JPPIPA 11(10) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Impact of STEM-Integrated Argument-Driven Inquiry on Developing Scientific Argumentation in Indonesian Middle Schools

Neni Hasnunidah[1*], Nadya Meriza[1], Sherly Fadhila[1], Undang Rosidin[2]

[1] Department of Biology Education, University of Lampung, Bandar Lampung, Indonesia.
[2] Department of Physics Education, University of Lampung, Bandar Lampung, Indonesia.

Received: August 02, 2025
Revised: September 20, 2025
Accepted: November 21, 2025
Published: November 21, 2025

Corresponding Author:
Neni Hasnunidah
neni.hasnunidah@fkip.unila.ac.id

DOI: 10.29303/jppipa.v11i10.12912

Abstract: This study explores the effectiveness of integrating Argument-Driven Inquiry (ADI) with Science, Technology, Engineering, and Mathematics (STEM) education to improve high school students' argumentation skills on the topic of the human respiratory system. This study was conducted at MTs Negeri 2 North Lampung, using a quasi-experimental design with a non-equivalent group design. The population consisted of 166 students spread across five different classes. From this population, samples were taken, namely students in class VIII 1 as the experimental group and students in class VIII 3 as the control group, through a cluster random sampling technique. The research instrument was a 10-question essay test that had been validated to assess students' argumentation skills. The N-Gain data of the argumentation skills of both classes were shown to be normally distributed. Based on the homogeneity of the data obtained, both had homogeneous variances. Data were analyzed using an Independent Samples t-test and effect size calculation. The results showed that the experimental class achieved a significantly higher increase in argumentation skills compared to the control class (0.46 vs. 0.29, $p < 0.05$). The large effect size (1.26) confirmed the model's substantial impact. Student feedback was overwhelmingly positive (82.50%). Based on the evidence, it can be concluded that the ADI-STEM learning model effectively improves students' argumentation skills and fosters 21st-century skills by aligning scientific practices with interdisciplinary learning.

Keywords: Argumentation skills; Argument-driven inquiry; Human respiratory system; STEM

Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results. Communication, particularly argumentation, is a cognitive tool that can enhance students' ability to evaluate ideas, construct knowledge collaboratively, and participate meaningfully in scientific dialogue (Kimmerle et al., 2021). It is widely recognized as a fundamental skill in science education, enabling students to express reasoned judgments, challenge assertions, and draw conclusions based on scientific reasoning (Fischer et al., 2014). Students with strong argumentation skills can confidently asses' ideas, articulate evidence-based justification, and participate meaningfully in scientific dialogue, which are essential competencies or both academic success and informed citizenship (Yıldız-Feyzioğlu & Kıran, 2022).

How to Cite:
Hasnunidah, N., Meriza, N., Fadhila, S., & Rosidin, U. (2025). Impact of STEM-Integrated Argument-Driven Inquiry on Developing Scientific Argumentation in Indonesian Middle Schools. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 986–997. https://doi.org/10.29303/jppipa.v11i10.12912

Despite its recognized importance, the development of argumentation skills remains a significant challenge in many science classrooms, particularly in Indonesia. Preliminary observations and interviews with science teachers at the study's location revealed a persistent problem that students frequently offer opinion without supporting evidence or logical reasoning. Classroom discussion often lacks critical evaluation, with the students passively accepting peers' claim rather than engaging in constructive critique. This issue stem from a lack explicit instructional focus on argumentation and limited opportunities for students to practice these skills in a structured manner. This classroom-level problem reflects broader systemic challenges, including insufficient instructional time and teachers limited pedagogical knowledge in teaching argumentation, which students" development of scientific reasoning abilities (Songsil et al., 2019; Putri et al., 2023; Dawson, 2024).

Modern science education emphasizes that learning is not merely the transmission of facts but an active process of constructing knowledge. This is particularly true for complex biological topics like the human respiratory system. The key characteristics of effective science learning for this topic include conceptual understanding over rote memorization, connecting to real-world phenomena, and addressing abstract concepts (Roth, 2013; Lestari et al., 2023). Learning about the respiratory system should go beyond memorizing the names of organs (e.g., trachea, bronchi, alveoli). It requires students to understand it as a dynamic and integrated system. This involves grasping complex processes such as gas exchange, the mechanics of breathing (diaphragm and intercostal muscle movement), and the connection between respiration and cellular metabolism. Furthermore, the respiratory system is directly relevant to students' daily lives. Effective teaching connects the topic to tangible experiences like exercise, yawning, hiccupping, and the effects of pollution or smoking. This context makes the learning more meaningful and helps students see the practical application of scientific knowledge. Eventually, while students can feel their own breathing, the most critical processes are abstract and invisible. Gas exchange at the alveolar level, the transport of oxygen by hemoglobin, and the role of carbon dioxide in regulating breathing rate are not directly observable. Therefore, learning requires the use of models, analogies, and investigations to make these abstract concepts concrete (Liana et al., 2022; Kurniawan, 2023).

Scientific argumentation is the process of making claims, supporting them with evidence, and justifying them with scientific reasoning. Inquiry-based learning provides the perfect platform for developing these skills because it inherently follows the structure of an argument (Satriya & Atun, 2024; Nuzulah et al., 2023). An inquiry activity does not start with a conclusion; it starts with a question. As students conduct their investigation (e.g., measuring lung capacity or holding their breath), they gather data. This data is their evidence. Based on patterns in this evidence, they must formulate a claim. For instance, a claim might be: "People who exercise regularly have a larger vital lung capacity than those who do not." This claim is not a memorized fact but a conclusion derived from their own investigation. The most critical step for developing argumentation is moving beyond the claim and evidence. The teacher, using the inquiry framework, must constantly ask, "How does your evidence support your claim?" and "What is the scientific reason for this?" This forces students to provide reasoning. In the lung capacity example, the student must connect their evidence to the scientific principle that regular exercise strengthens the respiratory muscles, allowing for a greater volume of air to be exchanged. This structure, Claim, Evidence, Reasoning is the cornerstone of scientific argumentation (McNeill & Krajcik, 2008; Clement, 2013).

A teacher must use inquiry to teach the human respiratory system because the topic involves unobservable processes that cannot be deeply understood through passive learning. The inquiry process transforms students from being receivers of information into active investigators. This investigative context naturally requires them to collect evidence, make claims, and provide reasoning, thus providing an authentic and effective environment for practicing and mastering scientific argumentation skills. One learning model that can be used for this purpose is Argument-Driven Inquiry (ADI) with a Science, Technology, Engineering, and Mathematics (STEM) approach. The ADI model itself provides a structured, inquiry-based environment where students design investigation, collect data, and engage in explicit argumentation sessions to defend their conclusion (Sampson & Walker, 2012). By integrating STEM, this research enriches the inquiry process, situating scientific within authentic, real-world problems that require interdisciplinary thinking and hands-on design (Kelley & Knowles, 2016). This framework enriches the inquiry process by embedding technological and engineering components, allowing students to apply scientific concepts to real-world problem-solving (Ntemngwa & Oliver, 2018; Fortes et al., 2022; Fitria et al., 2025).

This ADI-STEM model is designed to provide the necessary scaffolding for students to move from making simple claims to constructing robust, evidence-based arguments, thereby directly tackling the observed deficiencies in classroom practice. Fitria et al. (2025) reported significant improvements in students' argumentation skills particularly in constructing claims, providing evidence, and articulating justifications when the ADI model was implemented with a STEM-based approach. Suhirman & Prayogi (2023) and Fitria et al. (2025) found that such integration promotes active learning, interdisciplinary thinking, and the capacity to engage in scientific reasoning. This multidimensional approach not only enhances engagement but also reinforces argumentation through authentic problem-solving contexts. Eugenijus (2023), Paramita et al. (2019), and Imranah et al. (2025) have shown that STEM integration facilitates contextual learning and fosters innovation, making it well-suited for the development of argumentation skills in science classrooms.

Therefore, the primary objective of this research is to investigate the effectiveness of the integrated ADI-STEM learning model on the scientific argumentation skills of Indonesian junior high school students. Focusing on the topic of the human respiratory system, this study aims to determine if a significant difference exists in the argumentation abilities of students taught with conventional methods. By providing rigorous empirical evidence within a specific Indonesian educational context, this study seeks to fill a gap in the existing literature and offer a practical, effective pedagogical solution for enhancing students' argumentation skills.

Method

Type of Research

This study uses quasi-experimental research design, specifically a non-equivalent control group pretest-posttest design. This approach was selected due to the practical constraints of the educational setting, which precluded the random assignment of individual students to different instructional groups (Creswell, 2014). Instead, two pre-existing, intact classes were selected through cluster random sampling to serve as the experimental and control groups. The use of intact classes is the reason the groups are considered "non-equivalent. The design involved several key stages. Initially, both the experimental group (E) and the control group (C) were administered a pretest (O1) to establish a baseline measure of their scientific argumentation skills. Following the pretest, the independent variable (X) was introduced. The experimental group received instruction using the Argument-Driven Inquiry integrated with STEM (ADI-STEM) model, while the control group was taught using the conventional learning model. Upon completion of the instructional period, both groups were administered a posttest (O2) to measure the change in their argumentation skills. To address the potential bias arising from the initial non-equivalence of the groups, the analysis focused on comparing the normalized gain (N-Gain) scores rather than the raw posttest scores. The pretest scores allowed for the establishment of a baseline for each group, and the N-Gain calculation quantifies the improvement of each group relative to its own starting point. This method statistically controls for initial differences in proficiency between the experimental and control classes, allowing for a more accurate assessment of the ADI-STEM model's impact. The research procedure is detailed in Figure 1.

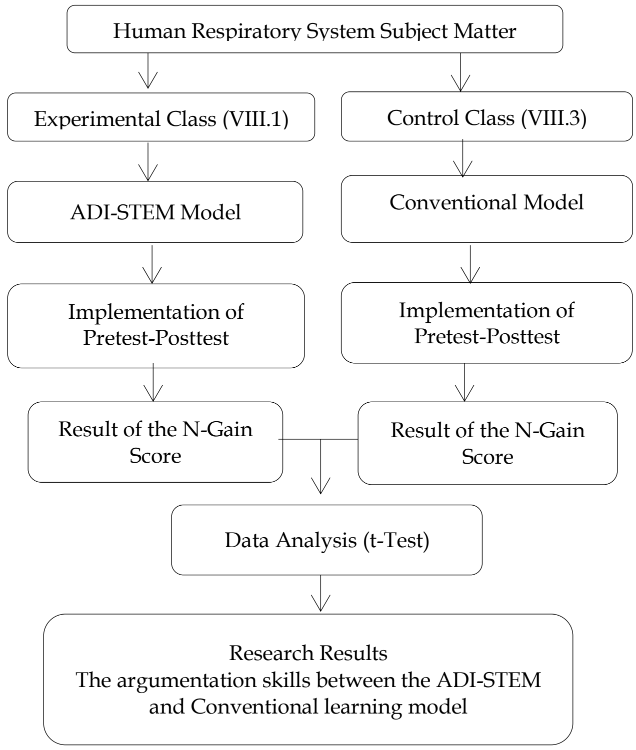

Figure 1. Research Flow Diagram

The ADI-STEM model implemented in the experimental group is the eight-step: identification of the task, generation of data, production of tentative argument, argumentation session, written investigation report, double-blind peer review, revision the report, explicit and reflective discussion (Sampson & Walker, 2012). This inquiry-based framework was then intentionally integrated with Science, Technology, Engineering, and Mathematics (STEM) practices to create a more authentic, hands-on problem-solving experience, reflecting educational principles. An illustration of learning using the ADI-STEM model in the Human Respiratory System material can be seen in Table 1.

Population and Sample

Population of this research comprised all students VIII grade at MTs Negeri 2 North Lampung Indonesia.

This population consisted of 166 students distributed across five distinct classes. A cluster random sampling technique was employed to select the participants for this study. This method was chosen because the students were already organized into pre-existing groups (classes), making it the most feasible approach (Mweshi & Sakyi, 2020). To ensure random selection and justify the use of this technique, a specific procedure was followed: the names of all five eighth-grade classes were written on separate slips of paper. These slips were folded, placed into a container, and mixed thoroughly. Subsequently, two slips were drawn at random to determine the sample. The first class drawn (VIII.1) was assigned to the experimental group, and the second class drawn (VIII.3) was assigned to the control group. The final sample consisted of 66 students, with 32 students in the experimental group and 34 in the control group.

Table 1. ADI-STEM model for human respiratory system (Sampson & Walker, 2012)

Stage of ADI-STEM	Teacher's Role	Student Activities
Identification of the Task	Presents a guiding question, e.g., "How does physical activity affect the rate of human respiration, and why?"	Listen, ask clarifying questions, and form small investigation groups.
Generation of Data	Provides necessary materials (stopwatches, etc.) and ensures safety. Facilitates but does not dictate the method.	In groups, design a method to collect data (e.g., measure breaths per minute at rest, after walking, and after running). Collect and record data.
Production of Tentative Argument	Circulates among groups, asking probing questions to help students link their evidence to a claim.	Analyse the collected data, identify patterns, and construct an argument on a whiteboard consisting of a claim, evidence, and reasoning.
Argumentation Session	Organizes a "gallery walk" or group presentations. Establishes norms for respectful critique and questioning.	Present their arguments to peers. Question and critique the arguments of other groups, focusing on the quality of evidence and reasoning.
Written Investigation Report	Provides a template or guidelines for the written report, emphasizing the key components of the argument.	Write an individual investigation report that explains their research, presents their argument, and justifies their conclusions.
Double-Blind Peer Review	Manages the anonymous distribution of reports for review. Provides a rubric for feedback.	Read and critique the reports of their peers, providing constructive feedback on the strength of the claim, evidence, and reasoning.
Revision of the Report	Provides guidance to students on how to incorporate feedback effectively.	Revise their reports based on the peer feedback they received, aiming to strengthen their argument.
Explicit & Reflective Discussion	Leads a whole-class discussion to summarize findings, clarify common misconceptions, and reinforce the core scientific concepts.	Participate in the discussion, reflect on what they learned about both the respiratory system and the process of scientific inquiry.

Research Instruments

The instrument used to measure students' argumentation skills in this study was a test. The test consisted of 10 essay questions referring to the Toulmin argumentation pattern according to the assessment rubric adopted from Sampson & Clark (2008), as shown in Table 2. Before the argumentation skills test questions were administered, several tests were first conducted, namely validity and reliability tests. In addition, students' responses to the ADI-STEM model were explored using a questionnaire. The purpose of this questionnaire was to collect information from students about their learning experiences. The questionnaire instrument used the Guttman scale. Student response data is fundamentally important in educational research because this data allows researchers to obtain empirical evidence about the process of internalizing learning experiences in students (Romdona et al., 2025).

Data Analysis

The research data were analyzed using an independent sample t-test. Normality was previously tested using the Kolmogorov-Smirnov test and homogeneity was tested using the Levene test. The quality of students' argumentation skills was measured by the average Normalized Gain (N-Gain) through the increase in student scores from pre-test to post-test. This N-Gain calculates the actual gain as a percentage of the maximum possible gain (Cohen, 2013), then interpreted based on the criteria of High (N-gain ≥ 0.7); Medium ($0.3 \leq$ N-gain < 0.7); Low (N-gain < 0.3). A further test to determine the extent of the influence of the ADI-STEM learning model on argumentation skills is the effect size. If ADI-STEM shows a large effect size on argumentation scores, it indicates that the model makes a substantial and practical difference for students and is worthy of implementation.

Student response data to the ADI-STEM model was measured at the end of the lesson using a questionnaire.

The answer options in the questionnaire were "yes/no." If a student chose "yes," they were given a score of 1, and if they answered "no," they were given a score of 0. The questionnaire data were analyzed qualitatively and descriptively in the form of percentages, then analyzed in the form of categories.

Table 2. Rubric for assessing scientific argumentation (Sampson & Clark, 2008)

Component	Level 1: Beginning	Level 2: Developing	Level 3: Proficient
Claim	Makes an inaccurate claim or no claim at all.	Makes an accurate but simple or incomplete claim.	Makes an accurate, complete, and specific claim.
Evidence	Provides no evidence, or the evidence is irrelevant to the claim.	Provides appropriate evidence, but it is insufficient to fully support the claim. May include some irrelevant data.	Provides sufficient and relevant, high-quality evidence to support the claim.
Reasoning	Provides no reasoning, or repeats the claim as the reason. The link between evidence and claim is not explained.	Provides reasoning that links the claim and evidence, but the link is weak or does not connect to a larger scientific principle.	Provides clear, logical reasoning that explicitly links the evidence to the claim and is supported by established scientific principles.

Result and Discussion

Argumentation Skills Score

This research was conducted at MTs Negeri 2 North Lampung using a test instrument to collect data. Data analysis was used to compare the average argumentation skills of seventh-grade junior high school students between the group using the ADI-STEM learning model and the group using the conventional learning model. The pretest and posttest results, as well as the N-Gain for the experimental and control classes, are presented in Table 3.

Table 3. Pretest, posttest, and N-Gain data experimental class and control class

Value	Class	Mean ± SD	Category
Pretest	Experiment	58.40 ± 12.35	Less
	Control	50.18 ± 13.72	Less
Posttest	Experiment	77.09 ± 9.81	Good
	Control	64.23 ± 13.25	Enough
N-Gain	Experiment	0.46 ± 0.14	Keep
	Control	0.29 ± 0.13	Low

The pretest and posttest results revealed a clear improvement in students' argumentation skills after the ADI-STEM intervention. As shown in Table 3, the experimental group's mean score increased from 58.40 (SD = 12.35) in the pretest to 77.09 (SD = 9.81) in the posttest, producing an N-Gain of 0.46 (SD = 0.14, medium category). In contrast, the control group's mean score increased from 50.18 (SD = 13.72) to 64.23 (SD = 13.25), yielding an N-Gain of 0.29 (SD = 0.13, low category).

Data Normality Test and Homogeneity Test Results

This study uses the Kolmogorov-Smirnov normality test with the help of SPSS software at a significance level of 0.05 to determine whether the data is normally distributed or not. If the significance value is greater than 0.05, then the data is considered normally distributed. The results of the normality test analysis as follows Table 4, it can be seen that the significance values for the experimental and control classes are both greater than 0.05, namely 0.200 for the experimental class and 0.183 for the control class. Therefore, it can be concluded that the data in both classes are normally distributed.

Table 4. Normality test result

Value	Class	Kolmogorov-Smirnov		
		Statistic	df	Sig
N-Gain	Experiment	0.120	32	0.200
	Control	0.127	34	0.183

This study uses the Levene test with the help of SPSS software at a significance level of 0.05 to determine whether the data variance of the two classes is homogenous or not. If the significance value is greater than 0.05, then the data variance is considered homogenous. The results of the homogeneity test analysis as follows Table 5. From the Table 5, it can be seen that a probability value of 0.367 which is greater than 0.05, it can be concluded that the data variance of the two classes is homogeneous.

Table 5. Homogeneity test results

Parameters	Levene Statistic	df1	df2	Sig.
Based on Mean	0.825	1	64	0.367
Based on Median	0.796	1	64	0.376
Based on Median and with adjusted df	0.796	1	62.713	0.376
Based on trimmed mean	0.858	1	64	0.358

Hypothesis Testing

Hypothesis testing was conducted using the independent t-test at a significance level of 0.05 through the SPSS application. If the significance value is less than 0.05, it can be concluded that that the differences in argumentation skill gains between the experimental and control class were statistically significant. Conversely, if the significance value is greater than 0.05, then the differences in argumentation skill gains between the experimental and control class were statistically no significant.

The results showed that the significance value of 0.000 ($p < 0.05$), confirming that the differences in argumentation skill gains between the experimental and control groups were statistically significant. It's proved that the ADI-STEM learning model has a significant effect on students' argumentation skills. Table 6 presents the results of the independent sample t-test to determine the statistical significance of differences between the two learning models.

Table 6. Independent sample t-test result

		t-Test for Equality of Means						
		t	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Differences	
							Lower	Upper
N-Gain Result	Equal variances assumed	5.130	64	0.000	0.167	0.033	0.102	0.232
	Equal variances not assumed	5.123	63.282	0.000	0.167	0.033	0.232	0.232

Effect Size Test Result

This study uses an effect size test to determine the magnitude of the influence of the ADI-STEM learning model on students' argumentation skills, which can be found in Table 7. The experimental group achieved an effect size of 1.26, which falls into the "large" category. This shows that the ADI-STEM learning model is very effective and has a great influence in improving students' argumentation skills.

Table 7. Effect size test results

Class	Average N-Gain	Standard Deviation	Effect Size	Category
Experiment	0.46	0.14	1.26	Big
Control	0.29	0.13		

The next analysis focused on students' achievement in claim-making, argument-based (ground), argument-justified (warrant), and argument-supported skills (backing). In the experimental group, the greatest improvement was observed in students' claim-making abilities, which increased from "good" to "very good." This indicates that students found it easier to formulate clear and convincing statements supported by their understanding of the material. Conversely, the argument-supported indicator recorded the lowest improvement, indicating that students had difficulty integrating theoretical justification into their arguments. The results of the N-Gain analysis of students' claim-making, argument-based, argument-justified, and argument-supported skills are presented in Figure 2.

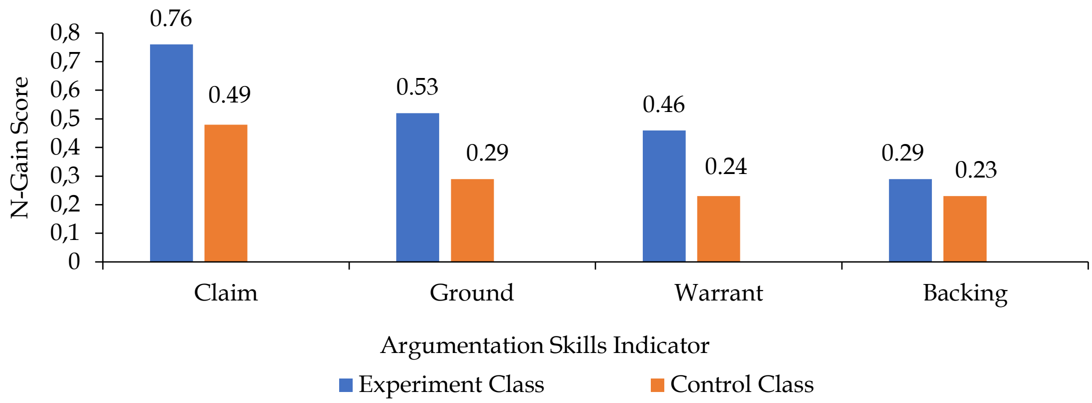

Figure 2. N-Gain Scores of Argumentation Skills Indicator

Results of The Student Response Questionnaire Regarding Learning

Students' responses to the use of the ADI-STEM learning model in learning activities are presented in Table 8. It is known that the percentage of student responses to the use of the ADI-STEM learning model in the experimental class is 82.50%. This shows that students give a positive response so that it can be said that the ADI-STEM model can be very well accepted to improve students' argumentation skills. The highest ratings were attributed to increased group collaboration (93.75%) and motivation (90.64%). Notably, students also reported enhanced ability to construct arguments, particularly in the areas of Claims (87.50%), Evidence

(84.38%), and Warrants (81.25%). However, some students expressed low confidence in presenting arguments, especially concerning the Backing component (75.00%).

Table 8. Student responses to learning with ADI-STEM

Statement: Students	Yes (%)
More active and motivated during respiratory system	90.64
Perceived the model as somewhat burdensome	71.88
Helped structure arguments with clarity and completeness	81.25
Improved group collaboration	93.75
Increased confidence in presenting arguments	71.88
Assisted in delivering arguments effectively	87.50
Enabled development of relevant claims	87.50
Supported use of evidence that aligns with ideas	84.38
Facilitated explanation of the link between evidence and ideas	81.25
Encouraged use of theoretical justification (backing)	75.00
Average	82.50

Discussion

The findings of this study demonstrate that the ADI-STEM learning model significantly improves students' argumentation skills in the topic of the human respiratory system. The pretest and posttest results revealed marked differences between the experimental and control class. While both classes began with similarly low levels of argumentation proficiency, the experimental class exhibited a stronger post-intervention performance, achieving a "good" level, in contrast to the control group, which only reached the "adequate" category. The N-Gain analysis confirmed a medium level of improvement in the experimental class versus a low level in the control class. This indicates the efficacy of the ADI-STEM learning model in fostering students' ability to express reasoned scientific arguments, aligning with the findings of Nurhidayati et al. (2023) that this model promotes student engagement and supports evidence-based reasoning.

The underperformance of the control class may be attributed to insufficient exposure to structured argumentation and conceptual understanding. According to Sarira et al. (2019), students require targeted instruction to develop these competencies. Ishaq et al. (2022) support this by noting that argumentation skills remain underdeveloped when not actively trained. Furthermore, traditional teacher-centered approaches, as highlighted by Hardini & Alberida (2022), limit students' opportunities to practice and refine their reasoning skills.

When broken down by indicators, the experimental group demonstrated the most improvement in constructing claims likely due to the relative simplicity of formulating initial positions compared to providing theoretical justification (backing), which showed the least improvement. This is consistent with prior research by Bambut (2025) and Noer et al. (2020), which observed that students tend to perform better in forming claims than in integrating theoretical frameworks. The challenges in generating valid backing statements were also highlighted by Novianti et al. (2022), who found that students often omit critical justifications, leading to weaker overall arguments.

The overall superiority of the experimental class across all indicators reinforces the value of ADI-STEM in developing robust scientific arguments. The model's structured phases especially the tentative argumentation, peer-review, and reflective discussion stages create a scaffolded environment conducive to deep reasoning. Sulistianingsih & Yanto (2024) and Setiawan & Jumadi (2023) also affirm that ADI-oriented learning enhances students' ability to build and revise arguments systematically, supported by empirical data.

The effect size value of 1.26, classified as large, further substantiates the model's strong impact. This corroborates Putri & Paidi (2023), who reported significant gains in argumentation skills using ADI-based biology instruction. These findings collectively affirm that the ADI-STEM model facilitates both conceptual understanding and argumentative competence through active, student-centered learning.

Moreover, student responses support these quantitative results. With an approval rating of 82.50%, learners reported high motivation and perceived the model as effective for constructing structured arguments. Hidayanti et al. (2022) and Syarqiy et al. (2023) also found that students respond more favorably to ADI methods than to conventional techniques, particularly in contexts requiring collaborative inquiry.

The effectiveness of ADI-STEM can also be attributed to its practical integration of STEM disciplines during learning activities (Figure 3). In the problem identification stage, students engaged in real-life contextualization of the respiratory system topic by formulating testable questions, aligning with Choi et al. (2021) and Tambunan et al. (2024) students identified the effect of cigarette smoke on the function of respiratory organs by using cigarettes and filter paper in the design of the smoker model. Color change on the filter paper showed that there were harmful substances in cigarette smoke. In the data collection stage, students carry out investigate activities to collect and analyze data in cooperative manner. Students constructed and employed tools, applying scientific and mathematical reasoning to collect and analyze data, which is consistent with the interdisciplinary nature of STEM as described by Kelley & Knowles (2016) and Zulirfan & Yennita, (2022). Students designed experiments to make products that are integrated with STEM, namely Models of

Respiratory Organs such as healthy lungs and bronchi and smokers. In designing and manufacturing products that are integrated with STEM, knowledge of human respiratory volume and the dangers of cigarette smoke to respiratory organs is required.

Figure 3. Learning the human respiratory system with the ADI-STEM learning model

With guidance from educators, students design their own experiments, using scientific instruments that represent the technological discipline within STEM. The mathematical discipline is also applied to determine measurements for equipment assembly and to calculate variables, such as the volume of breathing air or to graph the relationship between cigarette smoke exposure and respiratory distress. This is consistent with Sujud et al. (2024) research, which emphasizes the application of mathematics in determining measurements for experimental equipment. Ultimately, these experimental activities at the data collection stage help students accurately formulate a claim and collect the necessary data as evidence to support it Firdaos et al. (2021) and Saiful et al. (2017).

The preparation of arguments allowed students to formulate complete reasoning chains from claims to backing deepening their understanding of the argumentative process. This was followed by the argumentation session, a stage that not only fostered oral communication but also required critical evaluation and rebuttal, thereby refining their argumentation structure, as emphasized by Walker et al. (2011) and Songsil et al. (2019). Students presented and evaluated.

The subsequent phases of the study, such as report writing, peer review, and revision, mirrored authentic scientific practices and encouraged metacognitive reflection, key to developing high-quality arguments. Nurhidayati et al. (2023) noted that such iterative writing and feedback processes reinforce clarity, accuracy, and justification in students' scientific reasoning. Reports included background, objectives, procedures, and arguments (claims, data, warrants, backing). Writing helped students consolidate learning and enhance understanding, consistent with Marhamah et al. (2017). Students reviewed each other's reports under teacher guidance using peer review sheets assessing content and argument quality (Figures 3). This process allowed revision based on feedback, enhancing rebuttal skills. It aligns with Nurhidayati et al. (2023) and findings by Walker et al. (2011), who noted the importance of peer feedback in developing argumentation. Students revised reports based on peer reviews, addressing incomplete sections (Figure 3). Revisions improved argument quality, as argued by Sampson et al. (2014), and were returned to original groups for final review. In this final stage, students summarized their learning in written reflections, building structured claims supported by evidence. This reinforces skills in claims, data, warrants, and backing. It aligns with Nurhidayati et al. (2023) and Pritasari et al. (2016), who noted that reflective discussions help students construct valid, evidence-based conclusions (Figure 3).

Conclusion

This study showed that the ADI-STEM learning model significantly enhances students' argumentation skills in science education, particularly on the topic of the human respiratory system. The experimental group showed greater improvement compared to the control group, as evidenced by higher N-Gain scores and effect size. The results highlight the pedagogical strength of ADI-STEM, which effectively integrates inquiry, collaboration, and interdisciplinary thinking to support the development of structured, evidence-based arguments. While improvements were evident across all argumentation components, 'claim' formulation showed the highest enhancement, aligning with the model's emphasis on initial position articulation. However, developing robust 'backing' statements remained a challenge, indicating an area for future pedagogical refinement. The findings contribute to the growing body of research advocating for integrative, student-centered models in science instruction. By fostering deep reasoning and reflective dialogue, ADI-STEM not only improves conceptual understanding but also prepares learners for complex problem-solving in real-world contexts. Student responses further confirm the model's relevance and acceptance in classroom settings.

Acknowledgments

This work was brought to fruition through the guidance and support of many people, and I would like to extend my heartfelt thanks to them all. I am particularly indebted to the students, educators, and administrators of the participating schools. Their willingness to engage with this research and their valuable input were essential to the success of this project.

Author Contributions

N. H.: conceptualized the research idea, research methods, and analyzed the data; U.R., N.M., and S.F.: guided the review and editing authors supervised and validated the instruments used in the research.

Funding

This research was funded by the 2025 DIPA BLU UNILA grant.

Conflicts of Interest

The authors declare no conflict of interest.

References

Bambut, K. E. N. (2025). Eksplorasi Perbedaan Kualitas Argumentasi Ilmiah Mahasiswa Berdasarkan Tingkat Semester Melalui Pendekatan Socio-Scientific Issues. *DIKSI: Jurnal Kajian Pendidikan dan Sosial*, *6*(3), 512–519. https://doi.org/10.53299/diksi.v6i3.2618

Choi, J., Lee, S. E., Bae, J., Kang, S., Choi, S., Tate, J. A., & Yang, Y. L. (2021). Undergraduate Nursing Students' Experience of Learning Respiratory System Assessment Using Flipped Classroom: A Mixed Methods Study. *Nurse Education Today*, *98*, 104664. https://doi.org/10.1016/j.nedt.2020.104664

Clement, J. J. (2013). Roles for Explanatory Models and Analogies in Conceptual Change. In *International Handbook of Research on Conceptual Change* (pp. 412–446). Routledge. https://doi.org/10.4324/9780203154472.ch22

Cohen, J. (2013). *Statistical Power Analysis for the Behavioral Sciences*. Routledge. https://doi.org/10.4324/9780203771587

Creswell, J. W. (2014). *Research Desing: Qualitative, Quantitative and Mixed Methods Approaches* (Vol. 54). United State of America: Sage Publications.

Dawson, V. (2024). Teachers' Support in Developing Year 7 Students' Argumentation Skills About Water-Based Socioscientific Issues. *International Journal of Science Education*, *46*(3), 222–239. https://doi.org/10.1080/09500693.2023.2226334

Eugenijus, L. (2023). Integrating Blended Learning and STEM Education: Innovative Approaches to Promote Interdisciplinary Learning. *Research and Advances in Education*, *2*(9), 20–36. https://doi.org/10.56397/RAE.2023.09.03

Firdaos, I. N., Pursitasari, I. D., & Permana, I. (2021). Pembelajaran Argument Driven Inquiry pada Materi Suhu dan Kalor untuk Meningkatkan Kemampuan Argumentasi Ilmiah Siswa. *Jurnal Penelitian Pendidikan*, *21*(2), 88–97. https://doi.org/10.17509/jpp.v21i2.37134

Fischer, F., Kollar, I., Ufer, S., Sodian, B., Hussmann, H., Pekrun, R., Neuhaus, B., Dorner, B., Pankofer, S., Fischer, M., Strijbos, J-W., Heene, M., & Eberle, J. (2014). Scientific Reasoning and Argumentation: Advancing an Interdisciplinary Research Agenda in Education. *Frontline Learning Research*, *2*(3), 28–45. https://doi.org/10.14786/flr.v2i2.96

Fitria, A. R., Hasnunidah, N., Fadiawati, N., & Suyatna, A. (2025). Enhancing Scientific Argumentation Through the Integration of Argument-Driven Inquiry and STEM in E-Worksheets for Secondary Science Education. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 263–272. https://doi.org/10.29303/jppipa.v11i7.11603

Fortes, G., Guzmán, V., & Larrain, A. (2022). Studying Argumentation and Education in South America: What Has Been Advanced and What Lies Ahead. *Argumentation and Advocacy*, *58*((3-4)), 266–280. https://doi.org/10.1080/10511431.2022.2138174

Hardini, S. D., & Alberida, H. (2022). Analisis Kemampuan Argumentasi Peserta Didik. *Jurnal Biologi dan Pembelajarannya*, *17*(1). Retrieved from https://jurnal.untirta.ac.id/index.php/biodidaktika/article/view/16108

Hidayanti, N., Juhanda, A., & Nuranti, G. (2022). Pengaruh Model Argument Driven Inquiry Terhadap Kemampuan Berpikir Tingkat Tinggi Berdasarkan Perbedaan Gaya Belajar Siswa SMP pada Materi Sistem Ekskresi. *Bioscientist: Jurnal Ilmiah Biologi*, *10*(2), 563. https://doi.org/10.33394/bioscientist.v10i2.5397

Imranah, I., Kasman, R. A., & Fuad, M. (2025). Systematic Literature Review: Implementation of STEM Integrated PBL Model in Improving 21st Century Skills. *Cerdas: Jurnal Ilmu Pendidikan Sosial dan Humaniora*, *1*(1), 1–9. Retrieved from https://jurnal.itkpi.ac.id/index.php/cerdas/article/view/34

Ishaq, I. M., Khaeruddin, K., & Usman, U. (2022). Analisis Kemampuan Berargumentasi dalam Pembelajaran Fisika Peserta Didik SMA Negeri 8 Makassar. *Jurnal Sains dan Pendidikan Fisika*, *17*(3), 211. https://doi.org/10.35580/jspf.v17i3.29781

Kelley, T. R., & Knowles, J. G. (2016). A Conceptual Framework for Integrated STEM Education. *International Journal of STEM Education*, *3*, 1–11. https://doi.org/10.1186/s40594-016-0046-z

Kimmerle, J., Fischer, F., & Cress, U. (2021). Argumentation and Knowledge Construction. In *International Handbook of Computer-Supported Collaborative Learning* (pp. 183–198). Springer.

Kurniawan, E. S. (2023). Strategi Jembatan Konsep Analogi untuk Meningkatkan Phyhots Peserta Didik pada Pembelajaran Fisika. *Jurnal Inovasi Pendidikan Sains (JIPS)*, *4*(1), 26–35. https://doi.org/10.37729/jips.v4i1.3023

Lestari, A. K., Fitriani, A., & Kusnadi, K. (2023). Application of STEM-Integrated Guided Inquiry Model to Improve Science Process Skills of Junior High School Learners on Human Respiratory System Material. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11078–11084. https://doi.org/10.29303/jppipa.v9i12.5845

Liana, D. E., Muzzazinah, M., & Indrowati, M. (2022). Development of Science E-Modules Based of Guided Inquiry to Improve Students' Critical Thinking Ability. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1368–1375. https://doi.org/10.29303/jppipa.v8i3.1668

Marhamah, O. S., Nurlaelah, I., & Setiawati, I. (2017). Penerapan Model Argument-Driven Inquiry (ADI) dalam Meningkatkan Kemampuan Berargumentasi Siswa pada Konsep Pencemaran Lingkungan di Kelas X SMA Negeri 1 Ciawigebang. *Quagga: Jurnal Pendidikan dan Biologi*, *9*(02), 45. https://doi.org/10.25134/quagga.v9i02.747

McNeill, K. L., & Krajcik, J. (2008). Scientific Explanations: Characterizing and Evaluating the Effects of Teachers' Instructional Practices on Student Learning. *Journal of Research in Science Teaching*, *45*(1), 53–78. https://doi.org/10.1002/tea.20201

Mweshi, G. K., & Sakyi, K. (2020). Application of Sampling Methods for the Research Design. *Archives of Business Research*, *8*(11), 180–193. https://doi.org/10.14738/abr.811.9042

Noer, H. A., Setiono, S., & Pauzi, R. Y. (2020). Profil Kemampuan Argumentasi Siswa SMP pada Materi Sistem Pernapasan. *Jurnal Pelita Pendidikan*, *8*(2), 138–144. https://doi.org/10.24114/jpp.v8i2.17702

Novianti, D., Mulyani, B., & Susanti, E. (2022). Analisis Kemampuan Argumentasi Ilmiah Peserta Didik Kelas X MIPA SMA Negeri 2 Surakarta pada Materi Hukum Dasar Kimia. *Jurnal Pendidikan Kimia*, *11*(1), 75–81. https://doi.org/10.20961/jpkim.v11i1.50585

Ntemngwa, C., & Oliver, J. S. (2018). The Implementation of Integrated Science Technology, Engineering and Mathematics (STEM) Instruction Using Robotics in the Middle School Science Classroom. *International Journal of Education in Mathematics, Science and Technology*, *6*(1), 12–40. https://doi.org/10.18404/ijemst.380617

Nurhidayati, E., Masykuri, M., Isma, D., & Fakhrudin, A. (2023). Pengaruh Model Pembelajaran Argument Driven Inquiry (ADI) dengan Pendekatan STEM Terhadap Keterampilan Argumentasi pada Materi Cahaya dan Alat Optik. *Jurnal Pendidikan IPA*, *12*(3). https://doi.org/10.20961/inkuiri.v12i3.79317

Nuzulah, D. F., Kirana, T., & Ibrahim, M. (2023). Validity of Inquiry-Based Learning Tools on Students' Scientific Argumentation Ability. *IJORER: International Journal of Recent Educational Research*, *4*(2), 137–148. https://doi.org/10.46245/ijorer.v4i2.309

Paramita, A. K., Dasna, W., & Yahmin, Y. (2019). Kajian Pustaka: Integrasi STEM untuk Keterampilan Argumentasi dalam Pembelajaran Sains. *Jurnal Pembelajaran Kimia*, *4*(2), 92-99. https://doi.org/10.17977/um026v4i22019p092

Pritasari, A. C., Dwiastuti, S., & Probosari, R. M. (2016). Improvement of Argumentation Skill Through Implementation of Problem Based Learning in X MIA 1 SMA Batik 2 Surakarta in the Academic Year 2014/2015. *Jurnal Pendidikan Biologi*, *8*(1), 1–7. Retrieved from https://jurnal.uns.ac.id/bio/article/view/8286/7444

Putri, M. D., Lubis, N. A., & Fairuz, T. (2023). Quality of Student Scientific Argumentation Through the Application of Problem-Based Learning with Flipped Classroom Approach. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 369–377. https://doi.org/10.29303/jppipa.v9i1.2504

Putri, W. A., & Paidi, P. (2023). Pengaruh Pembelajaran Biologi Berbasis ADI Topik Keanekaragaman Hayati untuk Meningkatkan Kemampuan Argumentasi Siswa. *Jurnal Edukasi Biologi*, *9*(1), 22–34. https://doi.org/10.21831/edubio.v9i1.19130

Romdona, S., Junista, S. S., & Gunawan, A. (2025). Teknik Pengumpulan Data: Observasi, Wawancara dan Kuesioner. *JISOSEPOL: Jurnal Ilmu Sosial Ekonomi dan Politik*, *3*(1), 39–47. https://doi.org/10.61787/taceee75

Roth, K. J. (2013). Developing Meaningful Conceptual Understanding in Science. In *Dimensions of Thinking and Cognitive Instruction* (pp. 139–175). Routledge.

Saiful, S., Rosidin, U., Suyatna, A., & Viyanti, V. (2017). Performance Assessment Berbasis Inkuiri Terbimbing untuk Membangun Keterampilan Argumentasi Siswa. *Jurnal Inovasi dan Pembelajaran Fisika*, *4*(2), 170–181.

Sampson, V., & Clark, D. B. (2008). Assessment of the Ways Students Generate Arguments in Science Education: Current Perspectives and Recommendations for Future Directions. *Science Education*, *92*(3), 447–472. https://doi.org/10.1002/sce.20276

Sampson, V., & Walker, J. P. (2012). Argument-Driven Inquiry as a Way to Help Undergraduate Students Write to Learn by Learning to Write in Chemistry. *International Journal of Science Education*, *34*(10), 1443–1485. https://doi.org/10.1080/09500693.2012.667581

Sampson, V., Patrick, E., Gleim, L., Grooms, J., Hester, M., Southerland, S., & Wilson, K. (2014). *Argument-Driven Inquiry in Biology: Lab Investigations for Grades 9-12*. NSTA Press.

Sarira, P. M., Priyayi, D. F., & Astuti, S. P. (2019). Hubungan Argumentasi Ilmiah dan Hasil Belajar Kognitif pada Penerapan Model Problem Based Learning (PBL). *Edu Sains Jurnal Pendidikan Sains & Matematika*, *7*(2), 1–10. https://doi.org/10.23971/eds.v7i2.1258

Satriya, M. A., & Atun, S. (2024). The Effect of Argument Driven Inquiry Learning Models on Scientific Argumentation Skills and Higher Order Students on the Topics of Acid Base. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2663–2673. https://doi.org/10.29303/jppipa.v10i5.6834

Setiawan, A., & Jumadi, J. (2023). Analysis of the Implementation of Argument Driven Inquiry (ADI) in Students' Argumentation Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 127–133. https://doi.org/10.29303/jppipa.v9i6.2725

Songsil, W., Pongsophon, P., Boonsoong, B., & Clarke, A.

(2019). Developing Scientific Argumentation Strategies Using Revised Argument-Driven Inquiry (RADI) in Science Classrooms in Thailand. *Asia-Pacific Science Education*, *5*, 7. https://doi.org/10.1186/s41029-019-0035-x

Suhirman, S., & Prayogi, S. (2023). Overcoming Challenges in STEM Education: A Literature Review That Leads to Effective Pedagogy in STEM Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 432–443. https://doi.org/10.29303/jppipa.v9i8.4715

Sujud, R., Rahmawati, Y., & Utami, A. D. (2024). Development of Science Literacy Through Group Choice STEM-PjBL Projects Integrated with Matter State Changes. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2552–2564. https://doi.org/10.29303/jppipa.v10i5.6441

Sulistianingsih, M., & Yanto, F. (2024). Studi Literatur: Pengaruh Penerapan Model Pembelajaran Argument Driven Inquiry (ADI) Terhadap Keterampilan Argumentasi Siswa pada Mata Pelajaran IPA SMP. *Jurnal Pendidikan Tambusai*, *8*(2), 18944–18954. https://doi.org/10.31004/jptam.v8i2.15168

Syarqiy, D., Yuliati, L., & Taufiq, A. (2023). Exploration of Argumentation and Scientific Reasoning Ability in Phenomenon-Based Argument-Driven Inquiry Learning in Newton’s Law Material. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7264–7272. https://doi.org/10.29303/jppipa.v9i9.4589

Tambunan, M. D., Zulfiani, Z., & Rosyidatun, E. S. (2024). Ill-Structured on Respiratory System: How Does the Contextual Problem Improve Students’ Problem-Solving Skills by Developing Electronic Worksheet? *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(3), 928–938. https://doi.org/10.22219/jpbi.v10i3.33817

Walker, J. P., Sampson, V., Grooms, J., Anderson, B., & Zimmerman, C. O. (2011). Argument-Driven Inquiry in Undergraduate Chemistry Labs: The Impact on Students’ Conceptual Understanding, Argument Skills, and Attitudes Toward Science. *Journal of College Science Teaching*, *41*(4), 74–81. Retrieved from https://www.researchgate.net/publication/259041844

Yıldız-Feyzioğlu, E., & Kıran, R. (2022). Investigating the Relationships between Self-Efficacy for Argumentation and Critical Thinking Skills. *Journal of Science Teacher Education*, *33*(5), 555–577. https://doi.org/10.1080/1046560X.2021.1967568

Zulirfan, Z., & Yennita, Y. (2022). Feasibility Test of STEM at Home Prototype Kit as Science Project-Based Learning Media for Junior High School students. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 57–66. https://doi.org/10.29303/jppipa.v8i1.1122