Enhancing Elementary School Student Debates on Socio-scientific Issues through Multiple Storyline Comics: An Exploratory Study

Fadhlan Muchlas Abrori[1*] , Zsolt Lavicza[2] , Branko Anđić[3] , Muhsinah Annisa[4] , Nurul Qamariyah[5]

[1,2,3] Linz School of Education, Johannes Kepler University Linz, Austria
[4] Elementary Teacher School Department, University of Lambung Mangkurat, Indonesia
[5] Primary School VI Guluk-Guluk, Sumenep, East Java, Indonesia
*fadhlan1991@gmail.com

Abstract. Utilizing debates as an educational tool holds significant importance, not only for evaluating students' capacity to construct arguments but also for evaluating their critical thinking abilities based on their existing knowledge. In this study, we introduce a multi-storyline comic that explores socio-scientific themes linked to the use of sunblock at the beach. Each storyline portrays a distinct perspective, either in favor of or against sunblock usage. Students are then divided into two groups: one supporting the idea and one opposing it. This research aims to investigate the effectiveness of multi-storyline comics in facilitating debates among elementary school students regarding socio-scientific issues (SSI). The central aim is to assess how comics can enhance the debate process, especially within a small class of 10 students engaged in discussions concerning sunblock application at the beach. A thematic analysis was conducted to evaluate student statements during the debates, uncovering eight overarching themes with 16 corresponding codes stemming from their arguments. The findings emphasize the efficacy of multi-storyline comics as a tool for introducing SSI scenarios, allowing students to formulate statements, contemplate diverse viewpoints, and deepen their understanding of the pertinent issues.

Keywords: multiple storyline comics, debates, socio-scientific issues

1   Introduction

Do you agree with using sunblock when going to the beach? The topic of sunblock usage at the beach prompts a socio-scientific inquiry about the perspectives on chemical sunblock, both from an individual standpoint and its long-term impact on the beach ecosystem. While these questions may seem simple and personal, they can be challenging for students to answer without understanding the nature of science or the ability to engage in debate. However, introducing socio-scientific issues in the classroom can facilitate answering such questions. Research suggests that incorporating socio-scientific issues helps students grasp the nature of science [1], [2] (and develop scientific literacy [3]–[5], enabling them to engage in debates and make informed decisions.

Although many studies have focused on implementing socio-scientific issues in high schools and colleges [6]–[8], there is a lack of research on integrating SSI into elementary schools [9]. However, it would be beneficial to introduce SSI to students from an early age to enhance their literacy skills. Introducing simple issues that do not require structured arguments can be a starting point. Nevertheless, due to the complexity of the content, there are concerns about the acceptance of SSI among elementary school students [9]. Therefore, it is essential to consider the classroom environment and learning resources. According to Sadler et al. [10], employing media and information literacy strategies is crucial in shaping students' perception of SSI in the classroom. Therefore, we aim to design appropriate media to introduce SSI to elementary school children.

We have chosen comic media as our preferred medium for introducing socio-scientific issues (SSI). This decision is based on several considerations. Firstly, since our goal is to enhance student literacy, we need a medium to present SSI scenarios effectively. However, as SSI scenarios often rely heavily on text, we have transformed them into visual forms more suitable for elementary school children [11], our target audience. Secondly, comic media can foster reading habits and positively motivate students [12].

However, we have made slight modifications to the comics we have developed. Instead of having a single storyline, we have created multiple storylines to allow students to experience different narratives based on their choices. These multiple storylines are designed to highlight SSI's pros and cons, intending to facilitate classroom debates. Through these debates, we aim to assess the extent to which students' scientific literacy is represented in their engagement with the comics.

This paper aims to outline and explore the debates among elementary school students on socio-scientific issues using multiple-storyline comics. We seek to examine the complexity of these debates through a thematic analysis of student debate transcripts. By analyzing these debates, we hope to gain insights into the challenges and abilities of elementary school children when engaging with socio-scientific issues in a classroom setting.

2   Method

2.1   Context of Study

This research is part of design-based research [13], [14] examining the impact of comics in introducing socio-scientific issues to students. Specifically, for this particular study, we worked with a small class of 10 students taught by the fifth author of this paper. Before conducting the debate, throughout seven sessions, we familiarized the class with comic media and introduced three different comics, each addressing a different socio-scientific issue. This study is an exploratory investigation [15] into the contribution of comics with multiple storylines to the debate process.

2.2   Comic Design

The comics with multiple storylines referred to in this study do not follow a linear storyline structure. Instead, within each comic panel, there are two distinct storylines

based on the choices made by students regarding the issues at hand. Our comic design was inspired by Tobita's study [16], which also employed multiple-storyline comics. Our study's chosen issue was whether or not to use sunblock at the beach. Figure 1 presents an example of the comic, where the fourth panel includes a choice for students to either use sunblock (leading to storyline A) or not use sunblock (leading to storyline B).
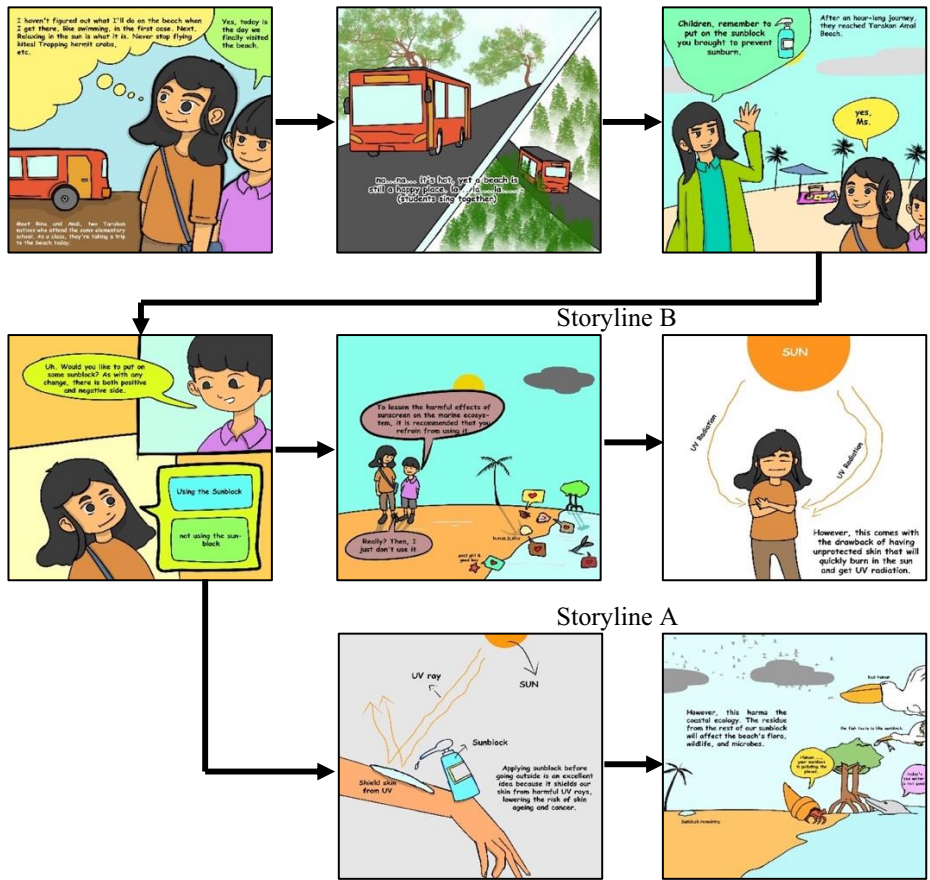

Fig 1. The multiple storylines of comics

2.3   Debate Process

The debate process was divided into three main stages—preparation, during, and after the debate stages—based on the work of Keller [17] and Peace [18] (see Figure 2). During the debate stage, we further divided it into six sub-stages: pro position, first rebuttal, con position, second rebuttal, teams questions, and closing statement. For this study, we focused solely on observing the activities during the debate stage.
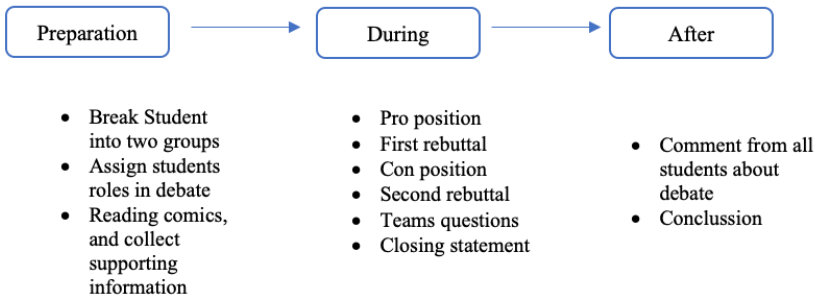
Fig 2. Debate process

2.4   Data Collection

Our study primarily focused on examining student statements during the debate process. We transcribed these statements verbatim, following a process adapted from previous studies [5], [19] that transcribed student statements in debates. However, our study concentrates on student statements and does not observe other variables.

2.5   Data Analysis

Thematic analysis [20] was employed to identify themes within the statements presented by students during the debate process. We organized these themes based on the codes that emerged from each statement in six sections: pro position, first rebuttal, con position, second rebuttal, team questions, and closing statement. To provide detailed data, we specified the frequency of each code by noting how many times it appeared in the statement process described by the students during the debate. In our findings, we use "f" to represent frequency, indicating the number of times the code was mentioned.

The first and fourth authors of this paper conducted the coding process. To ensure the reliability of the coding, we utilized interrater agreement with Cohen's kappa [21]. The resulting Cohen's kappa value in this study was 92%, indicating a high level of agreement between the two coders.

3   Findings

Based on our analysis of the transcript data during the debate, we conducted a thematic analysis to identify the themes reflected in the student's statements. The themes and corresponding codes that we identified are illustrated in Figure 3. In each debate stage, we found that there was generally one predominant theme, except for the first rebuttal and con position stages, where students expressed two themes in their statements.
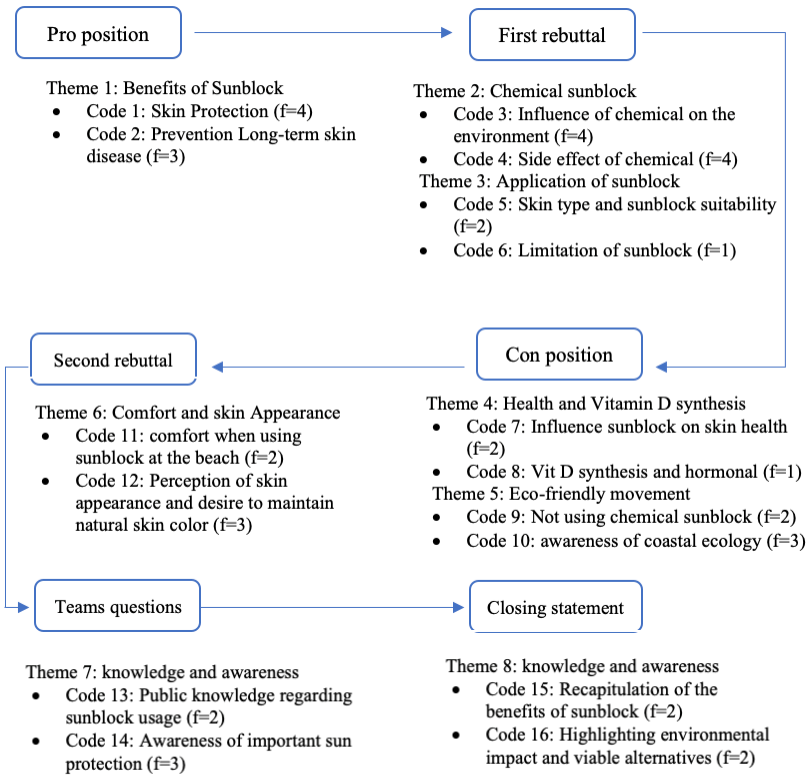
Pro position → **First rebuttal**

Theme 1: Benefits of Sunblock
- Code 1: Skin Protection (f=4)
- Code 2: Prevention Long-term skin disease (f=3)

Theme 2: Chemical sunblock
- Code 3: Influence of chemical on the environment (f=4)
- Code 4: Side effect of chemical (f=4)

Theme 3: Application of sunblock
- Code 5: Skin type and sunblock suitability (f=2)
- Code 6: Limitation of sunblock (f=1)

Second rebuttal ← **Con position**

Theme 6: Comfort and skin Appearance
- Code 11: comfort when using sunblock at the beach (f=2)
- Code 12: Perception of skin appearance and desire to maintain natural skin color (f=3)

Theme 4: Health and Vitamin D synthesis
- Code 7: Influence sunblock on skin health (f=2)
- Code 8: Vit D synthesis and hormonal (f=1)

Theme 5: Eco-friendly movement
- Code 9: Not using chemical sunblock (f=2)
- Code 10: awareness of coastal ecology (f=3)

Teams questions → **Closing statement**

Theme 7: knowledge and awareness
- Code 13: Public knowledge regarding sunblock usage (f=2)
- Code 14: Awareness of important sun protection (f=3)

Theme 8: knowledge and awareness
- Code 15: Recapitulation of the benefits of sunblock (f=2)
- Code 16: Highlighting environmental impact and viable alternatives (f=2)

Fig 3. Themes and codes based on the debate

3.1   Pro position and first rebuttal

During the pro position stage, the first group advocating for the use of sunblock at the beach emphasized several points regarding the benefits of sunblock. In their statements, they highlighted the importance of skin protection, mentioned twice, and the prevention of long-term skin diseases, mentioned three times. These two domains were coded under the "benefits of sunblock." To illustrate, we provide two excerpts from the transcripts of statements made by the pro sunblock group during the discussion.

Student 1: "UV rays are currently not very good for the skin, so for outdoor activities such as on the beach, you need a medium to counteract UV rays and protect the skin, namely sunblock."

Student 4: "I also add from my friend's opinion, not only protecting the skin, sunblock can also prevent skin cancer, which also occurs due to UV radiation."

During the rebuttal phase against the statements made by the pro group, the con group countered by claiming that the pro group's statements were not entirely accurate.

They specifically mentioned instances where sunblock may not be suitable for specific skin types (f=2). Additionally, some students in the Con group highlighted the limitations of sunblock in effectively blocking UV rays (f=1). We categorized these two codes under the theme of "application of sunblock." Here are a few statements that represent the con group's perspective:

> *Student 6: "I agree that sunblock can help protect the skin from UV rays, but I've read that sometimes sunblock can cause allergies because it doesn't suit certain skin types."*

> *Student 10: "I want to add something that the pro group hasn't acknowledged, which is that there are also limitations to sunblock. It cannot provide absolute protection to the skin. For example, individuals with darker skin may require a specific type of sunblock that ordinary sunblock cannot effectively protect against UV radiation."*

In addition to responding during the rebuttal, the con group highlighted the use of chemicals in many sunblocks available on the market, pointing out their potential side effects (f=4). They further emphasized that these side effects affect not only the users' skin but also the environment (f=4). Here are definitive statements representing this code:

> *Student 9: "Furthermore, we discovered that most sunblocks on the market contain chemicals that can have side effects on the skin, such as skin irritation and itching."*

> *Student 7: "As explained by my friend, the impact of sunblocks with chemicals extends beyond the user's skin. It can affect the ecosystem around coastal areas and cause pollution."*

From the students' statements, it can be observed that in the proposition and first rebuttal sections, the debate process involves direct responses from the con group to the statements made by the pro group. Furthermore, the Con group also added additional information to reinforce their arguments.

3.2   Con position and second rebuttal

In this section, it is the con group's turn to present their arguments against using sunblock. They first highlighted the natural importance of the sun for human skin health and vitamin D synthesis. Their initial statements focused on the harmful effects of sunblock on skin health (f=2) and the role of sunlight in vitamin D synthesis and hormonal balance (f=1). The following examples illustrate statements made by the Con group during the debate:

> *Student 9: "During the rebuttal section, we emphasized that sunblock can sometimes have adverse effects on the skin, such as itching and irritation. This*

indicates that sunblock can trigger allergies for certain users. Moreover, based on my readings, some chemical ingredients in sunblock can be absorbed into the body, potentially impacting the users' long-term health."

Student 8: "Why is it so challenging for us to use sunblock, even though we need sunlight to activate vitamin D and maintain hormonal balance in our bodies? Therefore, using sunblock seems futile for humans."

Apart from emphasizing the human perspective, the con group also made statements related to environmental concerns. They expressed their views against using chemical sunblock to protect the environment (f=2) and highlighted the importance of human awareness in safeguarding coastal ecosystems (f=3). The following statements represent this perspective:

Student 10: "We should remember that in this discussion, we consistently urge humans to minimize chemical exposure to sunblock to protect the environment."

Student 8: "Humans need to be aware that the use of sunblock also affects other living organisms. We need to be conscious of this, particularly for the well-being of coastal ecosystems."

Like the previous section, this stage also involves a rebuttal process. Here, the pro group responded to the statements made by the con group regarding skin health. Their responses predominantly revolved around the comfort and benefits of sunblock at the beach (f=2), as well as perceptions of skin appearance and the desire to maintain a natural skin color (f=2). The following statements represent these perspectives:

Student 2: "We must recognize that using sunblock enhances our comfort at the beach. It protects our skin, making us feel safer. The opinions expressed by the Con group regarding the use of sunblock or its effects on the skin are isolated cases. On the contrary, data shows that most sunblocks are effective in combating UV radiation."

Student 3: "There is also a social perception that emphasizes the importance of maintaining a natural skin color. This is precisely why sunblock plays a significant role in preventing sunburn and keeping our skin healthy."

During the con position and second rebuttal, the notable aspect of the debate process was the focus on data and discussions related to social and environmental aspects. However, there was limited response from the pro group regarding the eco-friendly movement.

3.3   Teams Questions

In this stage, both teams can ask questions to the opposing team, and the opposing team responds. Two notable codes emerged in this section: public knowledge regarding

sunblock usage (f=2) and awareness of the importance of sun protection (f=2). In the first code, the pro group asked questions to the con group, and the con group emphasized the need for more public knowledge in their responses. The following statement serves as an example of a representative response:

> *Student 5 (Pro group): "Why does your group place more emphasis on the environment, while we humans ourselves need sunblock to protect our skin from UV rays?"*

> *Student 7 (Con group): "We emphasize the environment because there are many cases where people lack knowledge about using sunblock. They often opt for inexpensive sunblocks with chemical ingredients that have negative impacts on the ecosystem. However, if we are willing to invest a little more and consider eco-friendly mineral sunblocks, we can address this issue. Therefore, we critique the lack of public knowledge regarding sunblock usage and stress the importance of awareness and wise decision-making."*

Next, the con group asked the pro group about their perception of why they consistently promote the use of sunblock. The Pro group responded by emphasizing raising awareness to protect oneself from the sun and its long-term effects. The following statement represents a typical response:

> *Student 10 (Con group): "None of you mentioned the environment in your statements. Why do you focus more on the human aspect?"*

> *Student 5 (Pro group): "It is not that we ignore the impact of sunblock on the environment. However, we aim to present a pro statement, so we primarily discuss the benefits of sunblock from the human perspective. Many people lack awareness of UV radiation. As the world is changing due to global warming, UV exposure is increasing. However, many individuals fail to use sunblock in hot environments. We want to raise awareness about the importance of skin health, particularly in light of the increasing incidence of skin cancer. Therefore, sunblock is essential for sun protection to maintain healthy skin."*

During the Teams Questions stage, the primary focus of both groups was to question the statements made by the opposing team. In response, the answering group provided further information related to awareness and knowledge of the subject matter.

3.4   Closing Statements

Each team presents a summary of their arguments in this stage and reaffirms their position by delivering a closing statement. Both groups focus on two main aspects, as indicated by the mentioned codes: recapitulation of sunblock benefits (f=2) and the environmental impact along with viable alternatives (f=2). The following closing statements represent these aspects:

Student 5 (Pro group): "Based on all our explanations supporting the use of sunblock, it is crucial to understand the dangers of UV radiation, particularly the heightened risk of skin cancer. Therefore, the benefits of sunblock lie in its ability to protect us from these dangers."

Student 7 (Con group): "As humans, we need to think broadly and be mindful of our environment. This is why our group has opposed the use of sunblock from the beginning, due to its environmental impact. We propose alternatives, such as utilizing environmentally friendly sunblocks, as a means to reduce environmental pollution resulting from sunblock usage."

These closing statements highlight each group's stance and reinforce their arguments by summarizing sunblock's benefits or proposing alternative solutions. It demonstrates that the purpose of the closing statements is to provide an overall summary of each team's arguments.

4   Discussion

This section examines whether using multiple storylines in comics contributes to the student debate process. The broad answer is that it facilitates students in formulating their positions, whether in favor or against the issue. It aligns with findings from previous studies that highlight the significant role of comic media in information gathering during debates [22], [23]. However, we observed some intriguing improvisations made by the students. During the debate, they provided information that did not appear explicitly in the comics, indicating that they had prior knowledge or acquired additional insights from sources outside the comic media. For instance, the con group introduced the concept of the suitability of sunblock for different skin types and the synthesis of vitamin D, which were not explicitly presented in the comics. This observation is intriguing and highlights the essence of learning through socio-scientific issues, which encourages the exploration of diverse information sources rather than relying solely on one [24], [25].

On the other hand, the pro group predominantly emphasized information provided within the comics. Their statements revolved around the benefits of sunblock from a human perspective. However, one interesting aspect to note is their argument in the second phase of the debate, which touched upon social perceptions regarding skin appearance. Their statement was thought-provoking, as they acknowledged the influence of social factors on the desire to maintain a bright skin complexion. It aligns well with the socio-scientific issues framework, where the emphasis extends beyond pure science and incorporates societal aspects [26], [27]. The Pro group displayed sensitivity in addressing this social dimension as part of their argument.

Taking positions and engaging in rebuttals plays a crucial role in debates [28], [29]. Taking a position involves expressing one's views through perspectives and arguments that are to be defended, accompanied by evidence, data, facts, and logical reasoning supporting that position [17]. On the other hand, rebuttals respond to invalid arguments, aiming to weaken the opponent's stance [18]. These two aspects are highly significant

when employing socio-scientific issues (SSI) in the classroom [29]. The controversial nature of SSI necessitates the existence of opposing sides, representing both pros and cons. In the case of the debate on using sunblock, it exemplifies the controversy inherent in SSI. Engaging in SSI debates has proven beneficial in fostering students' critical thinking skills and promoting the importance of respecting differing viewpoints [4].

An intriguing element arises during the stage where teams pose questions to each other, targeting the weak points in each group's statements. For instance, the Pro group questions the Con group about their emphasis on the environment while neglecting essential considerations from the human perspective. Similarly, the Con group asks the Pro group why their statements consistently focus on the human aspect rather than a broader, universal perspective regarding the environment. Both groups responded adeptly, demonstrating a high level of awareness regarding human health and environmental concerns. It aligns with research emphasizing the cultivation of awareness among individuals engaged in SSI [26], [30], [30], encouraging reflection on whether their positions on issues are beneficial in the long run.

The closing statements in the debate are equally intriguing. Both groups presented their recapitulations to reinforce the statements made throughout the debate. It holds significant importance in SSI learning as it strengthens students' positions on issues, requiring them to possess the skills to summarize and recapitulate all relevant facts and arguments [5], [29].

Suppose we assess the extent to which students can develop statements during the SSI discussion process. In this case, this study reveals that most of the statements provided by students rely heavily on the information presented in the comics, except for the Con group, which also incorporates additional information. However, it is essential to note that the information conveyed in these statements is limited to what the students can gather from various sources, regardless of the validity of those sources. It is the teacher's responsibility to provide access to reliable information, especially considering that the target audience in this study is elementary school children who may still need to gain knowledge in discerning valid information.

Another group could challenge some of the information presented by one group, but due to limited knowledge, such discussions did not occur extensively during the rebuttal phase. For example, when the Con group explained the process of vitamin D synthesis triggered by sunlight, the Pro group could argue that not all sunlight is equally adequate for activating vitamin D synthesis. They could have mentioned that the most effective sunlight for this purpose is during the morning or evening, as excessive heat can lead to skin problems. However, this aspect still needs to be addressed by the pro group.

Based on the findings, it is evident that engaging in classroom debates using multiple-storyline comics can positively impact students by enriching the information shared during the debate process. Nonetheless, there are areas where students need to improve, such as solely focusing on the comic information without exploring additional sources. It highlights the importance of students independently collecting and managing information from various sources, a skill that should be further addressed in future studies and educational practices related to SSI.

5   Conclusion

In conclusion, this study examined the use of multiple-storyline comics in facilitating student debates on socio-scientific issues (SSI). The findings indicate that using comics positively contributed to the debate process, allowing students to express their positions and engage in critical thinking. The comics served as an effective medium for introducing SSI scenarios to elementary school students, fostering scientific literacy, and promoting open-mindedness toward diverse perspectives.

However, it is essential to acknowledge certain limitations of this study. Firstly, the research was conducted in a small class with a limited number of participants, which may impact the generalizability of the findings. Further studies with larger sample sizes are needed to validate and expand upon these results. Additionally, the study primarily focused on student statements during the debate without thoroughly examining other variables or assessing the long-term impact of using multiple-storyline comics in SSI education.

Furthermore, the study predominantly relied on the information presented in the comics, and there needed to be more emphasis on students independently seeking and evaluating information from diverse sources. Future research should encourage students to explore a broader range of information and develop critical evaluation skills.

Lastly, the study mainly focused on elementary school students, and the results may differ for students at different educational levels. Investigating the impact of multiple-storyline comics in SSI discussions across various grade levels would provide a more comprehensive understanding of their potential benefits.

Despite these limitations, this study highlights the promising role of multiple-storyline comics in facilitating SSI debates among elementary school students. It provides valuable insights for educators and curriculum developers seeking innovative approaches to enhance students' engagement with socio-scientific issues.

References

1. J. S. C. Leung, "A practice-based approach to learning nature of science through socio-scientific issues," *Res. Sci. Educ.*, vol. 52, no. 1, pp. 259–285, 2022.
2. D. Karisan and D. L. Zeidler, "Contextualization of Nature of Science within the Socio-scientific Issues Framework: A Review of Research.," *Int. J. Educ. Math. Sci. Technol.*, vol. 5, no. 2, pp. 139–152, 2017.
3. T. D. Sadler, "Informal reasoning regarding socio-scientific issues: A critical review of research.," *J. Res. Sci. Teach. Off. J. Natl. Assoc. Res. Sci. Teach.*, vol. 41, no. 5, pp. 513–536, 2004.
4. K. De Checchi, G. Pallarès, V. Tartas, and M. Bächtold, "Epistemic Beliefs as a Means of Understanding Critical Thinking in a Socio-scientific Environmental Debate," in *Critical Thinking in Biology and Environmental Education: Facing Challenges in a Post-Truth World*, Springer, 2022, pp. 229–248.
5. M. Bächtold, G. Pallarès, K. De Checchi, and V. Munier, "Combining debates and reflective activities to develop students' argumentation on socio-scientific issues," *J. Res. Sci. Teach.*, vol. 60, no. 4, pp. 761–806, 2023.

6. H. Cian, "The influence of context: comparing high school students' socio-scientific reasoning by socio-scientific topic," *Int. J. Sci. Educ.*, vol. 42, no. 9, pp. 1503–1521, 2020.

7. V. Dawson, "Western Australian high school students' understandings about the socio-scientific issue of climate change," *Int. J. Sci. Educ.*, vol. 37, no. 7, pp. 1024–1043, 2015.

8. S.-Y. Wu and K.-K. Yang, "Influence and behavioral pattern of university students' participation in decision-making on socio-scientific issues," *Res. Sci. Technol. Educ.*, pp. 1–19, 2022.

9. T. J. Dolan, B. H. Nichols, and D. L. Zeidler, "Using socio-scientific issues in primary classrooms," *J. Elem. Sci. Educ.*, vol. 21, no. 3, pp. 1–12, 2009.

10. T. D. Sadler, P. Friedrichsen, and L. Zangori, "A framework for teaching for the socio-scientific issue and model-based learning (SIMBL)," *Educ. E Front. Bord.*, vol. 9, no. 25, pp. 8–26, 2019.

11. S. N. F. Hasanah *et al.*, "Using Digital Comics to Learn Indonesia's Geographical Characteristics: Social Studies Education Solutions for Elementary School Students during the Covid-19 Pandemic," in *2021 7th International Conference on Education and Technology (ICET)*, IEEE, 2021, pp. 214–220.

12. S. Nikmah, F. Haroky, I. Wilujeng, and H. Kuswanto, "Development of Android Comic Media for the Chapter of Newton's Gravity to Map Learning Motivation of Students," in *Journal of Physics: Conference Series*, IOP Publishing, 2019, p. 012051.

13. F. Wang and M. J. Hannafin, "Design-based research and technology-enhanced learning environments," *Educ. Technol. Res. Dev.*, vol. 53, no. 4, pp. 5–23, 2005.

14. J. Van den Akker, K. Gravemeijer, and S. McKenney, "Introducing educational design research," in *Educational design research*, Routledge, 2006, pp. 15–19.

15. R. De Langhe and E. Schliesser, "Evaluating philosophy as exploratory research," *Metaphilosophy*, vol. 48, no. 3, pp. 227–244, 2017.

16. H. Tobita, "Comic-crowd : Interactive comic creation that supports multiple storylines, visualizations, and platform," *ACM Int. Conf. Proceeding Ser.*, vol. 30-Novembe, no. Mum, pp. 163–172, 2015, doi: 10.1145/2836041.2836057.

17. T. E. Keller, J. K. Whittaker, and T. K. Burke, "Student debates in policy courses: Promoting policy practice skills and knowledge through active learning," *J. Soc. Work Educ.*, vol. 37, no. 2, pp. 343–355, 2001.

18. A. Peace, "Using Debates to Teach Information Ethics," *J. Inf. Syst. Educ.*, vol. 22, no. 3, pp. 233–238, Jan. 2011.

19. J. Bres, A. Nowakowska, and J.-M. Sarale, "Anticipative interlocutive dialogism: sequential patterns and linguistic markers in French," *J. Pragmat.*, vol. 96, pp. 80–95, 2016.

20. K. A. Neuendorf, "Content analysis and thematic analysis," in *Advanced research methods for applied psychology*, Routledge, 2018, pp. 211–223.

21. M. L. McHugh, "Interrater reliability: the kappa statistic," *Biochem. Medica*, vol. 22, no. 3, pp. 276–282, Oct. 2012.

22. C. Gormally, "Using Comics to Make Science Come Alive," Aug. 2021, doi: 10.24918/cs.2020.3.

23. C. L. da Silva, M. Cezarino, L. de Andrade Carvalho, and M. F. de Souza, "The effects of comic books on body beauty standards in Physical Education classes," *Corpoconsciência*, pp. 75–86, 2019.

24. M. L. Presley *et al.*, "A Framework for Socio-Scientific Issues Based Education," *Sci. Educ.*, vol. 22, no. 1, pp. 26–32, 2013.

25. D. L. Zeidler, "Socio-scientific issues as a curriculum emphasis. Theory, research, and practice.," in *Handbook of Research on Science Education, Volume II Edition: II*, Routledge, 2014, pp. 697–726.

26. Y. Hwang, Y. Ko, S. S. Shim, S.-Y. Ok, and H. Lee, "Promoting engineering students' social responsibility and willingness to act on socio-scientific issues," *Int. J. STEM Educ.*, vol. 10, no. 1, pp. 1–16, 2023.

27. I. M. Cruz-Lorite, D. Cebrián-Robles, M. del C. Acebal-Expósito, and M. Evagorou, "Analysis of the Informal Reasoning Modes of Preservice Primary Teachers When Arguing about a Socio-Scientific Issue on Nuclear Power during a Role Play," *Sustainability*, vol. 15, no. 5, p. 4291, 2023.

28. S. Kahn and D. L. Zeidler, "A conceptual analysis of perspective taking in support of socio-scientific reasoning," *Sci. Educ.*, vol. 28, pp. 605–638, 2019.

29. M. Martini, W. Widodo, A. Qosyim, M. Mahdiannur, and B. Jatmiko, "Improving undergraduate science education students' argumentation skills through debates on socio-scientific issues," *J. Pendidik. IPA Indones.*, vol. 10, no. 3, pp. 428–438, 2021.

30. N. Aznam and I. Irwanto, "Socio-Scientific Issues as a Vehicle to Promote Soft Skills and Environmental Awareness.," *Eur. J. Educ. Res.*, vol. 10, no. 1, pp. 161–174, 2021.