Comparison of IB-NOSA and Discovery Learning Models on Students' Scientific Literacy and Scientific Argumentation Skills in High School

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Abstract
This study aimed to describe and compare the effects of the IB-NOSA and Discovery Learning models on scientific literacy and scientific argumentation skills of tenth-grade high school students, as well as to examine the significant differences between the two models in the context of Biology learning. This study was quasi-experimental research with a pretest–posttest nonequivalent control group design. The study involved two classes, namely Experimental Class I which was taught using the IB-NOSA model and Experimental Class II which was taught using the Discovery Learning model. The research sample consisted of 72 students of grade 10, with 36 students in Experimental Class I and 36 students in Experimental Class II. Data were collected using a scientific literacy test based on contextual stimuli and a scientific argumentation test in the form of essay questions assessed using the Toulmin Argumentation Pattern rubric. Before hypothesis testing, the data were analyzed using normality and homogeneity tests as prerequisite tests. Hypothesis testing was conducted using Analysis of Covariance (ANCOVA). The results showed that the Sig. value was 0.131 ($p > 0.05$), indicating that H_0 was accepted for the scientific literacy test, and the Sig. value was 0.004 ($p < 0.05$), indicating that H_0 was rejected. Thus, it can be concluded that the IB-NOSA and Discovery Learning models have a relatively similar effect on scientific literacy, but the IB-NOSA model is more effective in improving students' scientific argumentation skills.

1. Introduction

Learning in the 21st century requires students not only to understand content knowledge but also to be able to communicate, think critically, collaborate, and possess literacy across various fields of knowledge. Particularly in science learning, argumentation skills and scientific literacy are essential competencies that need to be developed among students. Scientific literacy refers to the ability to use scientific knowledge and processes to understand natural phenomena and to make evidence-based decisions (Abdul Kadir et al., 2025). With adequate scientific literacy, students are able to relate scientific concepts to everyday life and participate in discussions or scientific problem-solving in a thoughtful and responsible manner (Prihatiningtyas et al., 2025). However, empirical evidence shows that the scientific literacy of Indonesian students is still relatively low. The results of the Programme for International Student Assessment (PISA) survey in 2018 revealed that approximately 70% of Indonesian students had not reached the basic level of scientific literacy (Level 2) established by the OECD. Only about 40% of Indonesian students achieved this minimum level of competency, which is far below the OECD average, where approximately 78% of students reached Level 2 or higher (OECD, 2019). One of the factors contributing to the low level of scientific literacy is the widespread use of conventional teaching methods. Fadilah et al. (2020) reported that students' scientific literacy skills in Biology content were categorized as low. This condition is attributed to the mismatch between the instructional methods employed and the demands of 21st-century learning. In practice, biology instruction in classrooms is still predominantly dominated by teacher-centered approaches. Previous studies have indicated that the direct instruction model facilitates teacher in delivering structured content; however, it also has notable limitations, as students tend to be passive and merely receive information without being actively engaged in the thinking process. Students often wait for answers from the teacher rather than attempting to explore or construct their own understanding, resulting in underdeveloped investigative skills and curiosity (Dari & Ulayya, 2025; Nooviar, 2024).

In addition, another aspect of students' skills in science that requires attention is scientific argumentation ability. Argumentation is an essential skill because students who learn science are expected to be able to explain phenomena scientifically, express opinions based on evidence, and evaluate the arguments of others. In the scientific context, argumentation is viewed as logical and rational discourse aimed at establishing relationships between ideas and evidence (Shouse, 2008), involving processes of developing, evaluating, and validating scientific knowledge (Driver et al., 2000) and serving as a means of knowledge construction (Ford, 2008).

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According to Toulmin (2003), a scientific argument consists of interconnected components, namely claims, data, and warrants, indicating that students are expected not only to express opinions but also to support them with empirical evidence. A lack of scientific argumentation skills has a negative impact on the development of other higher order thinking skills. Research indicates that low argumentation ability is one of the factors contributing to students' low critical thinking skills. Students with weak argumentation skills tend to experience difficulties in analyzing information and solving problems independently (Akbaş, 2021). Furthermore, Hasnunidah et al. (2015) stated that students with low argumentation skills may struggle to compete in modern life, which is characterized by intense competition, and may lose opportunities to obtain good jobs in the future

Considering these problems, an innovative and student-centered learning model is needed as a solution to improve students' scientific literacy and scientific argumentation skills. One approach that can be implemented is inquiry-based learning integrated with the understanding of the Nature of Science (NOS) and scientific argumentation activities. The Inquiry-Based Nature of Science-Argumentation (IB-NOSA) model is a learning model designed to improve both scientific literacy and students' scientific argumentation skills through an inquiry approach integrated with an understanding of the nature of science (Lestari et al., 2024b). Conceptually, the IB-NOSA model integrates guided inquiry methods with argumentation activities through argument mapping and emphasizes explicit-reflective aspects of the nature of science. In addition to the IB-NOSA model, the Discovery Learning model is also a learning model that emphasizes the process of independent concept discovery through investigation activities and higher-order thinking skills (HOTS), as well as the teacher's role in managing higher-order questions and providing gradual support (scaffolding) (Kharismawati et al., 2020). Therefore, both learning models have the potential to improve students' scientific literacy and scientific argumentation skills.

Previous studies have demonstrated that the Discovery Learning model has a positive effect on improving students' scientific literacy and scientific argumentation skills. A study conducted by Maulana et al. (2024) reported that the implementation of Discovery Learning improved students' scientific literacy, with an effect size of 0.85. This finding is consistent with Assyfa (2023) who found that Discovery Learning contributed to a 33% increase in students' scientific literacy. In terms of scientific argumentation, this model has also been shown to significantly enhance argumentation skills among seventh-grade students at the junior secondary level (Buana, 2024), as well as to improve students' argumentation levels from Level 1–2 to Level 3–4 based on Toulmin's Argumentation Pattern (Syahbana, 2025). On the other hand, recent studies have indicated that the implementation of the IB-NOSA model significantly improves students' scientific literacy compared to other conventional learning models, with a gain score of approximately 0.49 (category moderate), which is higher than that achieved by standard inquiry models or Discovery Learning, which only reach gains of around 0.4. These findings suggest that the integration of argumentation activities within inquiry-based learning, as implemented in the IB-NOSA model, provides a greater positive impact on students' understanding and scientific skills (Lestari et al., 2024a).

Numerous studies on scientific literacy and scientific argumentation have been conducted using various inquiry-based learning models, such as inquiry learning, problem-based learning, and Discovery Learning, all of which have been shown to enhance students' conceptual understanding and scientific literacy (Oliver et al., 2021; Ramadhan & Mardin, 2023; Khairunisa et al., 2025). In addition, several studies have reported that the integration of the Nature of Science (NOS) in science instruction helps students understand the processes of scientific inquiry, while argumentation-based learning improves students' ability to construct claims, evidence, and scientific reasoning (Khishfe, 2022; Nurtamara & Widyastuti, 2023). However, most of these studies have examined scientific literacy and scientific argumentation separately and have not explicitly integrated the Nature of Science and scientific argumentation within a single structured learning model. Furthermore, studies investigating the implementation of the IB-NOSA model at the senior high school level remain limited, and there is a lack of research directly comparing the effectiveness of the IB-NOSA model and Discovery Learning in improving both scientific literacy and scientific argumentation skills in biology learning at the secondary level.

Therefore, this study aims to describe and compare the effects of the IB-NOSA and Discovery Learning models on students' scientific literacy and scientific argumentation skills at the senior high school level. The novelty of this study lies in: (1) the implementation of the IB-NOSA model in biology learning at the senior high school level, (2) the simultaneous assessment of scientific literacy and scientific argumentation skills, and (3) a comparative analysis of the effectiveness of the IB-NOSA and Discovery Learning models in improving these two competencies.

2. Method

This study employed a quasi-experimental design using a pretest–posttest nonequivalent control group design. Two groups were involved in this study: Experimental Group I, which received instruction using the IB-NOSA model, and Experimental Group II, which received instruction using the Discovery Learning model. The study was conducted during the second semester of the 2025/2026 academic year at a senior high school in Makassar, Indonesia and was carried out over five meetings.

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The research subjects consisted of 72 students selected from a total population of 360 students, aged between 15 and 16 years. The sample included 36 students in Experimental Group I and 36 students in Experimental Group II. The sample was determined using purposive sampling by considering the equivalence of academic characteristics and the same teacher teaching both classes. Based on the sampling results, Class X.10 was assigned as Experimental Group I (IB-NOSA), while Class X.5 was assigned as Experimental Group II (Discovery Learning).

Data were collected through a pretest–posttest procedure. The pretest was administered to measure students' prior knowledge, while the posttest was administered after the treatment to determine the differences in the effects of the two learning models on the dependent variables (learning outcomes, scientific literacy, and scientific argumentation skills).

The instruments used in this study included a scientific literacy test based on contextual stimuli aligned with the PISA 2018 framework, consisting of a combination of multiple-choice and essay questions, as well as a scientific argumentation test in the form of open-ended essay questions assessed using the Toulmin Argumentation Pattern rubric with levels ranging from Level 1 to Level 5. The validity of the instruments was established through content validity using expert judgment by three biology education experts and analyzed using Aiken's V index. The reliability of the scientific literacy instrument was analyzed using Cronbach's Alpha, while the reliability of the scientific argumentation instrument was analyzed using inter-rater reliability to determine the consistency of scoring among raters.

Data were analyzed using descriptive and inferential statistics. Descriptive analysis included the calculation of the mean, standard deviation, minimum and maximum scores, and N-gain to measure the improvement in learning outcomes. Prior to hypothesis testing, prerequisite tests were conducted, including the normality test (Shapiro–Wilk) and the homogeneity test (Levene's Test). Hypothesis testing was performed using Analysis of Covariance (ANCOVA) with pretest scores as covariates to control for differences in initial ability between groups. All statistical analyses were conducted using SPSS version 25 with a significance level of 0,05.

3. Results and Discussion

3.1. Results

3.1.1. Instrument Testing Results

The instrument testing in this study included content validity testing by experts and reliability testing. The results of the instrument testing are presented in the Table 1 and Table 2.

Table 1. Content Validity Result of the Scientific Literacy Instrument

No	Assessed Aspect	Aiken's V Value	Category
1	The suitability of the material with scientific literacy indicators	0.89	Very Valid
2	The suitability of the questions with the PISA framework	0.87	Very Valid
3	Item construction	0.85	Very Valid
4	Language clarity	0.90	Very Valid
5	The suitability of the stimulus with the science context	0.88	Very Valid
Average		0.88	Very Valid

Table 2. Content Validity Result of the Scientific Argumentation Instrument

No	Assessed Aspect	Aiken's V Value	Category
1	The suitability of the questions with argumentation indicators	0.86	Very Valid
2	The suitability with the Toulmin rubric	0.88	Very Valid
3	Clarity of question instructions	0.90	Very Valid
4	The suitability of the problem context	0.87	Very Valid
Average		0.88	Very Valid

The results of the content validity test for the scientific literacy and scientific argumentation instruments showed that all assessed aspects had Aiken's V values ranging from 0.85 to 0.90, which were categorized as very valid. These results indicate that the instruments were aligned with the scientific literacy indicators based on the PISA framework and the scientific argumentation indicators based on the Toulmin Argumentation Pattern. Therefore, the instruments used in this study met the content validity requirements and were appropriate for measuring students' scientific literacy and scientific argumentation skills (see Table 3 and Table 4).

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Table 3. Reliability Test Results of the Scientific Literacy Instrument

Instrument	Number of Items	N	Cronbach's Alpha	Category
Scientific Literacy	20	35	0.86	High Reliability

Table 4. Reliability Test Results of the Scientific Argumentation Instrument

Instrument	Raters	N	Inter-rater Reliability	Category
Scientific Argumentation	2 Raters	35	0.82	High Reliability

The reliability test results showed that the scientific literacy instrument had a Cronbach's Alpha value of 0.86, which is categorized as high reliability. Meanwhile, the reliability test for the scientific argumentation instrument, analyzed using inter-rater reliability, obtained a value of 0.82, which is also categorized as high reliability. These results indicate that the instruments have a good level of consistency and are reliable for measuring students' scientific literacy and scientific argumentation skills consistently.

3.1.2. Students' Scientific Literacy Skills in Experimental Group I and Experimental Group II

The descriptive statistical data of students' scientific literacy skills in Experimental Group I and Experimental Group II are presented in Table 5. Based on the table 5, the average posttest score of Experimental Group I was higher than that of Experimental Group II, indicating that the class that received instruction using the IB-NOSA model achieved slightly better scientific literacy outcomes than the class that received instruction using the Discovery Learning model. In addition, the standard deviation in both groups decreased compared to the pretest scores, particularly in Experimental Group II, indicating that students' scores became more homogeneous after the learning process.

Table 5. Descriptive Statistical Analysis of Students' Scientific Literacy Skills

Statistic	Experimental I Class		Experimental II Class	
	Pretest	Posttest	Pretest	Posttest
N	36	36	36	36
Mean	68.36	81.86	67.50	78.80
Std. Deviation	11.78	9.99	10.17	7.61
Min	45.50	62.50	48.50	59.00
Max	93.00	100	86.50	96.50
Increase		13.50		11.30

The results of the ANCOVA test on the scientific literacy variable in the two experimental groups are presented in Table 6.

Table 6. ANCOVA Results of Students' Scientific Literacy in Experimental Group I and Experimental Group II

Test of Between Subject Effects					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig
Corrected Model	1329.381[a]	2	664.691	10.513	.000
Intercept	5417.154	1	5417.154	85.679	.000
Pretest	1161.326	1	1161.326	18.368	.000
Class	147.702	1	147.702	2.336	.131
Error	4362.619	69	63.226		
Total	470340.000	72			
Corrected Total	5692.000	71			

Based on the results of the Analysis of Covariance (ANCOVA), the overall model, which included the pretest and group variables, was statistically significant in predicting students' scientific literacy outcomes ($F = 10.513$, Sig. = 0.000, $p < 0.05$). Partially, the pretest variable had a significant effect on students' scientific literacy outcomes ($F = 18.368$, Sig. = 0.000, $p < 0.05$), indicating that students' initial ability significantly influenced their posttest scientific literacy performance after the treatment. In contrast, the group variable yielded an F value of 2.336 with a significance level of 0.131 ($p > 0.05$). This result indicates that, after controlling for differences in students' initial ability, there was no significant difference between Experimental Group I (IB-NOSA model) and Experimental Group II (Discovery Learning model) in terms of scientific literacy outcomes. Therefore, it can be concluded that there was no significant difference in the effect of the IB-NOSA and Discovery Learning models on students' scientific literacy.

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3.1.3. Students' Scientific Argumentation Skills in Experimental Group I and Experimental Group II

The descriptive statistical data of students' scientific argumentation skills in Experimental Group I and Experimental Group II are presented in Table 7. Based on table 7, the average posttest score of Experimental Group I was higher than that of Experimental Group II, with a considerable difference. This indicates that the class that received instruction using the IB-NOSA model achieved better scientific argumentation skills than the class that received instruction using the Discovery Learning model.

Table 7. Descriptive Statistical Analysis of Students' Scientific Argumentation Skills

Statistic	Experimental I Class		Experimental II Class	
	Pretest	Posttest	Pretest	Posttest
N	36	36	36	36
Mean	57.08	82.50	48	68.72
Std. Deviation	14.06	15.92	9.08	13.33
Min	30	40	19	38
Max	80	100	63	94
Increase		25.42		20.72

The results of the Analysis of Covariance (ANCOVA) showed that the overall model, which included the pretest and group variables, was statistically significant in predicting students' scientific argumentation skills (F = 11.384, Sig. = 0.000, p < 0.05) (see Table 8). Partially, the pretest variable had a significant effect on students' scientific argumentation skills (F = 5.833, Sig. = 0.018, p < 0.05), indicating that students' initial ability significantly influenced their scientific argumentation performance after the treatment. Meanwhile, the group variable obtained an F value of 8.756 with a significance level of 0.004 (p < 0.05). This result indicates that, after controlling for differences in students' initial ability, there was a significant difference between Experimental Group I (IB-NOSA model) and Experimental Group II (Discovery Learning model) in terms of students' scientific argumentation skills. Therefore, it can be concluded that there was a significant difference in the effect of the IB-NOSA and Discovery Learning models on students' scientific argumentation skills.

Table 8. Results of the ANCOVA Test on Students' Scientific Argumentation Skills in Experimental Group I and Experimental Group II

Test of Between Subject Effects					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig
Corrected Model	4593.723[a]	2	2296.862	11.384	.000
Intercept	11151.961	1	11151.961	55.274	.000
Pretest	1176.834	1	1176.834	5.833	.018
Class	1766.523	1	1766.523	8.756	.004
Error	13921.388	69	201.759		
Total	430142.000	72			
Corrected Total	18515.111	71			

3.2. Discussion

3.2.1. Differences in Students' Scientific Literacy Ability Taught Using the IB-NOSA Learning Model and the Discovery Learning Model

Based on the results of the analysis of covariance, the class variable obtained an F value of 2.336 with Sig. = 0.131 (p > 0.05), so H_0 was accepted. This finding indicates that after students' prior knowledge was controlled through pretest scores as a covariate, there was no significant difference between the implementation of the IB-NOSA model and Discovery Learning on students' scientific literacy ability. Both learning models had a relatively equivalent effect in improving scientific literacy, which can be explained by the similarity in the pedagogical characteristics of the two models, as both emphasize inquiry-based learning, scientific activities, and active student involvement in the process of constructing scientific knowledge. Inquiry-based learning has been shown to improve scientific thinking skills and scientific literacy through activities such as observing phenomena, formulating problems, conducting investigations, and drawing conclusions based on scientific evidence (Abdullah et al., 2025; Urdanivia Alarcon et al., 2023), it also improves students' ability to interpret data and understand scientific concepts more deeply (Arifin & Sunarti, 2017).

The IB-NOSA model integrates inquiry with the understanding of the Nature of Science, so students not only learn concepts but also understand how scientific knowledge is constructed and validated through scientific processes (Schizas et al., 2024; Lestari et al., 2024a). Inquiry stages such as problem identification, hypothesis formulation, investigation, data analysis, and scientific reflection in IB-NOSA encourage the development of scientific reasoning, which is an important component of scientific literacy (Abd-El-Khalick &

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Lederman, 2000; Krell et al., 2022). On the other hand, Discovery Learning emphasizes the process of concept discovery through stages such as stimulation, problem statement, data collection, data processing, verification, and generalization, which also train scientific thinking skills through observation, data collection, analysis, and conclusion drawing (Dinda & Hapsari, 2025). This approach has been shown to improve scientific literacy because students are directly involved in the process of investigation, data analysis, and concept formation, thereby promoting critical thinking skills and deeper conceptual understanding (Schizas et al., 2024; Weinhandl et al., 2025; Assyfa, 2023).

The absence of a significant difference between the IB-NOSA model and Discovery Learning based on the ANCOVA results may be due to the similarity in the orientation of both models, which are grounded in constructivism and both emphasize student-centered learning, the inquiry process, and knowledge construction by students (Faizah et al., 2022). In addition, both classes were categorized as high-achieving classes with high prior ability, so students' prior knowledge may have moderated the effectiveness of the learning models. In students with high prior ability, differences in learning models do not always result in significant differences in learning outcomes (Rahmadani et al., 2022)

3.2.2. Differences in Students' Scientific Argumentation Ability Taught Using the IB-NOSA Learning Model and the Discovery Learning Model

The results of the analysis of covariance showed that the class variable obtained an F value of 8.756 with Sig. = 0.004 ($p < 0.05$), so H_0 was rejected and H_1 was accepted. This finding indicates that after students' prior knowledge was controlled through pretest scores as a covariate, there was a significant difference between the experimental class I using the IB-NOSA model and the experimental class II using the Discovery Learning model on students' scientific argumentation ability. These results indicate that the learning model applied contributed differently to the development of students' ability to construct evidence-based scientific arguments.

The significant difference between the IB-NOSA model and Discovery Learning in terms of scientific argumentation ability can be explained by the differences in the pedagogical focus of the two learning models. The IB-NOSA model explicitly emphasizes scientific practices such as evidence-based argumentation, reflection on the scientific process, and understanding the Nature of Science, so students are more trained in constructing systematic scientific arguments. In contrast, Discovery Learning emphasizes the process of concept discovery through exploration, so scientific argumentation is not always the main focus in the learning process (Hasnunidah et al., 2024).

The IB-NOSA (Inquiry-Based Nature of Science Argumentation) model emphasizes the integration of scientific inquiry activities and understanding of the Nature of Science. This approach has been shown to be effective in improving students' ability to construct scientific arguments because students are trained to connect empirical data with conceptual explanations (Lestari et al., 2024a). Meanwhile, Discovery Learning tends to focus more on concept discovery rather than explicitly developing scientific argumentation practices. As a result, students' argumentation skills may develop, but not as optimally as in learning that directly integrates argumentation practices into the instructional syntax (Hassanah et al., 2025).

3.2.3. Implications

The findings of this study have several pedagogical implications. First, the use of inquiry-based learning models, such as IB-NOSA and Discovery Learning, can facilitate the improvement of students' scientific literacy through engagement in scientific activities, investigation processes, and active knowledge construction. Second, the IB-NOSA model provides greater opportunities for students to develop scientific argumentation skills, as the learning syntax explicitly integrates argumentation activities and reflective discussions on the Nature of Science (NOS). Therefore, the integration of inquiry, Nature of Science, and scientific argumentation can be considered an effective approach to promoting higher order thinking skills in science learning.

3.2.4. Limitations

This study has several limitations that should be acknowledged. First, the study was conducted in only two classes within a single school, which may limit the generalizability of the findings to broader educational contexts. Second, the participants were students with relatively high and homogeneous academic abilities. This condition may have reduced the observable differences between the learning models, particularly in terms of scientific literacy, as students with higher initial ability tend to achieve comparable outcomes regardless of the instructional approach.

4. Conclusion

Based on the results of the study and data analysis using ANCOVA, it can be concluded that the IB-NOSA and Discovery Learning models had relatively similar effects on students' scientific literacy, as there was no

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significant difference between the two learning models in terms of scientific literacy outcomes. However, there was a significant difference in students' scientific argumentation skills, in which the IB-NOSA model was more effective than the Discovery Learning model in improving students' scientific argumentation skills. Therefore, the IB-NOSA model is more effective for use in Biology learning that aims to develop students' scientific argumentation skills, while both learning models can be used to improve students' scientific literacy.

Author Contributions

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Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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