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The Implementation of SSI Model Assisted by *Oray-Orayan* Game Regarding Students' Argumentation Skills in Reproductive System Material

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ABSTRACT
Scientific argumentation skills are an essential 21st-century competency, yet remain relatively underdeveloped in biology education, particularly in reproductive system material rich with socio-scientific issues. This study investigated the effect of applying the Socio-Scientific Issues (SSI) model assisted by the Oray-Orayan game on high school students' argumentation skills. A quasi-experimental design with a nonequivalent control group was employed involving 50 students (25 experimental, 25 control) at SMA Muhammadiyah Sukabumi. Argumentation skills were measured using 10-item essay test based on Toulmin's six argumentation indicators (claim, data, warrant, backing, qualifier, rebuttal) for both pretest and posttest, and a student response questionnaire was administered to the experimental class. Statistical analysis using Mann-Whitney U test showed a significant difference between posttest scores of the experimental and control groups (Asymp. Sig. = 0.000 < 0.05). Implementation observation scores reached 94% (experimental) and 89% (control), both categorized as "Very Good." Student responses were consistently positive across all indicators. These findings confirm that the SSI model assisted by the Oray-Orayan game effectively enhances students' scientific argumentation skills in reproductive system material and can serve as an innovative, contextual, and meaningful alternative learning model in biology education.

INTRODUCTION

Twenty-first century skills demand that students possess critical thinking, problem-solving, and scientific argumentation abilities (Irvan & Admoko, 2020). Argumentation competency holds high significance as it integrates critical thinking and communication, both considered core 21st-century skills (Muaziyah et al., 2023; Akili et al., 2022). Scientific argumentation has become one of the major emphases in contemporary science education (Smith, 2023). Argumentation is defined as a method of strengthening opinions through critical reasoning supported by evidence and logical reasoning (Khodabandeh, 2014). The Toulmin Argumentation Pattern (TAP) remains the most widely used framework in science education research, analyzing argument structure through six components: claim, data, warrant, backing, qualifier, and rebuttal (Toulmin, 2003).

Studies across various regions consistently report that students' scientific argumentation skills remain low. Few students dare to articulate arguments in class, indicating an urgent need for further development (Suartha et al., 2020). Science learning that focuses solely on information memorization fails to develop argumentation skills (Ginanjar et al., 2019). Initial observations at SMA Muhammadiyah Sukabumi revealed that Grade XI students struggled to link reproductive system concepts with social issues such as free association and sexually transmitted infections (STIs). HIV/AIDS remains one of the major global public health concerns (World Health Organization, 2024), making it important for students to understand reproductive health issues through evidence-based scientific reasoning. Student interviews further exposed that their scientific arguments were weak, lacking evidence-based reasoning, highlighting a gap between 21st-century learning demands and actual classroom argumentation skills.

To address this problem, the Socio-Scientific Issues (SSI) model offers a pedagogical approach that uses controversial socially debated issues with scientific dimensions as the context for science learning (Zeidler, 2014). SSI-based learning has been proven to enhance scientific argumentation, science literacy, and students' decision-making through analysis of social issues related to scientific concepts (Devi & Hariyono, 2024). Beyond contextual approach, student engagement can be increased through educational games. A 2024 meta-analysis demonstrated that game-based learning enhances student motivation, conceptual understanding, and scientific argumentation (Fatih, Rahman, et al., 2024).

In this study, the *Oray-Orayan* game a traditional West Javanese game adapted to resemble a snake-and-ladder format was used as the SSI-based learning medium on reproductive system material. Every section of the game contains problems prompting students to construct scientific arguments through claims, evidence, and reasoning aligned with the Toulmin (Fatih, Rahman, et al., 2024). The integration of the game with SSI contributes to structured and meaningful development of scientific argumentation skills. Thus, this study aims to analyze the effect of the SSI model assisted by the *Oray-Orayan* game on students' argumentation skills in reproductive system material at SMA Muhammadiyah Sukabumi.

The SSI model implemented in this study followed five sequential learning syntaxes. First, socio-scientific issue identification, in which students were introduced to controversial issues related to the reproductive system, such as free association, HIV/AIDS, syphilis, and gonorrhea, through the *Oray-Orayan* game board. Second, scientific exploration, in which students gathered and examined scientific information related to the issue raised in each game section. Third, social and moral value analysis, in which students discussed the social, ethical, and religious dimensions of the issue. Fourth, argument evaluation and decision-making, in which students formulated claims, supported them with data and warrants, and considered counter-arguments following the Toulmin framework. Fifth, reflection and social action, in which students reflected on the lesson and proposed practical responses to the issue. Each section of the *Oray-Orayan* game corresponded to one of these syntaxes, guiding students step by step through the SSI learning process while constructing scientific arguments.

METHOD

This study used a quantitative approach with a quasi-experimental design employing a nonequivalent control group (Kuncoro, 2021; Sugiyono, 2018). The study was conducted at SMA Muhammadiyah Sukabumi. Purposive sampling was used to select two Grade XI classes: Class XI IPA 1 (n = 25) as the experimental group and Class XI IPA 2 (n = 25) as the control group, totaling 50 students in Semester 2 of the 2025/2026 academic year.

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_3
Control	O_2	X_2	O_4

(Source: Sugiyono, 2018)

The experimental class received learning treatment using the SSI model integrated with the *Oray-Orayan* game, while the control class used the Discovery Learning model. Both classes studied the same material: sexually transmitted infections (STIs) in the reproductive system topic of the Merdeka Curriculum.

The main instrument was a 10-item essay argumentation skills test based on Toulmin's six argumentation indicators: claim, data, warrant, backing, qualifier, and rebuttal. A student response questionnaire (12 items) was also administered to the experimental class. Instrument quality was verified through validity, reliability (KR-20), and difficulty level analyses following the procedures proposed by Arikunto (2013) using Anates v4.0. Learning implementation was observed using an observation sheet assessed by two observers.

Data analysis followed a sequential procedure: normality testing (Shapiro-Wilk), homogeneity testing (Levene's Test), and hypothesis testing. Because pretest data for the control class and posttest data for both classes did not meet normality assumptions, the nonparametric Mann-Whitney U test was applied to compare group means, using SPSS v25.0 at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Normality and Homogeneity Tests

Prior to hypothesis testing, prerequisite tests were performed. Shapiro-Wilk normality test results showed that pretest scores of the experimental class (Sig. = 0.355) were normally distributed, while the control class pretest (Sig. = 0.020) was not normally distributed. For posttest scores, both the experimental class (Sig. = 0.019) and control class (Sig. = 0.002) were not normally distributed. Homogeneity of variance was confirmed for pretest (Levene Sig. = 0.524) and posttest (Levene Sig. = 0.994) data (Table 3 and Table 4). Since normality assumptions were not fully met for all groups, the nonparametric Mann-Whitney U test was selected for hypothesis testing.

Table 2. Summary of Pretest Statistical Test

Test Type	Parameter	Class	Sig. Value	Conclusion
Normality	Shapiro-Wilk	Experimental	0.355	Normal
		Control	0.020	Not Normal
Homogeneity	Levene's Test	Combined	0.524	Homogeneous
Non-Parametric	Mann-Whitney U	Control vs. Experimental	0.283	Not Significantly Different

The posttest results revealed a different pattern. As shown in Table 3, both classes showed non-normal distributions in their posttest scores, necessitating the continued use of the Mann-Whitney U test for hypothesis testing.

Table 3. Summary of Posttest Statistical Test

Test Type	Parameter	Class	Sig. Value	Conclusion
Normality	Shapiro-Wilk	Experimental	0.019	Not Normal
		Control	0.002	Not Normal
Homogeneity	Levene's Test	Combined	0.994	Homogeneous
Non-Parametric	Mann-Whitney U	Control vs. Experimental	0.000	Significantly Different

Hypothesis Testing

The Mann-Whitney U test comparing posttest scores between the experimental and control groups yielded Asymp. Sig. (2-tailed) = 0.000, which is below the threshold of $\alpha = 0.05$. Therefore, H0 is rejected and H1 is accepted, indicating a statistically significant difference in argumentation skills between students taught with the SSI model assisted by the *Oray-Orayan* game and those taught with Discovery Learning. These results demonstrate that the SSI model combined with the *Oray-Orayan* game effectively develops students' scientific argumentation skills in reproductive system material.

This finding aligns with Devi & Hariyono (2024), who confirmed that SSI-based learning significantly enhances students' argumentation and critical thinking compared to conventional approaches. Similarly, Ridwan et al. (2023) reported that SSI-based science learning improved scientific argumentation in their subject context. The *Oray-Orayan* game contributed to this improvement by creating an interactive, competitive, and joyful learning environment in which students practiced constructing arguments naturally within each game round. This finding is consistent with Günter and Alpat (2019), who reported that case-based learning improves students' academic achievement through contextual learning experiences. These findings are also supported by Rachmatullah et al. (2021), who found that game-based learning environments increase students' motivation and engagement in science learning. Furthermore, this finding is also consistent with Fatih, Rahman, et al. (2024), who found through meta-analysis that game-based learning enhances student motivation, conceptual understanding, and scientific argumentation.

Argumentation Skill Improvement per Indicator

Figure 1 presents the percentage improvement per argumentation indicator for both experimental and control classes. The experimental class consistently outperformed the control across all six Toulmin indicators.

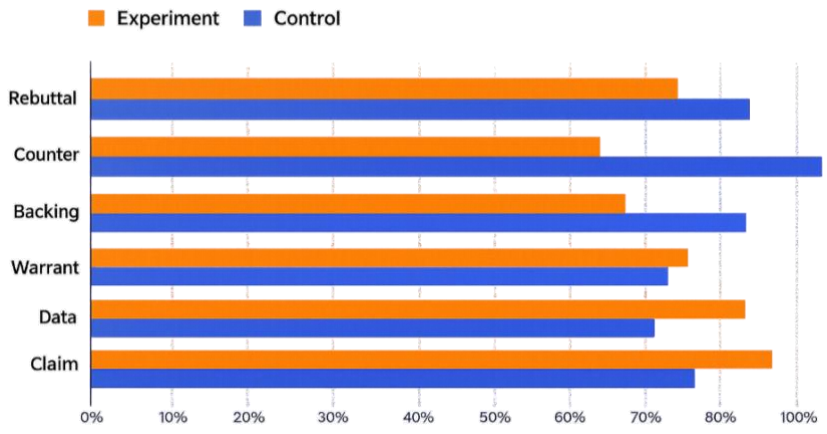

Fig.1. N-gain scores for each argumentation indicator

The experimental class showed notably higher performance on the Claim indicator (approx. 93%) compared to the control class (approx. 80%). The Data indicator similarly showed higher experimental class scores (87%) versus the control (70%). The Warrant indicator showed experimental class improvement of 83% versus 65% for control. For Backing, the experimental class reached 65% while the control achieved 86%, a reversal that may reflect the control class's stronger memorization of theoretical backing. The Qualifier indicator showed the most marked divergence, with the control group

reaching 100% while the experimental group scored 65%, suggesting structured drill approaches may favor qualifier use. The Rebuttal indicator showed experimental class performance at 77% versus control at 70%, showing the *Oray-Orayan* game debate structure effectively supported counter-argument articulation.

Overall, the SSI model effectively developed students' ability to construct socio-scientifically grounded arguments. By situating argumentation within real-world controversial issues (HIV/AIDS, syphilis, gonorrhea), students were motivated to engage with evidence and reason critically. Based on the observation results across the five SSI syntaxes, the social and moral value analysis stage and the argument evaluation and decision-making stage showed the highest implementation scores (each above 95%), as the *Oray-Orayan* game provided concrete, relatable contexts (HIV/AIDS, syphilis, gonorrhea) that prompted active discussion. The socio-scientific issue identification stage and the reflection and social action stage reached approximately 90-92%, while the scientific exploration stage scored slightly lower (around 88%), indicating that students required more guidance when independently searching for supporting scientific evidence. These findings suggest that the argument evaluation and decision-making stage was the most effective in stimulating students' argumentation skills. This is consistent with (Zeidler, 2014) who emphasized that SSI learning develops comprehensive science literacy, enabling students not only to master scientific content but to think deeply, construct arguments, and make accountable decisions.

Learning Implementation Observation

Learning implementation was assessed by two observers using an observation sheet with a maximum score of 18 points. Results showed that both the experimental class (Observer 1: 17/18, Observer 2: 17/18; average = 94%) and control class (Observer 1: 16/18, Observer 2: 16/18; average = 89%) were classified in the "Very Good" category (Table 4).

Table 4. Learning Implementation Observation Result

Class	Observer	Score Obtained	Max Score	Percentage (%)	Category
Experimental	Observer 1	17	18	94	Very Good
	Observer 2	17	18	94	Very Good
	Average			94	
Control	Observer 1	16	18	89	Very Good
	Observer 2	16	18	89	Very Good
	Average			89	

The high implementation score (94%) for the experimental class reflects the systematic and well-structured nature of the SSI model's five syntaxes socio-scientific issue identification, scientific exploration, social and moral value analysis, argument evaluation and decision-making, and reflection and social action when integrated with the *Oray-Orayan* game. The game facilitated smooth transitions between SSI stages, maintaining student engagement throughout. The slightly lower score of 89% for the control class still indicates effective implementation of Discovery Learning, confirming that both learning models were applied with high fidelity.

Student Response to Learning

The student response questionnaire administered to the experimental class comprised 12 items covering five indicators: (1) ability to analyze reproductive health issues from multiple perspectives, (2) ability to connect scientific facts with moral values through the *Oray-Orayan* game, (3) interest and comfort during discussion-based and game-based learning, (4) self-confidence in expressing logically supported opinions, and (5) ability to consider scientific, social, and religious perspectives in socio-scientific discussion. Figure 2 presents the student response scores for each participant after the implementation of the *Oray-Orayan* game-based learning.

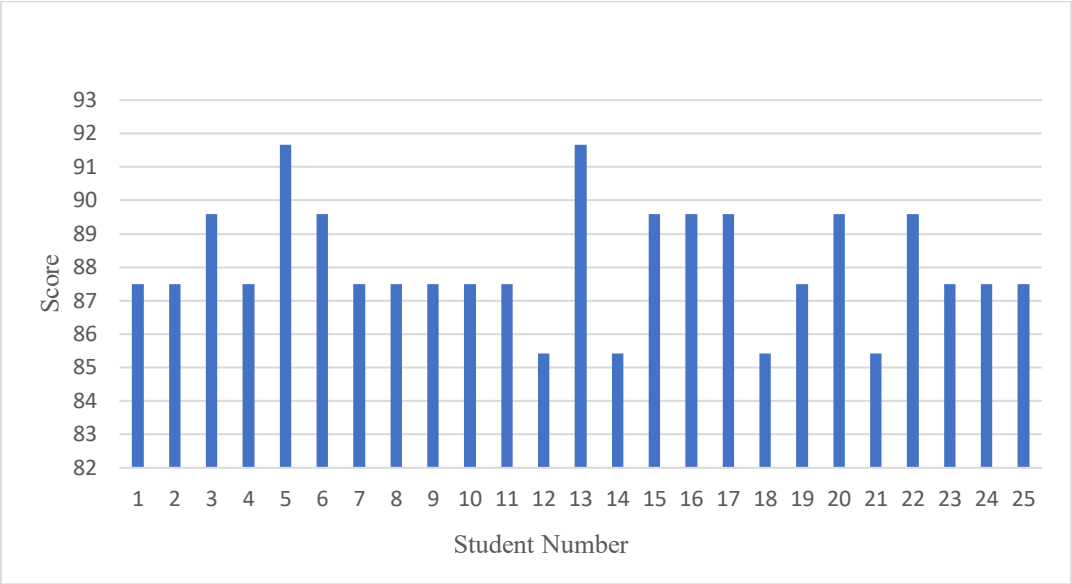

Fig.2. Student response scores across the 25 participants

To further contextualize these findings, Figure 3 presents a photograph of the *Oray-Orayan* game as implemented in the experimental class, illustrating the physical layout and interactive nature of the learning medium used throughout the study.

Fig.3. The Oray-Orayan game used in the study

Figure 2 shows that individual student response scores ranged from approximately 85 to 92, indicating consistently positive responses across the class. The majority of students reported that the *Oray-Orayan* game made reproductive system material more engaging, helped them connect scientific facts with moral values, and increased their confidence in articulating evidence-based arguments. In percentage terms, the five indicators received the following positive response rates: ability to analyze reproductive health issues from multiple perspectives (90%), ability to connect scientific facts with moral values through the *Oray-Orayan* game (92%), interest and comfort during discussion-based and game-based learning (94%), self-confidence in expressing logically supported opinions (88%), and ability to consider scientific, social, and religious perspectives in socio-scientific discussion (91%). These findings are consistent with Fatih, Alfi, et al. (2024) who demonstrated that game-based learning enhances student motivation and creates more interactive, purposeful learning. Similarly, Lumbantobing et al. (2025) reported that integrating technology with game-based learning significantly increased students' learning motivation. In addition, Lathifah et al. (2025) found that interactive multimedia based on problem-based learning promoted active student engagement and improved

analytical skills. These findings suggest that interactive learning media can create more meaningful learning experiences that actively involve students in the learning process. The integration of socio-scientific issues related to STIs (HIV/AIDS, syphilis, gonorrhea) within the game context proved meaningful and relevant to students' lives, reinforcing the contextual learning principle central to SSI pedagogy (Kahn & Zeidler, 2019).

CONCLUSION AND SUGGESTION

This study concludes that the application of the Socio-Scientific Issues (SSI) model assisted by the *Oray-Orayan* game significantly improves the argumentation skills of Grade XI high school students in reproductive system material at SMA Muhammadiyah Sukabumi. This is evidenced by the Mann-Whitney U test result (Asymp. Sig. = 0.000 < 0.05), indicating a statistically significant difference in posttest argumentation scores between the experimental and control groups. Learning implementation reached "Very Good" quality in both classes (experimental: 94%, control: 89%), and student responses to the SSI-*Oray-Orayan* learning were consistently positive. The SSI model effectively positioned real socio-scientific issues as meaningful learning contexts, while the *Oray-Orayan* game created an interactive and engaging environment that motivated students to actively construct and articulate arguments using the Toulmin framework.

Future researchers are encouraged to investigate the long-term retention of argumentation skills developed through SSI-game integration, extend the sample to multiple schools for greater generalizability, and explore the model's applicability to other biology topics with socio-scientific dimensions. Teachers and school practitioners are encouraged to adopt the SSI model with contextually appropriate educational games as an innovative alternative to conventional biology instruction.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, M.L.S., A.M., and S.S.; methodology, M.L.S.; formal analysis, M.L.S.; investigation, M.L.S., and M.M.; data curation, M.L.S.; writing—preparation of the original draft, M.L.S.; writing—review and editing, A.M. and S.S.; supervision, A.M., S.S., and M.M.

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DECLARATION OF GENERATIVE AI SOURCES

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

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