science education; global warming, air pollution and recycling. In *Proceedings of International Conference on Academic Studies in Technology and Education* (hal. 97–111). ARSTE Organization.

Höfrová, A., Balidemaj, V., & Small, M. A. (2024). A systematic literature review of education for Generation Alpha. *Discover Education*, *3*(1), 125. https://doi.org/10.1007/s44217-024-00218-3

Jukić, R., & Škojo, T. (2021). The educational needs of the Alpha Generation. *2021 44th International Convention on Information, Communication and Electronic Technology (MIPRO)*, 564–569. https://doi.org/10.23919/MIPRO52101.2021.9597106

Kumari, R. K. (2024). Revolutionizing Education: Harnessing Graph Machine Learning for Enhanced Problem-Solving in Environmental Science and Pollution Technology. *Nature Environment & Pollution Technology*, *23*(4). https://doi.org/10.46488/NEPT.2024.v23i04.038

Lee, H.-C., & Liu, W.-H. (2025). Implementing the Slow Fish curriculum for SDGs: Strategies, challenges, and policy suggestions through a case study. *Marine Policy*, *173*, 106538. https://doi.org/10.1016/j.marpol.2024.106538

Lee, H., Lee, H., & Ko, Y. (2024). Evolution and Future Directions of SSI Education in South Korea: A 2-Decade Review and Beyond. *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, 287–309. https://doi.org/10.1007/978-3-031-63382-9_16

Liang, W. (2023). Towards a set of design principles for technology-assisted critical-thinking cultivation: A synthesis of research in English language education. *Thinking Skills and Creativity*, *47*, 101203. https://doi.org/10.1016/j.tsc.2022.101203

Mathis, J. E., Gillet, M. C., Disselkoen, H., & Jambeck, J. R. (2022). Reducing ocean plastic pollution: Locally led initiatives catalyzing change in South and Southeast Asia. *Marine Policy*, *143*, 105127. https://doi.org/10.1016/j.marpol.2022.105127

Mehmood, U. (2021). Contribution of renewable energy towards environmental quality: The role of education to achieve sustainable development goals in G11 countries. *Renewable Energy*, *178*, 600–607. https://doi.org/10.1016/j.renene.2021.06.118

Mudaliyar, M., Sharma, A., & Panja, A. (2022). Strategies for Reducing Greenhouse Gas Emissions and Promoting Renewable Energy. *Journal of Universal Community Empowerment Provision*, *2*(2), 45–51. https://doi.org/10.55885/jucep.v2i2.207

Mundy, L. K., Canterford, L., Moreno-Betancur, M., Hoq, M., Sawyer, S. M., Allen, N. B., & Patton, G. C. (2021). Social networking and symptoms of depression and anxiety in early adolescence. *Depression and anxiety*, *38*(5), 563–570. https://doi.org/10.1002/da.23117

Myers, K. F., Doran, P. T., Cook, J., Kotcher, J. E., & Myers, T. A. (2021). Consensus revisited: quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later. *Environmental Research Letters*, *16*(10), 104030. https://doi.org/10.1088/1748-9326/ac2774

OECD. (2019). PISA 2018 Assessment and Analytical Framework. In *OECD Publishing*.

Priatna, D., & Khan, S. M. (2024). The importance of education and role of educational institutions in climate change mitigation and achieving UN SDG 13 "Climate Action." *Indonesian Journal of Applied Environmental Studies*, *5*(1), 1–5. https://doi.org/10.33751/injast.v5i1.10559

Purnama, S., Ulfah, M., Machali, I., Wibowo, A., & Narmaditya, B. S. (2021). Does digital literacy influence students' online risk? Evidence from Covid-19. *Heliyon*, *7*(6). https://doi.org/10.1016/j.heliyon.2021.e07406

Rundgren, C.-J., & Chang Rundgren, S.-N. (2024). Science and Moral Inquiry as the Yin and Yang of SSI Education: Two Examples of SSI Research from Sweden. In *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues* (hal. 311–331). Springer. https://doi.org/10.1007/978-3-031-63382-9_17

Saxena, V. (2025). Water Quality, Air Pollution, and Climate Change: Investigating the Environmental Impacts of Industrialization and Urbanization. *Water, Air, & Soil Pollution*, *236*(2), 1–40. https://doi.org/10.1007/s11270-024-07702-4

Singh, B. (2025). Assimilating Virtual Reality (VR) for Environmental Conservation in Tourist Spots. In *Solutions for Managing Overtourism in Popular Destinations* (hal. 193–212). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-8347-6.ch010

Solihin, A., Gunansyah, G., Mariana, N., Nursalim, M., & Julianto, J. (2025). Zero-waste Culture in Sustainable Ethnopedagogy in Surabaya for SDG 12's Goals of Responsible Consumption and Production. *Jurnal Pendidikan Edutama*, *12*(1), 107–119. https://doi.org/10.30734/jpe.v12i1.4998

Soysal, Y. (2021). Talking science: Argument-based inquiry, teachers' talk moves, and students' critical thinking in the classroom. *Science & Education*, *30*(1), 33–65. https://doi.org/10.1007/s11191-020-00163-1

Suryanti, S., Prahani, B. K., Widodo, W., Mintohari, M., Istianah, F., Julianto, J., & Yermiandhoko, Y. (2021). Ethnoscience-based science learning in elementary schools. *Journal of Physics: Conference Series*, *1987*(1). https://doi.org/10.1088/1742-6596/1987/1/012055

Suwono, H., Rofi'Ah, N. L., Saefi, M., & Fachrunnisa, R. (2023). Interactive socio-scientific inquiry for promoting scientific literacy, enhancing biological knowledge, and developing critical thinking. *Journal of Biological Education*, *57*(5), 944–959. https://doi.org/10.1080/00219266.2021.2006270

Wahyutami, K., Madyawati, L., & Sulistyaningtyas, R. E. (2023). Pengaruh Problem Based Learning Berbantuan Loose Parts Terhadap Kompetensi Pedagogik Guru. *JP2KG: Jurnal Pendidikan, Pengasuhan, Kesehatan, dan Gizi Anak Usia Dini*, *4*(2), 42–55. https://journal.unesa.ac.id/index.php/jt

Wells, J. C. K., Marphatia, A. A., Amable, G., Siervo, M., Friis, H., Miranda, J. J., Haisma, H. H., & Raubenheimer, D. (2021). The future of human malnutrition: rebalancing agency for better nutritional health. *Globalization and health*, *17*, 1–25. https://doi.org/10.1186/s12992-021-00767-4

Widodo, W., & Yermiandhoko, Y. (2021). Gadget-Based Interactive Multimedia on Socio-Scientific Issues to Improve Elementary Students' Scientific Literacy. *International Journal*

of Interactive Mobile Technologies, *15*(1). https://doi.org/10.3991/ijim.v15i01.13675

Ziatdinov, R., & Cilliers, J. (2022). Generation Alpha: Understanding the next cohort of university students. *arXiv preprint arXiv:2202.01422*. https://doi.org/10.48550/arXiv.2202.01422