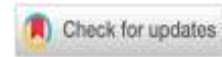




## Enhancing high-order thinking abilities through disc socio-scientific issues discussion on the virus concept



Adelia Siti Nur Apriliani, Yanti Herlanti \*

Biology Education Study Program, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Indonesia

\*Corresponding author: [yantiherlanti@uinjkt.ac.id](mailto:yantiherlanti@uinjkt.ac.id)

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### ABSTRACT

Based on national and international assessments, Indonesian students' higher-order thinking is inadequate, highlighting the need for effective learning. This study aimed to explore the impact of discussion of a socio-scientific issue on the development of higher-order thinking related to the concept of viruses. A quasi-experimental design used a nonequivalent pretest and posttest control group framework. The experimental group engaged in a socioscientific issue discussion model comprising the stages of Polemic, Exploration, Action, and Conclusion (PEAK). In contrast, the control group was instructed with a constructivist learning approach with discussion, students' presentations, and teacher explanations. The experimental group included 26 males and 46 females, while the control group had 30 males and 41 females. The findings showed that the experimental group's average pretest score was 55.1, while the control group's was 60.1. After the intervention, the experimental group achieved a posttest average of 73.3, compared to 69 for the control group. The N-gain test results demonstrated higher average gain in the experimental group ( $\bar{x}$ -gain 0.5) than the control group ( $\bar{x}$ -gain 0.2). Additionally, the Mann-Whitney U test indicated a significant effect of the socioscientific issue discussion learning model on students' HOTS. This model offers a promising alternative to enhance students' high-level thinking.

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### INTRODUCTION

The current era, characterized by the Industrial Revolution 4.0 and the emergence of Society 5.0, necessitates the cultivation of high-level thinking skills in students. These skills encompass



critical thinking, analysis, creativity, and the capacity to solve problems effectively (Suratno et al., 2020; Alam, 2019). Higher-order thinking skills are of critical importance in preparing learners to face the challenges of life and the world of work, which are dynamic, complex, and rife with competition. Individuals who have cultivated higher-order thinking skills tend to process information more efficiently, adapt to changing circumstances with greater ease, and make decisions that are aligned with the situation at hand. However, the results of international assessments indicate that the higher-order thinking skills of Indonesian students remain comparatively low. The Programme for International Student Assessment (PISA) report shows that the science literacy scores of Indonesian students consistently fall below the OECD average. Students' cognitive abilities in higher-order thinking domains are suboptimal, with 60% performing at level I, 40% at levels 2-4, and none reaching levels 5-6 (PISA, 2019). The trends in the International Mathematics and Science Study (TIMSS) report from 2003 to 2015 reflect a similar trend in Indonesia. In the 2015 TIMSS, Indonesian students' science scores ranged from 220 to 580, with an average score of 397 (on a scale of 0 to 800). This is significantly below the international average of 500. A substantial proportion of students, approximately 80%, scored below 500 on the standardized tests (Mullis, 2016).

The dearth of higher-order thinking skills among students can be attributed to pedagogical approaches that fail to incorporate higher-order thinking strategies into the teaching and learning process. As a result, students' comprehension and logical reasoning skills remain underdeveloped, particularly in addressing societal issues (Kurniasih et al., 2020; Arviani, 2023). Many education experts have criticized the current learning process in schools, arguing that it is not yet sufficiently oriented toward higher-order thinking skills (HOTS). This criticism stems from the perception that many aspects of learning still emphasize factual knowledge and rote memorization (Adawiyah, 2024). Moreover, educators face numerous challenges in implementing HOTS-based learning, including limitations in time, resources, and their own understanding of the HOTS framework (Ningsih & Shaleh, 2024; Djumadi et al., 2021). The implementation of HOTS within the education system remains a significant challenge, requiring the development of HOTS-oriented learning models and the integration of self-assessment as a strategy to foster reflective higher-order thinking (Adawiyah, 2024). HOTS-based learning encourages students to demonstrate advanced thinking skills, exhibit creativity, and solve problems independently. However, this potential has yet to be fully realized in current educational practice.

Therefore, an appropriate learning strategy is needed to develop higher-order thinking skills, one of which is the application of the Socio-Scientific Issues (SSI) approach. The SSI approach is a pedagogical strategy that integrates scientific concepts with real and contextual social issues, thereby providing students with meaningful and relevant learning experiences (Sismawarni, 2020; Rahayu, 2019). This approach aligns with student-centered learning strategies, which empower learners to explore, discuss, and actively construct understanding (Mad Saat, 2017). It is designed to equip students with the ability to comprehend scientific concepts, evaluate data, formulate opinions, and make decisions based on scientific evidence. The application of SSI has been shown to enhance functional scientific literacy, critical thinking skills, understanding of the nature of science, and collaborative problem-solving abilities (Rahayu, 2019; Kristina, 2019; Kolong, 2023). Furthermore, the implementation of learning models integrated with socio-scientific issues has demonstrated a significant impact on improving students' higher-order thinking skills (Kusumaningtyas, 2020).

The Socio-Scientific Issues (SSI) approach is an effective learning strategy for developing higher-order thinking skills. Its relevance lies in its focus on complex, real-world social issues that involve ethical, moral, and societal values. Such issues require deep understanding and rational decision-making (Rahayu, 2019; Sadler, 2004; Nurhalimah et al., 2024). They often arise from

tangible phenomena such as environmental, health, and technological concerns, making them highly relevant contexts for science learning (Azizah, 2022; Amin, 2025). The primary goal of SSI-based learning is to help students understand the interconnections between science, moral values, and their social environment (Zeidler, 2005), while also strengthening their reasoning abilities through discussions of controversial topics (Rohmaya, 2022). The PEAK learning model, comprising the stages of Polemic, Exploration, Action, and Conclusion, encourages students to engage in dialogue, collaboratively construct knowledge, and develop evidence-based solutions. This model aims to make the learning process more interactive, contextual, and socially meaningful (Herlanti, 2014).

A substantial body of research has examined the use of socio-scientific issues (SSI) in the context of biology education in Indonesia. The findings indicate that implementing this approach can enhance scientific literacy (Effendi et al., 2023; Hanifha et al., 2023), improve argumentation skills (Setyaningsih et al., 2019), and foster critical thinking (Kusumaningtyas et al., 2020). The application of the SSI approach to controversial environmental topics has also been shown to significantly impact students' higher-order thinking skills (HOTS) (Auliah et al., 2024). A key distinction between the present study and that of Auliah et al. (2024) lies in the use of HOTS indicators. While HOTS generally include analytical thinking, evaluative thinking, and problem-solving skills, this study refers specifically to the revised Bloom's taxonomy, which focuses on students' ability to analyze, evaluate, and create. These three indicators require students to develop a deep understanding of information, critically evaluate possible solutions, and design innovative alternatives (Fikri, 2022). Another distinction concerns the research focus: whereas previous studies addressed environmental issues (Auliah, 2024), the present study investigates health-related issues, particularly viruses.

Since the outbreak of Coronavirus Disease 2019 (COVID-19), concerns about viral infections have escalated into a global health crisis, prompting widespread public anxiety. These concerns include controversies related to the management, transmission, and overall impact of viruses on human life. In the Merdeka Curriculum, the topic of viruses is an essential component of the Grade 10 Biology syllabus, covering viral characteristics, replication, modes of transmission, and the roles of viruses in life (Akmal, 2022). The objective of this study is to examine the impact of the socio-scientific issue (SSI) discussion-based learning model on the enhancement of higher-order thinking abilities in 10th-grade high school students studying virus-related content.

## RESEARCH METHODS

### Research Design

The present study utilized a research design of a Nonequivalent Pretest and Posttest Control Group Design. The research design is initiated with a pretest, which is followed by the administration of special treatment. The two groups were administered disparate treatments. The experimental group was provided with specialized treatment, namely learning with the socioscientific issue discussion model. The control group was given a treatment group discussion on searching for information. Following the administration of various treatments, a posttest was administered at the conclusion of the learning period to each group to ascertain the impact of the learning model applied.

### Population and Samples

The population of this study comprised all grade X students at SMA Negeri 5 Depok. The research sample comprised four classes that were selected to represent the population. Two of these classes (X.1 and X.3) constituted the experimental group, while the remaining two classes (X.5 and X.6) functioned as the control group.



### Instruments

The assessment instrument employed was a multiple-choice examination comprising 20 items, designed to evaluate students' higher-order thinking skills (HOTS). The objective of this test is to obtain quantitative data on HOTS. It is prepared based on learning indicators and HOTS indicators in accordance with the revised Bloom's Taxonomy.

### Procedures

This research procedure consists of three main stages: planning, implementation, and finalization. In the planning stage, the researchers determined the research title and conducted a literature review by referencing both local and international journals as well as relevant previous studies. They also analyzed the Grade 10 Biology curriculum based on the Merdeka Curriculum, adjusted to align with the research timeline. In addition, the researchers developed a teaching module and student worksheets (LKPD) to support the implementation of the socio-scientific issue (SSI) discussion-based learning model on the topic of viruses. A test instrument consisting of 20 multiple-choice questions was also designed to assess students' higher-order thinking abilities. This instrument was validated by academic supervisors and Biology teachers at SMA Negeri 5 Depok to ensure its feasibility and accuracy. In the implementation stage, a pretest was administered to the experimental and control groups prior to the commencement of the learning process. This pretest was designed to ascertain the students' initial abilities. The determination of experimental and control classes has been established from the outset, with each class comprising two individuals. The experimental group was instructed based on the socioscientific issue discussion model with LKPD support, while the control group was instructed using a conventional learning model. Subsequent to the presentation of all pertinent materials, students were administered a posttest that employed the identical inquiries as the pretest to assess the impact of the implementation of the learning model on students' HOTS. The final stage of the research process encompasses the processing of data from the pretest and posttest, the analysis and discussion of the resulting research data, and the formulation of conclusions based on the findings of the analysis.

### Data Analysis

The present study utilizes the Normalized Gain (N-Gain) method to analyze the discrepancy between two scores, such as pretest and posttest, in order to assess the efficacy of a treatment or learning strategy in enhancing concept comprehension. This study utilizes the mean of N-Gain to ascertain the improvement value of each learner (Sukarelawa, 2024). The gain value indicates the extent to which students' understanding increases following their engagement in learning based on the discussion of socioscientific issues (Herlanti, 2020).

$$N - Gain = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal score} - \text{pretest score}}$$

**Table I.** Gain Value Criteria

Students	Category
$(g) \geq 0,7$	High
$0,3 < (g) < 0,7$	Medium
$(g) < 0,3$	Low

In order to provide supplementary support for the interpretation of the hypothesis test results, this study also employed crosstabulations. Crosstab is a cross-tabulation method used to

identify the relationship or association between two variables in the form of a contingency table. This analysis enables the determination of the proportion of relationships between variables, thereby facilitating the distinction between coincidental relationships and those that indicate a genuine association (Annisa et al., 2020).

Prior to conducting hypothesis testing, it is imperative to execute a normality test to ascertain the most suitable statistical test. The normality test was carried out using the Shapiro-Wilk test through the SPSS Statistics version 26 application. The data that were examined were the gains of the two research groups. In the event that the significance value is greater than 0.05, the data is deemed to be normally distributed and can be subjected to parametric tests. Conversely, if the value is less than 0.05, the data is classified as abnormal, and the analysis is conducted using nonparametric tests. In the event of a substantial discrepancy in pretest results between the experimental and control groups, the analysis proceeded with pure gain (the difference between posttest and pretest) to circumvent bias resulting from initial imbalance (Kurniawan, 2024).

Additionally, the enhancement in students' Higher Order Thinking Skills (HOTS) proficiency was gauged employing the Normalized Gain value that was derived. The gathered data were then subjected to thorough analysis using SPSS Statistics version 26, a software program designed for statistical analysis. This analysis yielded critical insights into the maximum, minimum, average, and standard deviation values. Subsequent to the completion of the normality test, in the event that the data is found to be normally distributed and homogeneous, the subsequent testing procedure will be conducted using an independent sample t-test. However, in instances where the data does not conform to a normal distribution, the Mann-Whitney nonparametric test is employed. The decision-making criteria were determined based on the Asymp. The significance of the value is determined by the statistical test known as the "sign test." In this test, if the value is found to be less than 0.05, it is indicative of a significant difference between the experimental and control groups.

## RESULTS

The current study utilizes a pretest-posttest design to assess the effectiveness of a learning approach centered on the discussion of socioscientific issues in enhancing students' High Order Thinking Abilities. Subsequently, the pretest and posttest data were analyzed using statistical tests. These tests were employed to compare the performance of the experimental and control classes, as well as to determine whether the learning method is effective in improving students' High Order Thinking Abilities.

**Table I.** Differences in Learning Implementation between the Control and Experimental

Aspect	Control Class	Experimental Class
Learning Approach	Conceptual information inquiry within a constructivist approach.	Contextual Issue with the Constructivist Approach
Learning model	Conceptual information discussion with information inquiry by group discussion (exploration), presenting the result of the discussion (elaboration), and explaining concepts by the teacher (3E: Exploration, Elaboration, and Explanation).	Socio-Scientific Issues (SSI) discussion learning model with PEAK stages (Polemik, Exploration, Action, Conclusion)

Number of meetings	2 meetings	4 meeting
Learning methods	Group discussion, lecture, question-and-answer, and presentation of worksheet (LKPD) results.	Polemic discussions, issue exploration, real-world actions, group debates (pro-contra), and joint conclusion.
Topics covered	<ul style="list-style-type: none"> <li>- Meeting 1: History and structure of viruses</li> <li>- Meeting 2: Virus replication, roles, and prevention</li> </ul>	<ul style="list-style-type: none"> <li>- Meeting 1: “What is a virus?”</li> <li>- Meeting 2: “How do viruses reproduce?”</li> <li>- Meeting 3: “Roles of viruses in life”</li> <li>- Meeting 4: “How to prevent virus transmission”</li> </ul>
Student activities	Completing worksheets (drawing virus structure, answering conceptual questions), group discussion, presenting findings, and receiving clarification from the teacher through lectures.	Analyzing issues based on assigned standpoints, engaging in pro-contra discussions, exploring topics through guided worksheets, performing real actions (e.g., virus prevention campaign), and jointly concluding the learning outcomes.
Teacher’s Role	Initial facilitator and main source of content through lecture and PowerPoint presentation.	Full facilitator: guiding critical discussions, providing standpoints, leading reflection on current issues, and mentoring action planning and implementation.
Learning focus	Strengthening conceptual understanding through group work and teacher clarification.	Developing scientific literacy, critical argumentation, issue-based problem solving, and connecting science with policy and daily life.
Learning outcomes	Virus structure diagrams, answers to conceptual questions, and basic discussion results.	Debate outcomes (pro-con), exploratory answers in worksheets, real-life action products such as prevention campaigns, and argumentative conclusions linked to science literacy and public policy.

As elucidated by the findings presented in Table 2, a more substantial increase in pretest to posttest scores was observed in the experimental classes (X1 and X3) compared to the control classes (X5 and X6). In the experimental group, the pretest score range (15–85) increased after the posttest, with the lowest score rising to 20 and the highest reaching 100. The group's mean score improved from 55.1 to 73.3, a 18.2-point increase. Similarly, the median rose from 60 to 80, and the mode increased from 70 to 90. The decrease in standard deviation from 19.301 to 17.453 indicates a more consistent distribution of scores. In contrast, the control group showed a smaller



improvement, with the mean increasing from 60.1 to 69.0 (a difference of 8.9 points). However, this gain was not as significant as that observed in the experimental group.

**Table 2.** Pre-test and Post-test Results by Research Group

Data	Pretest		Posttest	
	Experiment XI dan X3	Control X5 dan X6	Experiment XI dan X3	Kontrol X5 dan X6
Lowest Grade	15	10	20	15
Highest Score	85	85	100	95
Average	55,1	60,1	73,3	69
Standard Deviation	19,3	17,4	22,8	16,3
Median	60	65	80	75
Mode	70	80	90	85
Respondents	72	71	72	71

To corroborate the pretest and posttest results, an N-Gain analysis was conducted for each class, as presented in Table 3. The analysis reveals that the experimental classes had a higher proportion of students in the high N-Gain category than the control classes, with 15 students in XI and 10 in X3. In contrast, only three students from X5 in the control group were classified as high achievers, while none from X6 reached this level. Moreover, the number of students with moderate N-Gain scores was more stable in the experimental classes than in the control classes. The control classes, particularly X6, had a greater proportion of students in the low N-Gain category.

**Table 3.** N-Gain of Students

N-Gain Category	XI (Experiment)	X3 (Experiment)	X5 (Control)	X6 (Control)
Low N-Gain	9	15	14	25
Medium N-Gain	12	11	18	11
High N-Gain	15	10	3	0
Number of learners	36	36	35	36

**Table 4.** Student Score Based on Minimum Completeness Criteria

Criteria	Control				Experiment			
	Pretest		Posttest		Pretest		Posttest	
	N	%	N	%	N	%	N	%
Below KKM <75	50	70	32	45	59	81	24	33
Above KKM >75	21	29	40	56	13	18	48	66
Amount	71	100	71	100	72	100	72	100

Subsequent analysis using the crosstab technique was conducted to identify changes in the number of students who achieved scores above the Minimum Completion Criteria (KKM) before and after the treatment, as shown in Table 4. In the control class, before the treatment, 70% of

students scored below the KKM, which decreased to 45% after the posttest. Conversely, the experimental class demonstrated a significant improvement, with a reduction from 81% of students below the KKM in the pretest to only 33% in the posttest. This finding further supports the hypothesis that experiential learning based on socioscientific issue discussions is more effective in improving students' learning outcomes.

Initially, a normality test was conducted to determine the most appropriate statistical test. Preliminary data analysis indicated that, except for the pretest data from class X5, most of the pretest and posttest data were not normally distributed, as shown by the Shapiro-Wilk test results. Accordingly, the discrepancy analysis was carried out using the Mann-Whitney nonparametric test, in accordance with the guidelines for parametric assumptions when those assumptions are not met.

**Table 5.** Normality Test Result

Class	Kolmogorov-Smirnov			Shapiro-Wilk			Description
	Statistic	df	Sig.	Statistic	df	Sig.	
X1_PRE	.158	36	.026	.962	36	.242	Normally distributed data
X1_POS	.234	36	.000	.853	36	.000	Data is not normally distributed
X3_PRE	.088	36	.119	.971	36	.001	Data is not normally distributed
X3_POS	.275	36	.000	.844	36	.000	Data is not normally distributed
X5_PRE	.115	35	.002	.939	36	.130	Normally distributed data
X5_POS	.182	35	.003	.898	36	.002	Data is not normally distributed
X6_PRE	.266	36	.163	.824	36	.001	Data is not normally distributed
X6_POS	.247	36	.000	.848	36	.001	Data is not normally distributed

**Table 6.** Pretest Mann-Whitney Test Result

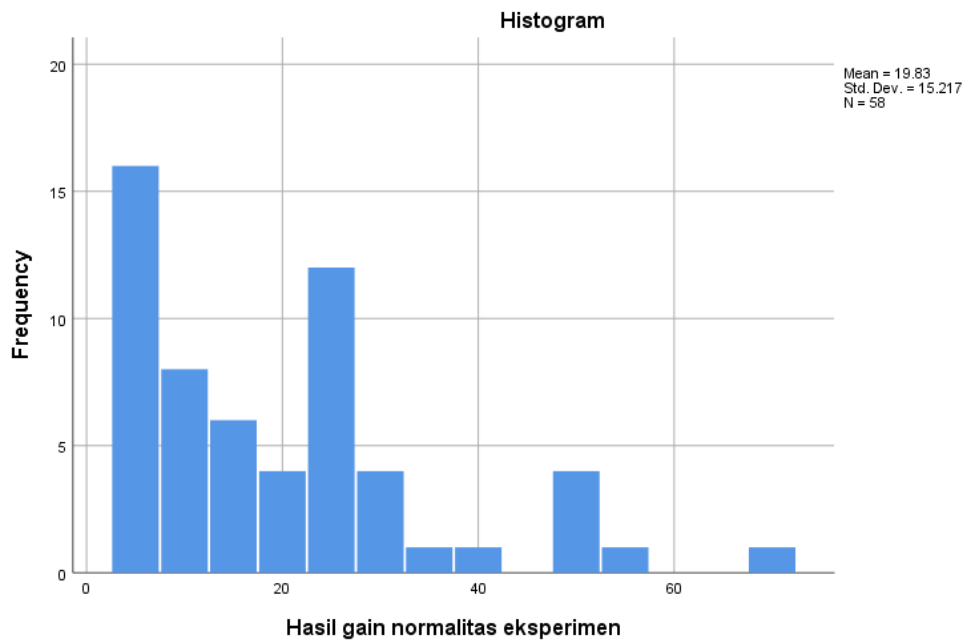
Class	Sig.	Result	Description
Pretest X1 (Experiment) - X5 (Control)	0,134	0,134 > 0,05	Ho accepted, Ha rejected
Pretest X1 (Experiment) - X6 (Control)	0,000	0,000 < 0,05	Ho rejected, Ha accepted
Pretest X3 (Experiment) - X5 (Control)	0,131	0,131 > 0,05	Ho accepted, Ha rejected
Pretest X3 (Experiment) - X6 (Control)	0,384	0,384 > 0,05	Ho accepted, Ha rejected

According to the Mann-Whitney U test results on the pretest between the experimental and control classes presented in Table 6, it is evident that most comparisons between classes do not show significant differences ( $p > 0.05$ ), except for classes X1 and X6, which exhibit significant differences ( $p = 0.000$ ). This finding suggests an imbalance in the students' initial ability levels, which would invalidate the comparison test on the posttest. Consequently, the analysis was continued using Gain data to assess the effectiveness of the treatment.

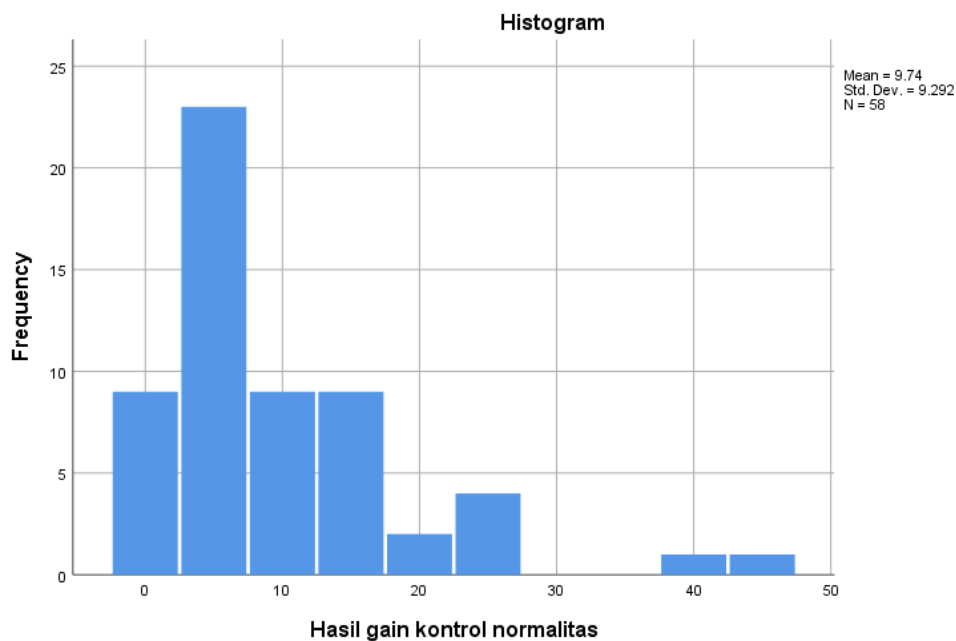
**Table 7.** Normality Test of Combined Gain Data

Class	Sig.	Results	Conclusion
Experimental class (X1 dan X3)	0,00	0,000 < 0,05	Data is not normally distributed
Control class (X5 dan X6)	0,00	0,000 < 0,05	Data is not normally distributed





**Figure 1.** Normality test diagram of combined gain data



**Figure 2.** Normality test diagram of combined gain data

Based on the visualization of the normality test diagram for the N-Gain data, it can be seen that the data distribution does not follow a normal pattern. This discrepancy is indicated by the asymmetrical shape of the graph as well as a noticeable deviation from the diagonal line on the normality plot. This finding is reinforced by the results of the Shapiro-Wilk test, where the significance value (sig.) is less than 0.05, as shown in Table 7. Thus, since most of the data from both the experimental and control groups were not normally distributed, further analysis of the N-Gain data was conducted using the Mann-Whitney U nonparametric statistical test.

**Table 9.** Mann-Whitney Difference Test Results Using Gain Score

Statistics	Class	N	Mean Rank	Sum of Ranks
Rank of Hasil Eks Post	Experimental class	72	87.33	6288.00
	Control class	71	56.45	4008.00
	Total	143		

**Table 9.** Mann-Whitney Difference Test Results Using Gain Score

Test Statistics	Rank of Results Eks Post
Mann-Whitney U	1452.000
Wilcoxon W	4008.000
Z	-4.506
Asymp. Sig. (2-tailed)	.000

As shown in Table 8 of the rank test calculation, the experimental group has a mean rank of 87.33 and a sum of ranks of 6,288.00, while the control group has a lower mean rank of 56.45 and a sum of ranks of 4,008.00. This discrepancy indicates that the experimental group's posttest results are more likely to exceed those of the control group. Furthermore, the Mann-Whitney test results on the N-Gain data, as presented in Table 9, show a U value of 1452.000 with a significance level of 0.000 ( $p < 0.05$ ). Consequently, the null hypothesis ( $H_0$ ) is rejected, and the alternative hypothesis ( $H_a$ ) is accepted. This indicates a substantial difference between the experimental and control groups. These findings suggest that a pedagogical approach centered on the discussion of socioscientific issues is effective in enhancing students' higher-order thinking abilities.

## DISCUSSION

The research results indicate that the analysis of N-Gain data provides additional insights into the effectiveness of the learning intervention. The N-Gain method was selected for its ability to illustrate the degree of improvement achieved by students while accounting for their initial abilities. Hake (1998) argues that the use of N-Gain offers more proportional information than simply examining the mean difference between pretest and posttest scores. The mean N-Gain value of the experimental class consistently exceeds that of the control class, as evidenced by the calculation results (Guntara, 2021). This finding further supports the notion that learning based on the discussion of socioscientific issues enhances not only absolute learning outcomes but also relative improvements when measured against each student's initial ability.

These results support the notion that presenting contextual and open-ended problems can be an effective strategy for developing High Order Thinking Abilities. Previous studies, such as that conducted by Lugina (2022), found that employing a real problem-based approach significantly enhanced students' High Order Thinking Abilities compared to traditional teaching methods. Similarly, Sukarelawa (2024) demonstrated that the integration of issue-based discussions in academic settings led to a significant improvement in critical thinking skills.

This conclusion is further reinforced by the crosstab analysis conducted in this study. This technique examines the relationship between learning outcome variables and the achievement of the Minimum Completion Criteria (KKM). The crosstab results show that, in the experimental class, there was a significant increase in the number of learners who met or exceeded the KKM after the learning intervention, in contrast to the control class. This finding is consistent with the conclusions of Billa (2021) and Pebrianti (2020), who assert that crosstabulations, despite their simplicity, are capable of identifying patterns in variable relationships through a descriptive lens.



This finding indicates that socioscientific issue discussion-based learning not only enhances learners' average scores but also increases the number of students who achieve success. This result is significant because it demonstrates the effectiveness of the method not only for high-performing students but also for those who were previously below the standard and have shown measurable improvement. A thorough examination of the data revealed that most did not meet the assumption of normal distribution, as indicated by the results of the normality tests conducted on the pretest, posttest, and N-Gain data. This deviation is an important consideration in selecting the appropriate statistical test. As Henry (2024) explains, the choice of statistical analysis must be tailored to the characteristics of the data distribution to ensure that the results remain valid and reliable. Given the non-normal distribution of most data in this study, the use of non-parametric analysis, specifically the Mann-Whitney U test, is considered the most appropriate approach.

The Mann-Whitney test was used to compare the Gain scores between the experimental and control classes, replacing parametric tests such as the independent samples t-test. As Prasetyo (2012) asserted, in circumstances characterized by non-normal data distribution, the implementation of nonparametric tests is often considered more appropriate than the use of parametric tests, as nonparametric methods can yield more valid conclusions. Prior to conducting the Mann-Whitney analysis, the data were transformed into rank form, a procedure intended to ensure the accuracy of the test results. The Mann-Whitney test on the Gain data yielded a p-value of 0.000 ( $p < 0.05$ ), indicating a statistically significant difference between the experimental and control classes. These findings support the hypothesis that the socioscientific issue discussion-based approach employed in the experimental class is more effective in enhancing students' High Order Thinking Abilities compared to the STAD-type constructivism-based learning method used in the control class.

## CONCLUSION

The findings of this study demonstrate that the socioscientific issue discussion learning model is effective in enhancing students' higher-order thinking abilities. This conclusion is supported by the results of the N-Gain analysis, which indicate that the experimental class experienced a greater improvement compared to the control class. Additionally, the crosstab analysis reveals that a higher number of students in the experimental class successfully met the Minimum Completion Criteria (KKM) following the intervention. The hypothesis test using the Mann-Whitney U test on the Gain data further strengthens this conclusion, showing a statistically significant difference between the experimental and control classes, with a p-value of 0.000 ( $p < 0.05$ ). Consequently, the null hypothesis ( $H_0$ ) is rejected, and the alternative hypothesis ( $H_a$ ) is accepted. Based on these findings, it can be concluded that socioscientific issue discussion-based learning is an effective alternative strategy to improve the quality of education, particularly in fostering students' higher-order thinking abilities. Beyond addressing the research objectives, these results also contribute to the advancement of contextual learning approaches that emphasize the integration of real-world issues into science education. It is therefore recommended that educators implement this model more broadly to better prepare students for the demands of the 21st century, which require critical, analytical, and creative thinking skills.

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