Jurnal Penelitian dan Pengkajian Ilmu Pendidikan:
e-Saintika
https://journal-center.litpam.com/index.php/e-Saintika/index

November 2025 Vol. 9, No. 3
e-ISSN: 2615-6881
pp. 750-770

Argument-Driven Inquiry Assisted by Lumi Education: Improving Students' Scientific Argumentation Skills on Static Electricity

Putri Avianita Salsabila, *Ahmad Fauzi Hendratmoko, Fikky Dian Roqobih

Department of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Surabaya, Indonesia.

*Corresponding Author e-mail: ahmadhendratmoko@unesa.ac.id

Received: September 2025; Revised: October 2025; Published: November 2025

Abstract

The aim of this study is to evaluate the effectiveness of the Argument-Driven Inquiry (ADI) learning strategy, supported by the Lumi Education platform, in enhancing the scientific argumentation skills of students related to static electricity. A quasi-experimental approach, employing a non-equivalent control group, was adopted in this study, including two ninth-grade classes in a junior high school as participants. The participants were exposed to instruction utilizing either the ADI strategy and the support of the Lumi Education website or standard instruction as a control group. The strategies developed included a scientific argumentation skills test, designed as a claim, evidence, and warrant procedure, as well as a questionnaire administered among students. The data gathered were statistically processed by comparing pre-test and post-test results, calculating the normalized gains, as well as a description analysis approach among the students' written responses. The results show that, compared to a low category average normalization gain of 0.18 among the control class, a significantly high average value, 0.70, was established by the experimental class, signifying a statistically significant difference between the two categories, yielding a significance at a probability value less than 0.001. The results among the experimental class developed a Cohen's value, or the standardized effect size, estimated as 0.53, signifying a medium effect, while among the control class, an estimated 0.11, signifying a small effect, was recognized. Students said they liked the learning experience and thought it was more interesting, dynamic, and simpler to comprehend when they worked together on real-world tasks. However, some still encountered difficulties with conceptual comprehension and problem-solving. These findings imply that integrating ADI with digital scaffolding, such as Lumi Education, can effectively strengthen scientific argumentation skills while promoting active and reflective learning.

Keywords: Argument-Driven Inquiry; Lumi Education; Scientific Argumentation Skills; Inquiry Learning; Science Education

How to Cite: Salsabila, P. A., Hendratmoko, A. F., & Roqobih, F. D. (2025). Argument-Driven Inquiry Assisted by Lumi Education: Improving Students' Scientific Argumentation Skills on Static Electricity. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *9*(3), 750-770. https://doi.org/10.36312/70dd6197

https://doi.org/10.36312/70dd6197

INTRODUCTION

Scientific argumentation is one of the most essential components of analytical intelligence skills, which are highly needed at this time (Hendratmoko et al., 2024). It is the skill of conveying a claim supported by evidence and a warrant to explain phenomena and solve problems based on a scientific framework, while also involving collaborative discussion through questions and answers (Lobczowski et al., 2020). These skills are not only crucial during the process of learning Science in school but also helpful in everyday life, such as analyzing facts, making decisions, and solving problems rationally (Nazidah et al., 2022). Scientific argumentation is also a very valuable part of engaging students in scientific literacy. It will help students discuss things that are already happening, offer arguments, and make well-informed decisions related to technology and other concerns of today's world, as mentioned by (Canoz et al., 2022). So, students will have to present strong scientific arguments to learn how to solve problems and make wise decisions.

The scientific argumentation skills is an asset that contributes significantly to the academic and professional world, and this asset is still a necessity to be developed. Based on past research, a number of students are proven to lack proper skills in scientific arguments, capable of making a point without proper evidence and warrant (Santri et al., 2023; Zairina & Hidayati, 2022). It is apparent by the prevalence of Teacher-Centric activities even in learning (Hasanah et al., 2022). As a result, the arguments made by the pupils are mere surface-level arguments, lacking proper proof or rationale. As a result, the pupils are complacent, rather than intellectually engaged in studying science.

As a crucial skill set that students should master, their scientific argumentation skills require a substantial amount of effort to achieve. One strategy to make this easier is by utilizing an Argument-Driven Inquiry (ADI) model developed (Grooms et al., 2015). The strategy emphasizes that a greater degree of involvement between students and their learning process should be promoted, in addition to their capacity to articulate their scientific arguments through statements, evidence, and explanations (Grooms et al., 2015; Muhaba et al., 2025). Arslan et al. (2023), have presented empirical evidence revealing that both the ADI model and conventional strategies are significantly outdone by the former model alone, leading to a philosophy that fosters greater competence, comprehension, and argumentative skills related to scientific inquiry. Based on the findings presented by Telenius et al. (2020), this study aims to examine whether or not the employment of the ADI model may present a better result related to the quality of arguments presented by the learners undergoing virtual science education, even if they didn't make extensive utilization of any other associated digital-based applications, rather experiencing the program and activities facilitated by an online-based learning system. Nevertheless, research by Aldahmash & Omar (2021), indicates that the implementation of ADI in the classroom still faces limitations, mainly due to a lack of interactive media support and the dominance of teacher-centered activities.

The ADI approach is widely recognized as an efficient teaching technique that enhances students' scientific argumentation skills. The approach emphasizes starting, justifying, and testing claims that are founded on evidence and warrant, as well as evaluating statements scientifically. Still, in actual classroom teaching, teachers will often face challenges or restrictions when applying the ADI strategy effectively, mainly in maintaining engagement activities and providing instant feedback relating to the arguments presented by students (Alfarraj et al., 2023). To address these limitations, the integration of digital tools that offer structured scaffolding and instant feedback has become increasingly necessary.

Paralleling technological developments, new approaches to interactive learning, such as Lumi Education, have emerged as possible ways to upgrade inquiry-based learning. Experimental studies show that Lumi Education positively impacts student engagement, concentration, and academic performance outcomes for a number of disciplines (Matana et al., 2024; Yuan et al., 2024). The model that Lumi Education adopts when formative feedback system helps learners identify and correct misconceptions, thereby strengthening conceptual understanding (Yulia et al., 2025). Additionally, Lumi Education helps with both personal and collective e-learning, enabling autonomy and active production of knowledge (Fajardo & Apellido, 2025; Zourmpakis & Papadakis, 2024).

It is thought that adding Lumi Education to ADI-based learning would improve the quality of students' scientific arguments. Nonetheless, there has been little study focusing on the integration of the two in scientific education. ADI typically focuses on group discussions without giving students a way to come up with their own claim, evidence, and justification. This implies that their scientific argumentation skills are often not very good (Aldahmash and Omar 2021; Papadakis et al., 2024). Integration with Lumi Education enables digital interventions that support both individual and collaborative practice, potentially overcoming these limitations. Assisted in implementing the ADI model, Lumi Education can overcome the limitations of conventional ADI implementations, which tend to focus on discussions without the support of interactive digital media. Thus, this study not only replicates the application of ADI but also incorporates Lumi's digital support, which has the potential to optimize the collaborative process of compiling and presenting arguments.

METHOD

Research Design

This research used a quasi-experimental approach using a non-equivalent control group model (Sugiyono, 2024). This method was chosen due to the impracticality of complete randomization of courses, while yet allowing for comparisons across groups (Creswell & Creswell, 2018). Figure 1 illustrates the research design flow.

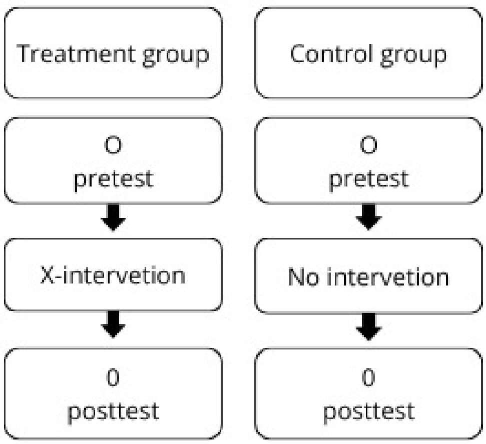

Figure 1. Research Design Scheme

The pre-test was delivered for 40 minutes to provide equal beginning circumstances across the two groups. During the treatment phase, the experimental group was taught using the Argument-Driven Inquiry (ADI) methodology together with the Lumi Education platform. The control class, by contrast, was handled by the conventional methods of lectures, group discussions, and other classroom interactions with no technological aids. The two instruction portions per class took approximately two to three hours each. To eliminate any bias or influence of the instructor, the same researcher handled both the control and experimental courses all through the learning activities. The two courses completed, a post-test was administered to examine the improvement attained by the students' scientific argumentation skills.

Participants and Ethics

The research was conducted at SMPN 8 Kota Surabaya with the official consent of the school (Approval Letter No. 400.3.5./419/436.7.1P8/2025). The people that took part were ninth graders in the 2024/2025 academic year. The selection of two courses was based on their comparable levels of academic skill. The experimental group was Class IX-F (n=30), whereas the control group was Class IX-H (n=30). There were 15 males and 15 girls in each group, and they were all 14 to 15 years old.

An independent sample t-test was conducted on pre-test scores to validate group comparability. The results indicated no significant difference between the groups ($t(58) = 1.68$, $p = 0.098$, $d = 0.28$, 95% CI [–0.07, 1.01]), so confirming that both groups have comparable baseline scientific argumentation skills. The calculation of effect size (Cohen's d) and confidence interval followed the procedures established (Lakens, 2013).

The students have to be actively enrolled and should be involved in both the pre-test and all activities if they are included. There were no specified reasons why a student may be excluded, other than excessively frequent absenteeism. All the participants completed all the courses. The objective of handing out pre-test was to ensure all the groups were similar before any activities took place. There was no identification, including names or any other personal information, shared or gathered with the aim of maintaining the confidentiality and privacy, respectively, of the participants. Before any analysis took place, all the data was kept anonymous, as participation took place voluntarily. The participants, as well as their parents, gave their fully informed consent, and all the methodologies practiced the ethics required by institutions as well as countries when dealing with minors.

Instruments

The primary study tools included pre-test and post-test evaluations, both applying the Toulmin Argument Pattern, to determine how effectively students could construct a scientific argument (Toulmin, 2003). The results were validated by surveys among the students, which were quantitative findings measured by the questionnaires. The validity of all tools was established by applying Aicken's V with three validators, while the reliability was estimated by utilizing Cronbach's Alpha values. The scientific argumentation skills competence entrance exam exhibits a degree of validity, $V = 0.84$, which indicated 'Very Valid.' The value shows reliability, indicated by the reliability index, $\alpha = 0.74$, 'Reliable.' The student response questionnaire exhibits a degree of 'Very Valid,' indicated by the value, $V = 0.94$, as well as a reliability index, $\alpha = 0.78$, 'Reliable.' The two judges independently measured the components of the Claim-Evidence-Warrant (CEW) by utilizing a three-tier level criteria scale, 'Basic,' 'Developing,' and 'Proficient.' The component indicated how deep or scientifically valid the argument was pitched. The procedure was measured as consistent by Cohen's Kappa statistic, κ = 0.87, among the ratings, meaning the process was objective, consistent, and could be replicated.

Procedure

Figure 2 shows that the deployment of ADI with Lumi Education proceeded through eight scheduled steps. Integration of Lumi Education was especially implemented in stages 1, 3, and 5, concentrating on individual digital engagement and formative feedback.

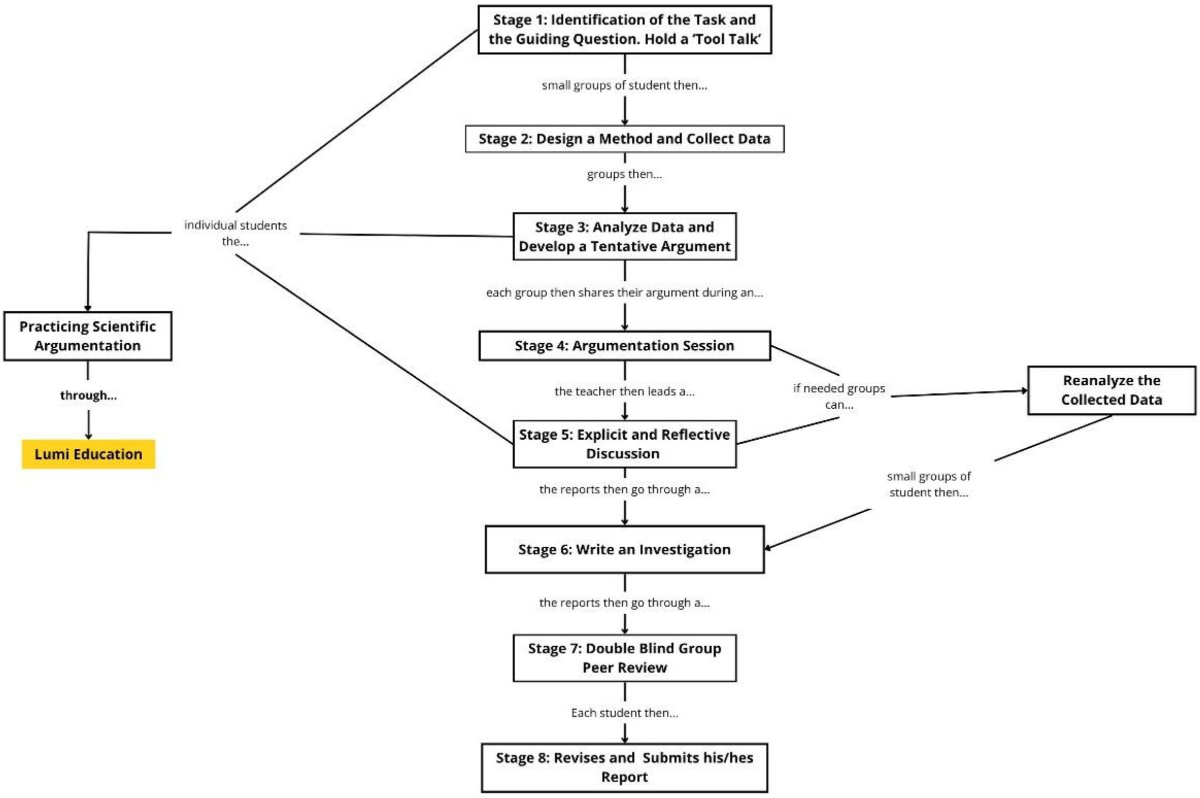

Figure 2. Procedures for the Implementation Stages of the ADI Model

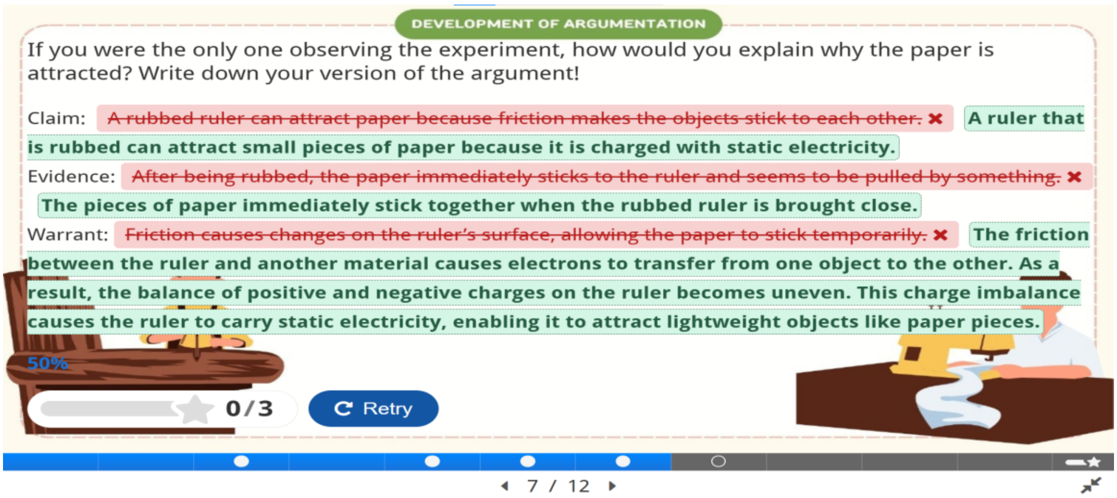

Figure 3. Display of scientific argumentation preparation activities and formative feedback on the Lumi Education platform.

Figure 3 shows that the platform gives automatic formative feedback using color-coded markers (green for right answers, red for changes), check icons, and recommendations for improvement based on examples. The digital integration was used in a planned way at the stages that were directly related to building an argument. This let students get feedback in real time and improve their scientific argumentation skills. Table 1 shows the integration matrix that connects ADI phases (phase 1, 3, and 5) with Lumi Education activities.

Table 1. Lesson Phases, Lumi Elements, and Feedback Types

ADI Phase	Lumi Element	Feedback Type	Time Allocation	Student Product	Teacher's Role
Phase 1: Identification of the Task	Interactive Video, Multiple-Choice	Immediate corrective feedback after each response	15 minutes	Digital responses to contextual questions reflecting prior knowledge	Guide students in identifying problems and clarifying misconceptions
Phase 3: Data Collection and Evidence Generation	Drag-and-Drop, Fill-in-the-Blanks	Real-time formative feedback via color-coded cues (green = correct, red = revision)	15 minutes	Completed digital data tables and structured evidence notes	Facilitate observation, monitor responses, and encourage data-based scientific argumentation
Phase 5: Argument Construction	Exportable Text Area (CEW Format)	Automated open-ended feedback with improvement suggestions	20 minutes	Written scientific arguments (Claim–Evidence–Warrant) in Lumi Education	Provide verbal scaffolding, review logic, and strengthen the conceptual link

Data Analysis Techniques

Data from the pre-tests and post-tests were analyzed descriptively to provide an overview of students' scientific argumentation skills before and after treatment. Skill levels were categorized according to Hendratmoko et al. (2024), as summarized in Table 2.

Table 2. Students' Scientific Argumentation Skill Level

Score	Level
$2.25 < n \leq 3.00$	Proficient
$1.50 < n \leq 2.25$	Advanced
$0.75 < n \leq 1.50$	Intermediate
$0.00 < n \leq 0.75$	Beginner

The advancement of learners' scientific argumentation skills as a result of the treatment given is based on the results of the N-gain analysis (Hake, 2002), with the following equation.

$$N - gain = \frac{\bar{X}posttest - \bar{X}pretest}{Skor\ Maks - \bar{X}pretest}$$

The N-gain values obtained are then interpreted according to the categories in Table 3 (Putri & Admoko, 2022).

Table 3. N-gain Standards

Standard Gain Velue	Criteria
g < 0.30	Low
0.30 ≤ g < 0.70	Medium
g ≥ 0.70	High

All quantitative analyses were conducted using IBM SPSS Statistics version 27. Prior to hypothesis testing, assumption tests were performed, including the Shapiro–Wilk for normality and Levene's test for homogeneity of variance. Effect sizes were calculated using Cohen's d for t-tests and the rank-biserial correlation (r) for nonparametric tests. Furthermore, 95% confidence intervals (CIs) for mean differences were reported following the recommendations of Lakens (2013), to provide a measure of precision and practical significance. Between-group comparisons employed the Mann-Whitney U test with effect size r and significance level was set at $p < 0.05$.

Data from the student response questionnaire were analyzed to identify learners' perceptions of the ADI model. The questionnaire comprised 13 closed-ended and 2 open-ended items. Quantitative responses were analyzed descriptively, while qualitative responses were coded to identify emerging themes and to support the interpretation of quantitative findings.

RESULTS AND DISCUSSION

Descriptive Results

The analytical data was both possess from the experimental class and the control class. The experimental class demonstrated a significant advancing in learners scientific argumentation skills through the implementations of the ADI approach, assisted by Lumi Education. The mean post-test scores in the both classes were higher than the previous test. The formulation results of the normalized gain (N-gain) also strengthened the increase. Details of data analysis results are presented more fully in Table 4.

Table 4. Data from Descriptive Statistical Analysis

	Experimental Classes	Control Class
n	30	30
Pre-test		
Maximum	48.15	44.44
Minimum	16.67	16.67
Mean	31.66	27.78
Standard Deviation	8.22	7.84

	Experimental Classes	Control Class
Post-test		
Maximum	98.14	72.22
Minimum	61.11	20.37
Mean	80.49	41.67
Standard Deviation	8.78	13.90
N-gain		
Maximum	0.98	0.50
Minimum	0.36	0.02
Mean	0.70	0.18
Standard Deviation	0.15	0.15

The independent-sample t-test confirmed that both groups had statistically equivalent pre-test means, t(58) = 1.68, p = .098, d = 0.28, 95% CI [–0.07, 1.01], ensuring comparable initial skills. Thus, subsequent improvements can be attributed to the applied learning intervention rather than prior differences.

Scientific Argumentation Skills Improvement

Students' scientific argumentation skills are formulated through pre-test and post-test scores obtained before and after learning. The findings of this measurement possess a difference in students' scientific argumentation skills between the initial and subsequent conditions, as illustrated in Figure 4.

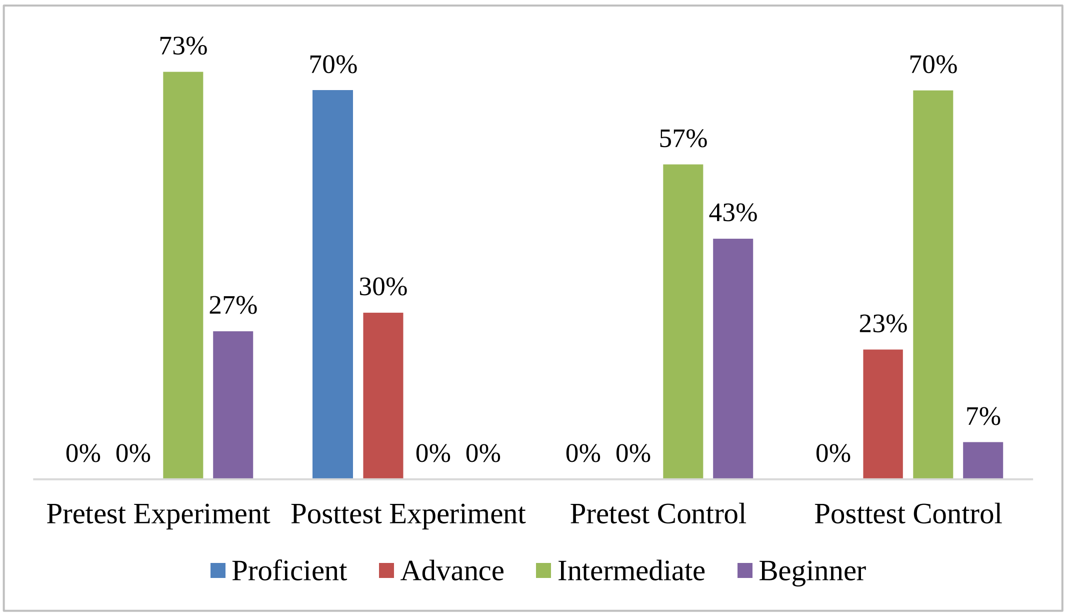

Figure 4. Students' Scientific Argumentation Skills Level

Figure 4 illustrates that most learners initially demonstrated low levels of scientific argumentation skills in both classes. After the treatment, the majority of students in the experimental class exhibited high-level scientific argumentation skills. This improvement indicates that the applied learning not only enhances outcomes but also strengthens students’ skills to construct scientific arguments. Based on the Toulmin Argument Pattern framework, prior to the intervention, many students tended to state claims without providing supporting evidence or warrant. However, after engaging in practicum activities and group discussions, students began to demonstrate more complete indicators of scientific argumentation. For example, students increasingly supported claims with appropriate evidence and warrant aligned with scientific concepts.

The results are consistent with other studies done by Erduran et al. (2004), as they show how the frameworks of students' scientific argumentations could change from the simple to complex level by utilizing a scaffolded approach and evidence-based discussions in science lessons, respectively. Direct instruction related to scientific argumentation skills enhances the interpretation of warrant indicators, especially if they are required to link findings to scientific principles, respectively (Wambsganss et al., 2022; Yang, 2022). Students in the control class mostly failed to enhance their skills, implying that conventional approaches to instruction strongly rely on rote memory rather than the development of skills related to scientific argumentation, respectively (Woods & Copur-Gencturk, 2024). The difference between the two approaches highlights how technology-based scaffolds can help reference both ideas and approaches through evidence-based discussions, respectively.

N-gain and Learning Effectiveness

It is even clearer from the average N-gain values of each class that the experimental and control groups are different, as shown in Figure 5. This proves that the ADI model works well with Lumi Education.

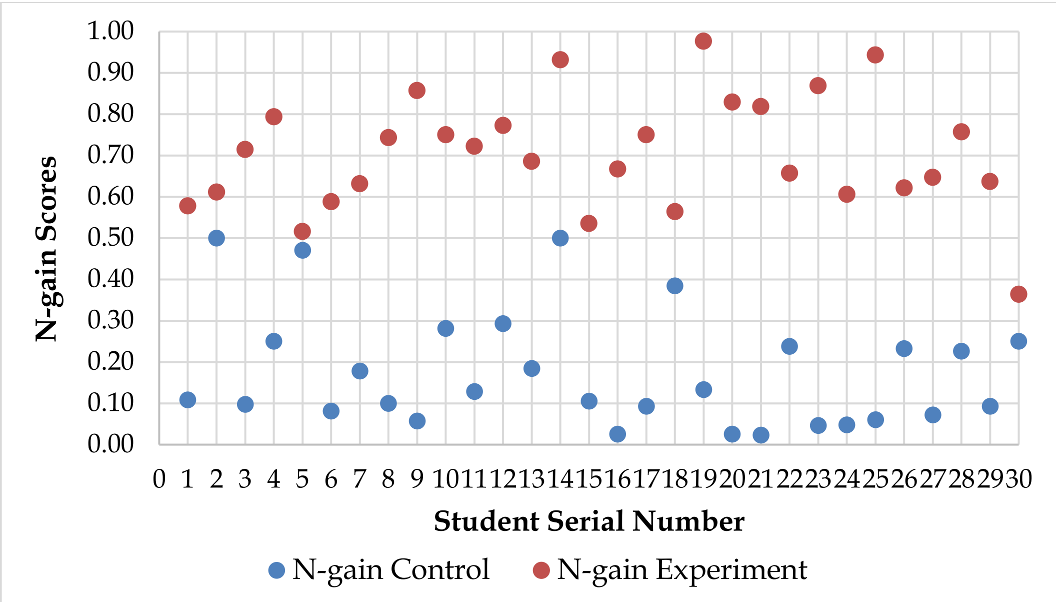

Figure 5. Comparison of N-gain Scores for Control and Experimental Classes

Figure 5 illustrates the distribution of personal N-gain values both the experimental and control groups. The Mann-Whitney U-test was employed since the data did not meet the normality assumption required for a t-test. The analysis revealed a significant difference between the two groups ($U = 4$, $Z = -6.59$, $p < 0.001$), indicating that students who learned through the ADI model integrated with the Lumi Education platform achieved better outcomes than those who received conventional instruction. Most learners in the experimental group obtained N-gain values between 0.6 and 0.9, with an average of 0.70 categorized as high, showing consistent improvement in scientific argumentation skills. In contrast, the control group mostly scored between

0.00 and 0.3, with an average N-gain of 0.18 categorized as low, suggesting that conventional learning had limited influence on students' scientific argumentation skills development.

The findings contained in Figure 5 are in accordance with the findings of previous empirical study which reported that the ADI technique, successfully improved students' scientific argumentation skills look at an average N-gain in the intermediate position, compared to the control which only reached the low category (Admoko et al., 2021; Fuadah et al., 2023; Mazita et al., 2024). Additionally, the results are supported by Coletta & Steinert (2020), who affirmed that the normalized N-gain is a reliable measure for comparing learning effectiveness. Theoretically, these findings align with constructivist learning theory, which emphasizes the importance of social interaction, scaffolding, and digital support in fostering conceptual understanding and equitable participation.

Paired Sample t-Test Results

The results of the N-gain analysis were also strengthened by the results of the paired sample t-test and effect size, as shown in Table 5.

Table 5. Paired Sample t-Test Results

Class	Test	Normality Test		Paired Sample t-Test				Effect Size	
		Sig.	Decision	df	t	Sig.	Decision	Cohen's d Score	Category
Experiment	Pre-test	0.284	Normal	29	-20.6	< 0.001	Significantly different	0.53	Medium
	Post-test	0.777	Normal						
Control	Pre-test	0.100	Normal	29	-7.05	< 0.001	Significantly different	0.12	Small
	Post-test	0.065	Normal						

The Paired Sample t-Test results indicate that both the experimental and control courses took large strides relative to their initial condition concerning arguing scientifically ($p < 0.001$), even if they were considerably different in many respects. The results are expressed as a medium effect size, measured by Cohen's d, with a value of 0.53, meaning that this improvement was both statistically and practically significant (Sawilowsky, 2009). However, a little effect was measured for the control class, represented by Cohen's d = 0.12, meaning that this improvement was limitedly enhanced. The experimental class achieved a mean difference value measured at 14.32 (95% CI [11.26, 17.38]) with a medium effect size measured by Cohen's d = 0.53, 95% CI [0.41, 0.65]. The results are both statistically and practically significant, meaning that they are useful, given that both values' confidence intervals exclude zero (Lakens, 2013). The results presented herein are further supported by their medium effect size, indicating that the learning process using the ADI model assisted by Lumi Education has a moderate to high educational impact. This suggest that the process enhances not only the quantity but also the quality of students scientific argumentation skills.

These findings corroborate the work of (Satriya & Atun 2024), which had previously established the efficacy of the ADI model in fostering scientific argumentation skills by leading students through a methodical construction of claims, evidence, and warrant. According to Rapanta (2021), conventional learning focuses on direct knowledge transmission, thus giving little opportunity for students to develop scientific argumentation skills. Bailey et al. (2020), reinforce these findings with their proof that active learning methods are superior to conventional ones in helping students attain an understanding of concepts. Taken together, these studies confirm that the approach presented significantly enhances students' scientific argumentation skills both statistically and practically when combined with structured scaffolding in ADI.

Mann-Whitney U Test Confirmation

Table 6 shows the Mann-Whitney U values for comparing the increased scientific argumentation skills abilities of control and experimental courses. The results, show a large difference between the results achieved by the experiment and control courses, proving the effectiveness of the ADI learning model, which is facilitated by Lumi Education, as it is significantly better at improving students' argumentation skills than other learning approaches. The ADI syntax approach carefully assists students to make arguments, which is why this approach is so successful.

Table 6. Mann-Whitney U Result Data

N-gain Argumentation Test	Normality		Homogeneity		Mann-Whitney			
	p	Decision	p	Decision	U	Z	p	Decision
Experiment	0.924	Yes	0.903	Yes	4	-6.59	<0.001	Significantly different
Control	0.001	No						

Interpretation and Theoretical Integration

During argument development, students learn to make claims based on the evidence they gain from experiments. This approach is beneficial in enhancing the scientific argumentation competencies of students by forcing them to link evidence with their claims (Walker & Sampson, 2013). In addition, during reflection, report writing, and peer review, students evaluate the coherence and completeness of arguments, thus enhancing their understanding and logical flow of their arguments (Sampson et al., 2013). These findings are supported by previous studies indicating that ADI significantly enhances students' scientific argumentation skills compared to conventional methods (Anazifa et al., 2024; Canoz et al., 2022; Clevenger et al., 2023). The integration of Lumi Education enhances these advantages by providing automated formative feedback, thus speeding up shifting from intuitive to evidence-based thinking. This continuous review strategy helps students locate their gaps and progress gradually (Wambsganss et al., 2022).

The H5P-based Lumi Education platform enhances both group and individual learning when incorporated into the ADI approach. Lumi helps students improve the art of argumentation in a step-by-step fashion through the ADI phases: first, by finding problems and making their first claims in phase 1; second, by helping them carry out small tasks at their own pace that help them link evidence to statements in a systematic way in phase 3; third, giving them feedback in phase 5 that encourages reviewing and improving their arguments based on what their peers and automated systems say. Interactive multiple-choice questions, drag-and-drop options, and exportable text areas enhance students' engagement and scientific argumentation skills (Widayanti, 2023; Mutawa et al., 2023). This scaffolding process aligns with Hattie and Timperley's (2007) "feed-up, feedback, and feed-forward" framework, which positions feedback as both diagnostic and developmental.

As identified by the Pattern of an Argument by Toulmin (claim-evidence-warrant) Toulmin (2003), auto-formative feedback enables students to glance at their mistakes immediately and correct their response afterwards: Such rapid feedback has been found to support self-evaluation as well as improving self-perception by students (Jacob & Centofanti, 2024). The features of H5P enable self-paced learning among students, which further encourages students to acquire control over their learning, control over their metacognition, and internalized motivation. All the aforesaid are important for building better arguments within science by students (Depany & Sukardiyono, 2023; Jacob & Centofanti, 2024; Sharmin et al., 2025).

Automated feedback in H5P plays a role similar to the notion of "black box feedback" mentioned by Hattie & Timperley (2007), This type of feedback reveals previously hidden aspects of the pupils' cognitive processes. This feedback does not only tell the instructor if something is right or wrong; it also gives a notion of how well kids understand, what they believe they know, and how they came to their judgments. It contains not only assessment functions but also diagnostic and remedial ones. It does this when it guides students through three main functions: feed up (clarifying goals and criteria), feedback (assessing existing attainment), and feed forward (directing development measures). This kind of feedback is of extreme help when it comes to scientific argumentation skills since students tend to have problems not in establishing claims but in finding the right evidence and putting it together logically (Hattie et al., 2021).

Automated feedback helps make sense of this cognitive process by assisting students in recognizing the gaps between their arguments and scientific facts, even before they are likely to be confused by them. Such interventions accelerate the shift to data-based cognition rather than intuition-based cognition (Romano et al., 2021). The greater the scaffolding, whether by teachers or technology, the better the quality of the students' scientific argumentation skills, which is measured both by its final outcome as well as by its cognitive processes involved (Hattie et al., 2021; Valero Haro, 2019)

The function of automated feedback in H5P aligns with the “black box feedback” concept proposed by (Hattie & Timperley, 2007), whereby students’ initially hidden thought processes are revealed through timely and targeted feedback. Instead of simply indicating correctness, this feedback provides diagnostic insights into students’ understanding, misconceptions, and reasoning prior to reaching conclusions. It serves not only evaluative purposes but also diagnostic and corrective roles by guiding learners through three main functions: feed up (clarifying goals and criteria), feedback (assessing current achievement), and feed forward (directing improvement steps). This type of feedback is especially relevant in scientific argumentation, where students often struggle not with formulating claims but with selecting appropriate evidence and linking it through logical warrants (Hattie et al., 2021). By making these cognitive processes visible, automated feedback helps students detect inconsistencies between their arguments and scientific principles before misconceptions are reinforced. Such interventions accelerate the shift from intuitive to data-driven scientific argumentation skills (Romano et al., 2021). When teachers and digital systems to provide more targeted scaffolding so that the quality of students’ scientific argumentation is assessed not only based on the final product but also on the underlying cognitive processes (Hattie et al., 2021; Valero Haro, 2019).

Student Response and Educational Significance

The quantitative data results in this research are further substantiated by students' replies to ADI learning, including 13 closed-ended questions and 2 open-ended questions. This response analysis was used to triangulate the quantitative data, so confirming the correlation between students' views and their evaluated performance results.

Table 7. Student Response Results to ADI Learning

No.	Statement	STS	TS	KS	S	SS
1.	I have had enough opportunities to work in groups during the learning process.	0%	0%	0%	43%	57%
2.	Learning activities such as discussions, experiments, and argument construction help me better understand the material.	0%	0%	0%	47%	53%
3.	The lab activities helped me better understand the concepts of static electricity.	0%	0%	0%	60%	40%
4.	This learning helps me improve my skills to formulate arguments logically.	0%	0%	0%	67%	33%
5.	The teacher provided clear explanations and helped me understand the learning process well.	0%	0%	3%	60%	37%
6.	Group discussions help me build strong arguments and support my understanding of concepts.	0%	0%	3%	43%	53%
7.	The learning process is interesting and motivates me to be more active in class.	0%	0%	0%	57%	43%
8.	The visualizations, images, or stimuli provided make it easier for me to understand the concepts being learned.	0%	0%	3%	63%	33%
9.	I feel comfortable expressing my opinions or asking questions during the learning process.	0%	0%	0%	70%	30%
10.	The teacher's clear and structured explanations made it easier for me to understand the material.	0%	0%	0%	57%	43%
11.	This learning model enhances my skills to analyze and explain concepts logically.	0%	0%	0%	63%	37%
12.	The way the teacher gives instructions helps me do my homework better.	0%	0%	3%	60%	37%
13.	The learning model used is quite interesting and helpful for the learning process.	0%	0%	7%	67%	27%

Note: STS= Strongly Disagree; TS= Disagree; KS= Slightly Disagree; S= Agree; SS= Strongly Agree

The response questionnaire indicates that, for most of the statements regarding the reaction to learning, the majority of the responses fall into either "agree" or "strongly agree," with very few negative comments. The instrument is reliable, as shown by its alpha value of 0.78, meaning these responses will always be a true reflection of the feelings of pupils. This Cronbach's Alpha score demonstrates that the internal consistency is excellent enough to make sure the students' responses indeed represent how interested and learning they felt. Observing the open-ended response results, two major categories are identified: good aspects and difficulties. The students expressed those activities involving practicums enhance learning as they make studying more engaging and allow an understanding of things better. They made statements like, "*It is fun to practice, so I now understand static electricity better than if I just read a book*," and "*Lumi shows me my mistakes immediately, so that I could fix them and* *learn faster*." A small number mentioned difficulties related to understanding or solving problems, as expressed by, "*Sometimes, I have trouble understanding the procedure if I'm making a virtual circuit connection*." It is obvious that the mixture between enthusiasm and small difficulties related to their ideas shows how ADI-based learning, including the use of Lumi Education, keeps learners motivated and helps teachers identify areas they should assist learners with as well.

These findings suggest that while students generally like the learning experience, specific mentoring strategies must be in place for mastery of concepts and enhancement of problem-solving skills. This also supports Sun et al. (2023), who noted that for active learning models to be effective, activities must be well-structured, and teacher scaffolding should be available to assure high-level cognitive engagement. The results qualitatively confirm the previously demonstrated quantitative gains, relating students' perceived engagement with the evaluated gain in scientific argumentation skills. The positive responses among the openly engaged students in the experimental class are an indication, not only of satisfaction but even greater drive to learn. The actual work undertaken, as well as class discussions, promoted meaningful encounters leading to active involvement, hence increasing the students' enthusiasm (Acosta-Gonzaga & Ramirez-Arellano, 2022; Yu et al., 2024). This motivational increase represents the affective dimension of learning gain, an indicator of educational significance that complements cognitive outcomes.

This increase in motivation aligns with the basic tenets of self-determination theory, which states that autonomy, social relatedness, and intrinsic competitiveness are basic drivers of internal motivation (Ryan & Deci, 2017). From this theoretical perspective, Lumi-based ADI promotes the three intrinsic drives: (1) autonomy through self-directed digital activities; (2) competence through constant formative feedback; and (3) relatedness through collaboration and peer engagement.

Mechanistic Link Between ADI Phases, Lumi Integration, and Argumentational Skills

Mechanistically, each phase of the ADI cycle contributed to the development of students' argumentation skills. The inquiry, data collection, argumentation, and peer-review stages of the ADI cycle refined the students to connect evidence with their arguments, and the argumentation, peer-review, and feedback components facilitated critical assessment of scientific argumentation skills among the students (Stell & Iwashita, 2024; Su et al., 2023; Zabolotna et al., 2023). Lumi Education enhanced these phases by interactive tools such as drag-and-drop activities and exportable text areas, which supported learners in visualizing their scientific argumentation structured and provided formative feedback throughout the process.

These results are supported by results from (Zheng et al., 2023), who proved that the whiteboard-based scaffolding approach and regulation patterns among group study participants improved their written argumentation skills in science, as well as their regulation patterns among group study participants, as they improved their written argumentation skills in science. The findings of the study, which employed the ADI approach alone, revealed that selecting a convincing argument was the easiest skill for students, whereas writing an argument or constructing a counter-argument posed greater difficulty (Evagorou et al., 2023). This demonstrates that Lumi's role extends beyond delivering content but also operationalizes the feedback cycle turning reflection into an integral part of knowledge construction.

Limitation and Future Implications

The type of research design adopted for this study is a Non-equivalent Control Group (NECG) design, and as a result, the findings related to causality should be interpreted carefully. Additionally, the fact that the same lecturer was involved in both courses may have resulted in little variations in instruction, which may have influenced this study's findings, a component known as the "teacher instruction effect." The "novelty effect" may likewise have played a crucial role, as the students may have been excited for a while by the prospect of using the Lumi Education system, and differences in how markers graded may have resulted in variability, influencing how well the findings related to accuracy. Despite all this, this study is much more reliable as a mixed-methods approach is involved, which takes both quantitative and qualitative pieces, including findings, into account. In future studies, a multi-site approach should be incorporated, investigating the long-term impacts that this approach may or may not have upon scientific argumentation skills development, as a result improving clarity related to the lifelong implications this may have in education.

CONCLUSION

The integration of Lumi Education into the ADI approach functions as a technological scaffold which corresponds to the process of identification, argument formation, and reflection. Results from this study among the participants disclosed a marked improvement in the scientific argumentation skills of the students, as reflected by a strong learning gain (N-gain = 0.70), a medium effect size ($d = 0.53$), and a large difference between the groups ($r = 0.50$, $p < 0.001$).

Through features such as multiple choice, single choice, drag-and-drop, fill in the blank and exportable text areas that include formative feedback, students are trained to evaluate and improve claim, evidence and warrant independently before entering group discussions.

Pedagogically, this approach provides a practical foundation for teachers to incorporate individual scientific argumentation exercises into the ADI syntax, while supporting inquiry-based learning policies that integrate digital scaffolding to strengthen scientific argumentation skills.

RECOMMENDATION

This research has several limitations that need to be considered. First, the number of participants is relatively small and comes from only two classes in one school, so the findings cannot yet be generalized to differentiate educational contexts. Second, the duration of interference lasts for a limited time, so that the dynamics of student development during implementation have not been observed more widely. Third, the learning process is still highly dependent on teachers as facilitators, so differences in teaching styles or mentoring intensity can affect the results obtained.

To reinforce the findings, further research is suggested involving a larger number of participants and coming from diverse characteristics. Comparison design can also be applied, such as comparing Lumi Education media with other digital media platforms, to see its relative advantages. In addition, studies of longer duration can be conducted to observe changes in scientific argumentation skills and student engagement on an ongoing basis.

Acknowledgment
The author sincerely appreciates the support and cooperation of all participants, teachers, and school staff who contributed to the completion of this study. Their involvement was invaluable in guaranteeing the effective execution of this study. The authors utilized OpenAI's ChatGPT to help revise and polish the phrasing in the introduction section. All generated outputs were carefully checked and approved by the authors.

Funding
No dedicated financial support or grant was obtained for this research for this educational research from any private institution, public organization, or nonprofit corporation.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
P. A. Salsabila	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
A. F. Hendratmoko				✓				✓	✓	✓	✓	✓		
F. D. Roqobih		✓		✓			✓			✓	✓	✓		

Conflict of interests
For this research, the authors confirm there are no possible conflicts of interest.

REFERENCES

Acosta-Gonzaga, E., & Ramirez-Arellano, A. (2022). Scaffolding Matters? Investigating Its Role in Motivation, Engagement and Learning Achievements in Higher Education. *Sustainability (Switzerland)*, *14*(20), 1–17. https://doi.org/10.3390/su142013419

Admoko, S., Hanifah, N., Suprapto, N., Hariyono, E., & Madlazim, M. (2021). The implementation of Argument Driven Inquiry (ADI) learning model to improve scientific argumentation skills of high school students. *Journal of Physics: Conference Series*, *1747*(1), 1–6. https://doi.org/10.1088/1742-6596/1747/1/012046

Aldahmash, A. H., & Omar, S. H. (2021). Analysis of activities included in Saudi Arabian chemistry textbooks for the inclusion of argumentation-driven inquiry skills. *Studies in Educational Evaluation*, *68*(July 2020), 1–7. https://doi.org/10.1016/j.stueduc.2020.100968

Alfarraj, Y. F., Aldahmash, A. H., & Omar, S. H. (2023). Teachers' perspectives on teaching science through an argumentation-driven inquiry model: A mixed-methods study. *Heliyon*, *9*(9), 1–12. https://doi.org/10.1016/j.heliyon.2023.e19739

Anazifa, R. D., Paidi, P., Pratama, A. T., & Kurniawati, A. (2024). Development of argument-driven inquiry model with blended learning approach in environmental science course. *Research and Development in Education (RaDEn)*, *4*(2), 1460–1472. https://doi.org/10.22219/raden.v4i2.35874

Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. *Teaching and Teacher*

Education, *121*(August), 1–12. https://doi.org/10.1016/j.tate.2022.103905
Bailey, R. L., Kiesel, V. A., Lobene, A. J., & Zou, P. (2020). Redesigning an Undergraduate Nutrition Course through Active Learning and Team-Based Projects Enhances Student Performance. *Current Developments in Nutrition*, *4*(4), 1–5. https://doi.org/10.1093/CDN/NZAA039
Canoz, G. M., Ucar, S., & Demircioglu, T. (2022). Investigate the effect of argumentation-promoted interactive simulation applications on students' argumentation levels, academic achievements, and entrepreneurship skills in science classes. *Thinking Skills and Creativity*, *45*(March), 1–11. https://doi.org/10.1016/j.tsc.2022.101106
Clevenger, L., Teshera-Levye, J., Walker, J. P., & Vance-Chalcraft, H. D. (2023). Using an Observation Protocol To Evaluate Student Argumentation Skills in Introductory Biology Laboratories. *Journal of Microbiology & Biology Education*, *24*(2), 1–8. https://doi.org/10.1128/jmbe.00209-22
Coletta, V. P., & Steinert, J. J. (2020). Why normalized gain should continue to be used in analyzing preinstruction and postinstruction scores on concept inventories. *Physical Review Physics Education Research*, *16*(1), 1–7. https://doi.org/10.1103/PhysRevPhysEducRes.16.010108
Creswell, J. W., & Creswell, J. D. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. In H. Salmon (Ed.), *Writing Center Talk over Time: A Mixed-Method Study* (5th ed.). SAGE Publications, Inc. https://doi.org/10.4324/9780429469237
Depany, P. D., & Sukardiyono, S. (2023). Penerapan Media Pembelajaran Fisika Lumi Education Untuk Meningkatkan Kemampuan Berpikir Kritis Dan Komunikasi. *Jurnal Pendidikan Fisika*, *10*(1), 60–71. https://doi.org/10.21831/jpf.v10i1.19458
Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education*, *88*(6), 915–933. https://doi.org/10.1002/sce.20012
Evagorou, M., Papanastasiou, E., & Vrikki, M. (2023). What do we really know about students' written arguments? Evaluating written argumentation skills. *European Journal of Science and Mathematics Education*, *11*(4), 615–634. https://doi.org/10.30935/scimath/13284
Fajardo, M. B., & Apellido, E. D. (2025). Development and Evaluation of Interactive Self- learning Materials (iSLeM) Using Lumi Application : Enhancing Student Engagement and Learning Outcomes in Computer System Servicing. *International Journal of Multidisciplinary Educational Research and Innovation*, *03*(02), 171–198. https://philpapers.org/rec/FAJDAE
Fuadah, M. I., Mubarok, H., & Suliyanah, S. (2023). The Effect of Argument Driven Inquiry (ADI) Model on the Scientific Argumentation Ability of High School Students on the Topic of Light Waves. *International Journal of Research and Community Empowerment*, *1*(2), 53–61. https://doi.org/10.58706/ijorce.v1n2.p53-61

Grooms, J., Enderle, P., & Sampson, V. (2015). Coordinating Scientific Argumentation and the Next Generation Science Standards through Argument Driven Inquiry What Is Scientific Argumentation and Why Is It important in Science? *Science Educator*, *24*(1), 45–50.

Hake, R. R. (2002). Relationship of individual student normalized learning gains in mechanics with gender, high-school physics, and pretest scores on Mathematics and Spatial Visualization. *Physics Education Research Conference*, *8*(August 2002), 1–14. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=10EI2q8AAAAJ&citation_for_view=10EI2q8AAAAJ:IjCSPb-OGe4C

Hasanah, F., Putra, P. D. A., & Rusdianto. (2022). Identifikasi Kemampuan Siswa SMP dalam Berargumentasi Melalui Pendekatan Pembelajaran Science, Technology, Engineering, and Mathematics (STEM). *Jurnal Literasi Pendidikan Fisika (JLPF)*, *3*(1), 1–9. https://doi.org/10.30872/jlpf.v3i1.974

Hattie, J., Crivelli, J., Van Gompel, K., West-Smith, P., & Wike, K. (2021). Feedback That Leads to Improvement in Student Essays: Testing the Hypothesis that "Where to Next" Feedback is Most Powerful. *Frontiers in Education*, *6*(May), 1–9. https://doi.org/10.3389/feduc.2021.645758

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Hendratmoko, A. F., Madlazim, M., Widodo, W., & Astutik, S. (2024). Debate Based on Inquiry Learning (DBOIL): An Innovative Learning Model to Improve Student's Skills Scientific Argumentation. *Debate Based on Inquiry Learning (DBOIL): An Innovative Learning Model to Improve Students' Skills in Scientific Argumentation*, *13*(4), 3295–3303. doi: 10.18421/TEM134-64

Hendratmoko, A. F., Madlazim, M., Widodo, W., Suyono, S., & Supardi, Z. A. I. (2024). Inquiry and Debate in Science Learning : Potential Strategy for Improving Students ' Scientific Argumentation Skills To cite this article : argumentation skills . International Journal of Education in Mathematics , Science , and Inquiry and Debate in Scie. *International Journal of Education in Mathematics, Science and Technology 2024, 12*(1), 114–138. https://doi.org/10.46328/ijemst.3152

Jacob, T., & Centofanti, S. (2024). Effectiveness of H5P in improving student learning outcomes in an online tertiary education setting. *Journal of Computing in Higher Education*, *36*(2), 469–485. https://doi.org/10.1007/s12528-023-09361-6

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*(NOV), 1–12. https://doi.org/10.3389/fpsyg.2013.00863

Lobczowski, N. G., Allen, E. M., Firetto, C. M., Greene, J. A., & Murphy, P. K. (2020). An exploration of social regulation of learning during scientific argumentation discourse. *Contemporary Educational Psychology*, *63*(10), 1–17. https://doi.org/10.1016/j.cedpsych.2020.101925

Matana, M. D. S., Maryati, S., & Koem, S. (2024). Development of Lumi Education Learning Media Based on H5P for Atmospheric Dynamics Subject at Senior High

School 1 Gorontalo Mohamat. *Jurnal Pendidikan Geografi*, *11*(1), 85–96. https://doi.org/10.20527/jpg.v10i2.16278

Mazita, A., Siswanto Siswanto, Suwito Singgih, Nuryunita Dewantari, & Djoko Sri Bimo. (2024). Implementation of Argument Driven Inquiry Instructional Model to Improve Cognitive Learning Outcomes. *Indonesian Journal of Science and Education*, *8*(1), 57–64. https://doi.org/10.31002/ijose.v8i1.1446

Muhaba, E. S., Geneti, S. A., Melka, D., & Mohammed Abdu, S. (2025). Prevalence, patterns and determinants of peripheral neuropathy among leprosy patients in Northeast Ethiopia: A retrospective study. *PLoS Neglected Tropical Diseases*, *19*(3), e0012944. https://doi.org/10.1371/journal.pntd.0012944

Mutawa, A. M., Al Muttawa, J. A. K., & Sruthi, S. (2023). The Effectiveness of Using H5P for Undergraduate Students in the Asynchronous Distance Learning Environment. *Applied Sciences (Switzerland)*, *13*(8), 1–15. https://doi.org/10.3390/app13084983

Nazidah, F., Kafii, M. S., & Admoko, S. (2022). Analisis Bibliometrik Penelitian Argumentasi Ilmiah dalam Pembelajaran Sains di Era Revolusi Industri 4.0 Society 5.0. *Jurnal Ilmu Pendidikan Dan Pembelajaran*, *1*(1), 7–14. https://doi.org/10.58706/jipp.v1n1.p7-14

Papadakis Zourmpakis, A.-I., Kasotaki, S., & Kalogiannakis, M., S. (2024). Teachers' perspectives on integrating adaptive gamification applications into science teaching. *Journal of Electrical Systems, 20(11s), 2593–2600.*

Putri, R. A., & Admoko, S. (2022). Development of Student Worksheets Based on Argument-Driven Inquiry Learning Model to Improve Students' Critical Thinking Skills. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *10*(3), 510–521. https://doi.org/10.33394/j-ps.v10i3.5277

Rapanta, C. (2021). Can teachers implement a student-centered dialogical argumentation method across the curriculum? *Teaching and Teacher Education*, *105*(105), 1–14. https://doi.org/10.1016/j.tate.2021.103404

Romano, L. G., Occelli, M., & Adúriz-Bravo, A. (2021). School Scientific Argumentation Enriched by Digital Technologies: Results With Preand in-Service Science Teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(7), 1–16. https://doi.org/10.29333/ejmste/10990

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Press. https://www.guilford.com/books/Self-Determination-Theory/Ryan-Deci/9781462538966

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2013). Writing to learn by learning to write during the school science laboratory: Helping middle and high school students develop argumentative writing skills as they learn core ideas. *Science Education*, *97*(5), 643–670. https://doi.org/10.1002/sce.21069

Santri, A., Asiyah, A., & Kusumah, R. G. T. (2023). *Analisis keterampilan argumentasi peserta didik dengan pendekatan socioscientific issues (SSI) pada mata pelajaran IPA di SMPN 01 Pajar Bulan Kabupaten Seluma* [UIN Fatmawati Sukarno Bengkulu].

http://repository.uinfasbengkulu.ac.id/id/eprint/905
Sawilowsky, S. S. (2009). Very large and huge effect sizes. *Journal of Modern Applied Statistical Methods*, *8*(2), 597–599. https://doi.org/10.22237/jmasm/1257035100
Sharmin, N., Houshyar, S., Stevenson, T. R., & Chow, A. K. (2025). Interactive Engagement with Self-Paced Learning Content in a Didactic Course. *Healthcare Informatics Research*, *31*(1), 96–106. https://doi.org/10.4258/hir.2025.31.1.96
Stell, A., & Iwashita, N. (2024). Enhancing collaboration: Exploring regulated learning strategies in the co-regulatory processes of collaborative L2 writing. *System*, *125*(103410), 1–16. https://doi.org/10.1016/j.system.2024.103410
Su, Y., Liang, J. C., Zheng, C., & Tsai, C. C. (2023). Co-regulation strategies and their associations with writing self-efficacy in a computer-mediated collaborative writing setting. *Journal of Second Language Writing*, *59*(10), 1–15. https://doi.org/10.1016/j.jslw.2023.100972
Sugiyono. (2024). *Metode Penelitian Kuantitatif Kualitatif dan R&D* (6th ed.). ALFABETA.
Sun, L., Kangas, M., Ruokamo, H., & Siklander, S. (2023). A systematic literature review of teacher scaffolding in game-based learning in primary education. *Educational Research Review*, *40*(100546), 1–21. https://doi.org/10.1016/j.edurev.2023.100546
Telenius, M., Yli-Panula, E., Vesterinen, V. M., & Vauras, M. (2020). Argumentation within upper secondary school student groups during virtual science learning: Quality and quantity of spoken argumentation. *Education Sciences*, *10*(12), 1–19. https://doi.org/10.3390/educsci10120393
Toulmin, S. E. (2003). The uses of argument: Updated edition. In *The Uses of Argument: Updated Edition*. https://doi.org/10.1017/CBO9780511840005
Valero Haro, A. (2019). First- and second-order scaffolding of argumentation of computer-supported collaborative argumentation. *Studies in Educational Evaluation*, *61*, 148–157. https://doi.org/10.1080/1475939X.2019.1612772
Walker, J. P., & Sampson, V. (2013). Learning to argue and arguing to learn: Argument-driven inquiry as a way to help undergraduate chemistry students learn how to construct arguments and engage in argumentation during a laboratory course. *Journal of Research in Science Teaching*, *50*(5), 561–596. https://doi.org/10.1002/tea.21082
Wambsganss, T., Janson, A., & Leimeister, J. M. (2022). Enhancing argumentative writing with automated feedback and social comparison nudging. *Computers and Education*, *191*(August), 1–17. https://doi.org/10.1016/j.compedu.2022.104644
Widayanti, Y. (2023). Penerapan Video Interaktif Berbasis "Lumi Education" untuk Meningkatkan Minat Belajar Kimia Peserta Didik. *Proceedings Series of Educational Studies National Conference from Magister of Education Management*, 133–136.
Woods, P. J., & Copur-Gencturk, Y. (2024). Examining the role of student-centered versus teacher-centered pedagogical approaches to self-directed learning through teaching. *Teaching and Teacher Education*, *138*(2), 1–34. https://doi.org/10.1016/j.tate.2023.104415

Yang, R. (2022). An empirical study on the scaffolding Chinese university students' English argumentative writing based on toulmin model. *Heliyon*, *8*(12), 1–11. https://doi.org/10.1016/j.heliyon.2022.e12199

Yu, J., Kim, H., Zheng, X., Li, Z., & Xiangxiang, Z. (2024). Effects of scaffolding and inner speech on learning motivation, flexible thinking and academic achievement in the technology-enhanced learning environment. *Learning and Motivation*, *86*(101982), 1–19. https://doi.org/10.1016/j.lmot.2024.101982

Yuan Samsudin, S., Abdullah, B., Farizan, N. H., Hassan, M. Z., & Cheng, J., W. (2024). The Review of Gamification Learning Methods on PE Teaching in Primary School through Adaptive Perspective. *Journal of Ecohumanism*, *3*(6), 1–14.

Yulia, Z. N. M. L., Triwahyudianto, T., Kumala, F. N., & Aiman, W. M. (2025). Interactive media based on project-based learning using Lumi Education for IPAS subjects in 4th-grade elementary school. *Journal of Environment and Sustainability Education*, *3*(1), 11–20. https://doi.org/10.62672/joease.v3i1.40

Zabolotna, K., Malmberg, J., & Järvenoja, H. (2023). Examining the interplay of knowledge construction and group-level regulation in a computer-supported collaborative learning physics task. *Computers in Human Behavior*, *138*(August 2022), 1–17. https://doi.org/10.1016/j.chb.2022.107494

Zairina, S., & Hidayati, S. N. (2022). Analisis Keterampilan Argumentasi Siswa SMP Berbantuan Socio-Scientific Issue Pemanasan Global. *PENSA E-Jurnal : Pendidikan Sains*, *10*(1), 37–43. https://ejournal.unesa.ac.id/index.php/pensa

Zheng, X. L., Huang, J., Xia, X. H., Hwang, G. J., Tu, Y. F., Huang, Y. P., & Wang, F. (2023). Effects of online whiteboard-based collaborative argumentation scaffolds on group-level cognitive regulations, written argument skills and regulation patterns. *Computers and Education*, *207*(August), 1–21. https://doi.org/10.1016/j.compedu.2023.104920

Zourmpakis Kalogiannakis, M., & Papadakis, S., A. I. (2024). The Effects of Adaptive Gamification in Science Learning: A Comparison Between Traditional Inquiry-Based Learning and Gender Differences. *Computers, 13(12), 324.*