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The Effect of Implementation Socio-Scientific Issue Approach in the Context of Controversial Environmental Issues on Students' HOTS (Higher Order Thinking Skills)

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Abstract: This research aims to see the influence of the SSI approach in the context of controversial environmental issues on chemistry students' HOTS abilities. The research method used was quasi-experimental with a post-test-only control group design. The research subjects were 26 students in class A of the chemistry education study program as the control class and 21 students in the ICP class of the chemistry education study program as the experimental class. The instruments used are observation sheets and test questions that measure students' HOTS abilities. The results of this study show that the average post-test score of the experimental class using the SSI approach was 80.15, while the average score of the control class was 60.5. The t-test shows that this difference is statistically significant with a p-value of 1.122 x 10-5, well below the 0.05 significance level. Because the p-value obtained is much smaller than 0.05, we can reject the null hypothesis (H_0), which states that there is no significant difference between the two groups. These results indicate that the SSI approach in the context of controversial environmental issues has a positive influence on chemistry students' HOTS abilities in electrochemical concepts.

Keywords: Environmental issues; Higher order thinking skills (HOTS); Socio-scientific issues

Introduction

Chemistry education is often considered a complex and challenging scientific discipline because it involves abstract concepts and complex problem-solving skills (Chiu, 2022; Karch et al., 2022). Problem-solving is one of the main components of higher-order thinking skills (HOTS). Higher-order thinking Skills (HOTS) are essential qualifications for 21st-century Human Resources (HR), especially in the context of chemistry education. HOTS includes analysis, evaluation, and creation skills, crucial for understanding and solving complex problems often encountered in chemistry (Nawawi et al., 2023; Rusmansyah et al., 2019). Chemistry education not only teaches basic concepts but also encourages students to think critically and creatively in applying their knowledge to real situations (Liang et al., 2023). Seeing the importance of instilling HOTS skills in students, teachers need to find innovative teaching approaches to honing HOTS skills in students. One approach that has shown great potential in this context is the Socio-Scientific Issues (SSI) approach (Rahayu, 2017; Safitri et al., 2022; Tampubolon et al., 2022; Ulfa et al., 2021).

The SSI approach integrates socially and scientifically relevant controversial issues into learning. This approach aims to improve students' scientific literacy as well as critical and analytical thinking skills through discussion and analysis of real problems faced in everyday life (Febriani et al., 2023; Greer et al., 2016; Ke et al., 2021; Permanasari et al., 2021). The SSI approach facilitates students in developing a deeper understanding of the relationships between science, technology, and society, as well as their impact on the environment and ethics.

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Controversial issues in the SSI Approach include environmental issues currently being discussed in various countries and regions. In the context of controversial environmental issues, the SSI approach plays an important role in increasing students' understanding of the complexity of environmental problems such as climate change, plastic pollution, and deforestation. This approach encourages students to explore multiple perspectives, develop critical thinking skills, and make decisions based on scientific evidence and ethical considerations. Through discussion and analysis of real environmental problems, students learn to connect scientific knowledge with social, political, and economic implications to participate actively and responsibly in an increasingly complex and global society.

Applying the SSI approach in chemistry education provides a relevant and applicable context for students to understand chemical concepts. For example, in research conducted by Purwanto et al. (2022), a socio-critical and problem-oriented approach is applied to develop students' critical thinking skills through analysis of environmental issues related to acids and bases (Badeo et al., 2022; Purwanto et al., 2022). The research results show a significant increase in critical thinking skills, motivation, and student involvement in learning. Other research shows that SSI can effectively improve students' higher-order thinking abilities (HOTS). For example, research by Wildan et al. students' critical thinking skills and character (Wildan et al., 2021). In addition, Saad et al. (2017) research revealed that SSI-based learning strategies improved students' scientific thinking skills in biology subjects, which are part of HOTS (Ke et al., 2020; Saad et al., 2017).

Although the studies above show the effectiveness of the Socio-Scientific Issues approach in improving students' higher-order thinking abilities (HOTS) and critical thinking skills, they have not identified further the influence of the use of controversial environmental issues, which plays a role in honing students' HOTS abilities. This research focuses on using the Socio-Scientific Issue (SSI) approach in the context of controversial environmental issues. It provides a new dimension in chemistry education by integrating discussion of real issues such as climate change, pollution, and deforestation, which previously may have received less attention in HOTS-related research.

This research aims to integrate controversial environmental issues, such as climate change, pollution, and deforestation, into the chemistry curriculum to provide a more relevant and applicable learning context. Thus, this research hopes to improve students' analytical, evaluation, and creative skills in solving complex environmental problems. The solution offered by this research is the application of the SSI approach, which combines critical discussion and real problem-solving in an environmental context, which is expected to encourage students to develop critical and creative thinking skills and increase their motivation and involvement in the chemistry learning process. Through this approach, students not only gain theoretical knowledge but can also apply it in real contexts, thus producing graduates better prepared to face global environmental issues.

Method

This research is quantitative research, which aims to measure and analyze numerical data relevant to the problem under study. Through this method, researchers can identify causal relationships between the variables involved and make generalizations based on the results obtained. The design of this research is quasi-experimental (Quasi-Experimental Design), using one control class and one experimental class that is not randomized. The research subjects were 26 students in class A of the chemistry education study program as the control class and 21 students in the ICP class of the chemistry education study program as the experimental class.

Table 1. Research Design

Group	Treatment	Post-test
E	X	O_1
K	-	O_2

Information:
E = Experimental class
K = Control class
X = Treatment (SSI approach in the context of controversial environmental issues)
O_1 = Experimental class post-test
O_2 = Control class post-test

Data was collected using a written test (post-test), which was given to both groups, namely the experimental group, which received treatment with the SSI approach, and the control group, which did not receive this treatment. The post-test was designed to measure students' HOTS abilities after the treatment was given. Data analysis was carried out by comparing the post-test results between the experimental group and the control group. Before testing the hypothesis, prerequisite tests are carried out, namely the normality test and data homogeneity test. Then, hypothesis testing was carried out using statistical tests, namely the t-test, to determine the significance of the differences between the two groups. Interpretation of analysis results is based on the p-value obtained from statistical tests.

Result and Discussion

The Socio-Scientific Issues (SSI) approach is a learning method that integrates controversial scientific issues with a social context to improve students' higher-order thinking skills and scientific literacy. Through this approach, students are invited to study and discuss real issues that are relevant to everyday life, such as climate change, biotechnology, health, and environmental ethics. The SSI approach encourages students to develop the ability to analyze, evaluate, and synthesize information, as well as to make decisions based on scientific evidence (Saad et al., 2017; Subiantoro et al., 2021). In addition, this approach also improves students' argumentation and reasoning skills because they are required to consider various perspectives, evaluate evidence, and articulate their arguments critically and logically (Anwar et al., 2020). Thus, SSI not only enriches students' understanding of scientific concepts but also prepares them to become more critical and responsible citizens in facing scientific and social issues in the future (Georgiou et al., 2023; Nurtamara et al., 2019).

The steps commonly used in learning with the SSI approach include: (1) Identification of social-scientific issues; (2) scientific investigation; (3) Development of arguments and discussions; (4) decision making; and (5) reflection and evaluation. Through these stages, the researcher implemented the SSI approach in the classroom by raising controversial environmental issues. In this research, the environmental issues raised are environmental issues that are often discussed on various social and electronic media and have become controversial issues in several countries.

Table 2. Controversial Issues

Cases	Environmental Issues	Environmental Issue Category
Use of lithium-ion batteries in electric vehicles	Production involves hazardous chemicals such as lithium, cobalt, and nickel; disposal of used batteries pollutes soil and water.	Pollution and wastes
Aluminum industry and large energy consumption	Greenhouse gas emissions from the use of fossil fuels; large energy needs are difficult to meet with renewable energy.	Climate change and greenhouse gas emissions
The complexity of lithium-ion battery recycling	Heavy metals in batteries that are not recycled pollute the environment; expensive and complex recycling process	Waste management and recycling

The following graph depicts the average score percentage of the influence of this SSI approach in efforts to improve students' HOTS abilities. The data presented provides deep insight into the effectiveness of this strategy in strengthening critical analysis, evaluation, and problem-solving skills among students.

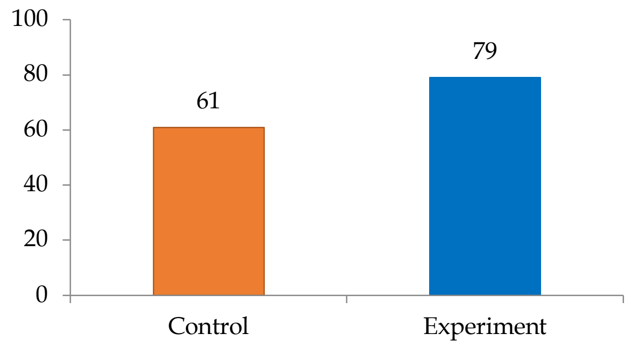

Figure 1. Percentage of average score HOTS abilities

Overall, the results of this study indicate that the SSI approach is effective in improving students' HOTS abilities compared to conventional learning methods. The experimental class that received treatment with the SSI approach showed a significant increase in performance compared to the control class. These findings support the use of the SSI approach as a learning strategy that can improve the quality of education in the field of chemistry.

The findings of this research are in line with the findings of several studies that show the effectiveness of the Socio-Scientific Issues (SSI) approach in improving higher-order thinking skills (HOTS) in chemistry education. Among them, Zamakhsyari et al. (2020) found that using SSI as a context for solving unstructured problems can significantly improve students' problem-solving skills, which involve high-level cognitive processes such as argumentation, creativity, and critical thinking. Similarly, (López-Fernández et al. (2022) report that addressing socio-scientific problems such as plastic pollution helps develop critical thinking by engaging students in real-world problems, improving their understanding and analytical skills in chemistry. Another study conducted by Rahayu (2019) emphasized that integrating SSI in chemistry education not only increases scientific literacy but also increases transferable skills, which are important for students' future careers. Kornatowski (2023) developed an SSI-based assessment instrument to measure HOTS, confirming its effectiveness in improving students' analytical and evaluative abilities. Lastly, Purwanto et al. (2022) showed that a socio-critical problem-oriented approach to environmental issues fosters critical thinking skills, which further supports the efficacy of SSI in chemistry education.

Higher-Order Thinking Skills (HOTS) include various indicators that are essential for developing students' understanding and skills in various academic contexts and everyday life. The first indicator is analytical ability, which requires students to break down complex information into smaller parts in order to understand the structure and relationships between these parts. This involves the process of identifying, comparing, and assessing information elements to uncover hidden patterns or meanings so that they can be used to reach deeper solutions or conclusions (Wakifah et al., 2023; Wulandari et al., 2023; Zamakhsyari et al., 2020). The second indicator is evaluation ability, which involves critical assessment of information or arguments based on certain criteria. Students must be able to determine the validity or relevance of information and weigh various perspectives before making decisions or conclusions. Good evaluation requires openness to new evidence and the ability to change opinions based on objective analysis (Basri et al., 2021; López-Fernández et al., 2022).

Problem-solving is the third indicator in HOTS, which requires students to use their knowledge and skills to find solutions to complex and often unstructured problems. This includes the ability to formulate problems, design resolution strategies, and evaluate and revise these strategies as needed (Helmita et al., 2022; Purwanto et al., 2022). The fourth indicator is the application of knowledge to new contexts, which involves the ability to transfer and apply concepts or skills that have been learned to situations or problems that are different from those previously known. Students must be able to see the similarities and differences between the old and new contexts and adapt their approach to solving problems in the new context (Rahayu, 2019; Sofyan, 2019). The final indicator is creation, which includes the ability to produce new ideas, concepts, or innovative products. This creation process involves imagination, synthesis of information from various sources, and the ability to develop unique and useful solutions or products (Jaenudin et al., 2020; Taslim et al., 2021). Creativity encourages students to think outside traditional boundaries and explore various possibilities in problem-solving or idea development.

Figure 2 shows that the aspects of the HOTS indicator that are still low are the ability to evaluate, create, and solve problems. Students face various obstacles in developing higher-order thinking skills (HOTS), especially in evaluation. One of the main obstacles is the need for more critical assessments of the information or arguments they encounter. Students often lack familiarity with an in-depth and objective assessment process, which includes assessing the validity and relevance of information and comparing multiple perspectives before making decisions or conclusions. Students are not very careful in evaluating information, so their answers are wrong. However, the evaluation ability of the experimental class is higher than that of the control class. This indicates that the Socio-Scientific Issues (SSI) approach can hone students' HOTS skills through controversial environmental issues (Jaenudin et al., 2020; López-Fernández et al., 2022).

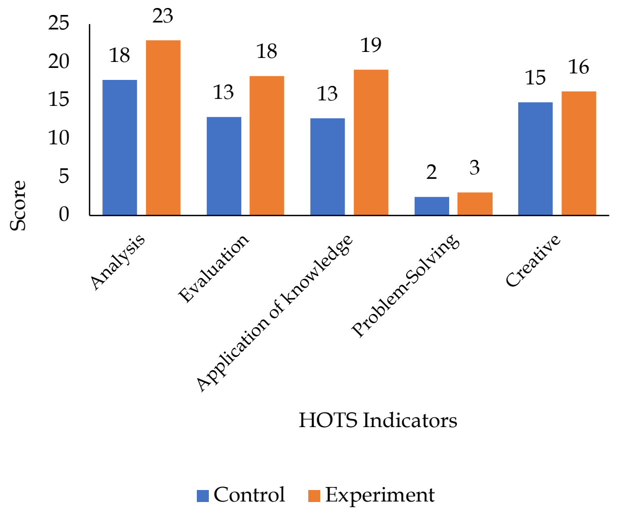

Figure 2. Student scores for each HOTS indicator

The problem-solving ability in HOTS is also still relatively low. One of the main obstacles is the need for more experience and skills in dealing with unstructured problems, which often require a creative and analytical approach to finding solutions. Many students are used to structured and direct problems, so they must be trained to formulate and solve complex and dynamic problems. This can hinder their ability to think critically and creatively in finding effective solutions (Abdullah et al., 2019; Zamakhsyari et al., 2020).

This research also found that students often face obstacles in terms of motivation and engagement. Complex and unstructured problems are often considered boring or scary, so students are less encouraged to be deeply involved in the problem-solving process. This low involvement can lead to a lack of in-depth understanding and the ability to develop effective problem-solving strategies (Purwanto et al., 2022). Students need guidance and constructive feedback to help them identify appropriate approaches and overcome obstacles that arise during the problem-solving process. Without adequate guidance, they may feel confused and frustrated, which can hinder the development of their problem-solving abilities (López-Fernández et al., 2022).

The graph shows that the problem-solving abilities of experimental class students are higher than those in the control class. Experimental classes using the SSI approach can significantly improve students' problem-solving abilities. These results are relevant to research conducted by Iman et al. (2023), where the SSI approach, which emphasizes the scientific process, critical thinking, and real collaboration, was proven effective in improving students' mathematical problem-solving skills. In line with Su (2021) research on the implementation of SSI with concept mapping, it is proven that the SSI approach, besides improving problem-solving abilities, can also improve students' argumentation abilities.

An aspect that is also classified as low is the creative aspect, which requires students to find creative solutions in solving problems. This obstacle is because students are used to working on questions or problems by the concepts being taught. This often prevents students from thinking outside the box and exploring new ideas. This limitation makes them less familiar with the creation process, which requires imagination, synthesis of information from various sources, and developing unique and useful solutions (Rahayu, 2019).

In addition, students often feel they lack the self-confidence to explore their creative ideas for fear of failure or criticism. An academic environment that is less supportive and does not provide a safe space to experiment and learn from mistakes can hinder the creative process. Without proper encouragement and guidance, they may be reluctant to take the risks necessary to create something new (López-Fernández et al., 2022). Lack of involvement in collaborative projects can also be an obstacle, as collaboration with peers can often spark inspiration and innovation. Limited access to relevant resources and learning materials can also hinder students' ability to develop their creative ideas (Purwanto et al., 2022). Even though the increase in students' creative thinking is not very high, the SSI approach has encouraged students to face every problem by thinking creatively. Several studies support this, where the SSI Approach has been proven to be effective in honing students' creative thinking skills, encouraging divergent thinking, increasing scientific arguments, and creativity in solving problems (Ismunandar et al., 2020; Pursitasari et al., 2022; Su, 2021).

Conclusion

Based on the research results, implementing the SSI approach in the context of controversial environmental issues significantly affects students' HOTS (Higher Order Thinking Skills) abilities. The HOTS indicators measured in this research are analysis, evaluation, problem-solving, application of knowledge, and creativity. These five aspects were proven to show higher scores in the experimental class compared to the control class, which had lower scores.

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Author Contributions

Conceptualization, validation, and resources, A.A. and J.D.; methodology, writing—review, and editing, A.A. and D.F; formal analysis and visualization, D.F.; investigation, data curation, supervision, and project administration, A.A.; writing—original draft preparation and funding acquisition, A.A., J.D., and D.F.

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Conflicts of Interest

The authors declare no conflict of interest.

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