Jurnal Studi Guru dan Pembelajaran, Vol. 8, No. 3, September - December 2025

The Effect of Argument-Driven Inquiry on Students' Scientific Reasoning and Argumentation Skills

Ielda Paramita [1*], Nurul Kami Sani [2], Syamsuriwal [3], Rudi Santoso [4], Indo Tang [5]

[1, 2, 3, 4] Universitas Tadulako, Indonesia

[5] SMA Negeri 4 Palu, Indonesia

* ieldaparamita@gmail.com

Abstract

Developing students' scientific reasoning and argumentation skills is essential for achieving meaningful learning in physics, as these competencies are fundamental to scientific literacy and higher-order thinking. Nevertheless, physics instruction in many secondary classrooms still prioritizes procedural problem solving, providing limited opportunities for students to engage in reasoning and scientific discourse. This condition highlights the urgent need for instructional models that explicitly integrate inquiry and argumentation into learning. This study examined the effect of the Argument-Driven Inquiry (ADI) model on students' scientific reasoning and argumentation skills using a mixed-method quasi-experimental design with a non-equivalent pretest–posttest control group. The participants were 72 eleventh-grade science students from a public senior high school in Central Sulawesi, Indonesia, divided into an experimental (ADI) and a control (conventional instruction) group. Data were collected using validated reasoning and argumentation instruments and analyzed through normalized gain, ANCOVA, and discourse analysis. The results showed that students in the ADI group achieved higher improvements in scientific reasoning (N-gain = 0.66, high) and argumentation quality (N-gain = 0.72, high) than those in the control group. Discourse analysis further revealed more frequent construction of claims, use of evidence, and rebuttals among ADI students, indicating deeper epistemic engagement. In conclusion, this study provides novel empirical evidence that ADI effectively strengthens reasoning-based physics learning by simultaneously enhancing students' scientific reasoning and argumentation, offering a robust pedagogical contribution for fostering higher-order thinking in secondary science education.

Keywords: *Argument-Driven Inquiry, Scientific Reasoning, Argumentation Skills*

Introduction

Developing students' scientific reasoning and argumentation skills is a central goal of contemporary science education, as both competencies are fundamental to scientific literacy and critical thinking (Inthaud et al.,2019; Sani et al., 2024). In physics learning, meaningful understanding requires more than memorizing formulas or performing procedural calculations. Students must be able to reason scientifically, interpret empirical evidence, and construct coherent explanations grounded in data (Shofiyah et al., 2020). Scientific reasoning and scientific argumentation, although closely related, represent distinct cognitive processes. Scientific reasoning refers to students' ability to generate hypotheses, apply logical inference, analyze relationships among variables, and draw evidence-based conclusions. In contrast, scientific argumentation focuses on the ability to formulate claims, support them with evidence, justify reasoning, and evaluate alternative explanations within a structured discourse (Arini, 2020; Shofiyah et al., 2020).

https://doi.org/10.30605/jsgp.8.3.2025.7342

Together, these higher-order skills form the foundation of authentic scientific inquiry and prepare students to engage in evidence-based decision-making in everyday life (Faize et al., 2018; Kamaluddin et al. 2023). Despite their importance, physics instruction in many Indonesian classrooms remains predominantly teacher-centered. Learning activities often emphasize explanation and verification-oriented laboratory work, with limited opportunities for students to articulate reasoning or engage in scientific discourse. As a result, students frequently participate passively in experiments without critically reflecting on data or evaluating conclusions. This instructional pattern contributes to fragmented conceptual understanding and restricts students' ability to transfer physics concepts to real-world contexts (Faize et al. 2018).

Consequently, instructional approaches that explicitly integrate reasoning and argumentation into classroom activities are needed to improve learning effectiveness. One instructional approach that has gained attention in science education is the Argument-Driven Inquiry (ADI) model. ADI encourages students to engage in collaborative investigations, construct claims, justify them with evidence, and participate in structured argumentation sessions. Previous studies have reported that ADI improves conceptual understanding, critical thinking, and student engagement in classroom discourse (Amelia et al., 2021; Kuki et al., 2023). By providing opportunities for peer negotiation and evaluation of evidence, ADI aligns closely with the goals of scientific literacy.

Studies conducted in Southeast Asian contexts further suggest that ADI supports active learning and student autonomy, which are essential competencies for 21st-century learnin (Antonio & Prudente, 2021; Melta et al. 2024). However, existing literature also reports inconsistencies in the impact of ADI on different learning outcomes. Several studies indicate that while ADI effectively supports claim and evidence construction, students' reasoning quality often remains at a moderate level. Difficulties commonly arise in interpreting data and linking empirical findings to theoretical explanations (Satriya & Atun, 2024; Suliyanah et al., 2020). These findings suggest that although ADI promotes argumentation practices, it does not automatically guarantee deep scientific reasoning unless cognitive scaffolding is carefully designed.

Moreover, many previous studies were conducted across multiple schools or large, heterogeneous samples, which may obscure context-specific classroom dynamics (Baharsyah & Admoko, 2020; Nurhidayati et al., 2023; Nurjannah et al., 2025). Based on these considerations, a gap remains in understanding how the ADI model specifically influences the development of scientific reasoning and argumentation in authentic physics classrooms. While prior research has established the general effectiveness of ADI, limited studies have isolated its impact on these two constructs using rigorous quantitative indicators, such as normalized gain and covariance analysis.

In addition, few studies have examined how students' classroom discourse evolves during ADI implementation, particularly in relation to their reasoning strategies and epistemic engagement. Therefore, this study aims to examine the effect of the Argument-Driven Inquiry (ADI) model on students' scientific reasoning and argumentation skills in physics learning. The research was conducted in one public senior high school in Central Sulawesi, Indonesia, involving Grade XI students using a mixed-method quasi-experimental design. Specifically, this study addresses two research questions:

1. How does the ADI model affect students' improvement in scientific reasoning compared to conventional instruction?
2. How does the ADI model influence the quality and structure of students' scientific argumentation in physics learning?

The novelty of this study lies in its focused, single-school investigation that combines quantitative and qualitative analyses to capture both learning gains and the depth of students' reasoning processes. Beyond methodological contributions, this research demonstrates how the ADI framework can be effectively implemented in resource-limited classroom settings. The findings are expected to inform teachers, curriculum developers, and policymakers about the potential of ADI to strengthen students' higher-order thinking, communication skills, and epistemic engagement in secondary physics education.

Method

This study employed a mixed-method, quasi-experimental design with a non-equivalent control group pretest–posttest structure, using a convergent mixed-method approach. Quantitative data were collected to examine the effect of the Argument-Driven Inquiry (ADI) model on students' scientific reasoning and argumentation skills, while qualitative data were used to explore students' discourse and epistemic engagement during learning. The integration of these two data sources allowed a comprehensive interpretation of both learning outcomes and reasoning processes.

The study was conducted at a public senior high school in Central Sulawesi, Indonesia, involving 72 Grade XI science-track students (aged 16–17 years). Two intact classes were purposively selected and assigned as the experimental group (ADI instruction) and the control group (conventional instruction). Random assignment at the individual level was not feasible due to administrative constraints; therefore, the study adopted a quasi-experimental design. To ensure equivalence of initial ability, pretest scores of scientific reasoning and argumentation were compared between groups, showing no statistically significant differences ($p > 0.05$). Both groups were taught by the same physics teacher and studied the same topic Heat and Temperature over four consecutive weeks to minimize instructional and content-related bias.

The instructional difference lay in the learning model applied. The experimental group was taught using the ADI model, which emphasizes inquiry, evidence-based reasoning, and structured argumentation. The ADI implementation followed seven phases: (1) task identification, (2) investigation design, (3) data collection, (4) tentative argument construction, (5) argumentation session, (6) explicit and reflective discussion, and (7) report writing. In contrast, the control group received conventional teacher-centered instruction involving explanation, demonstration, and verification-based experiments without structured argumentation activities.

Data were collected using two main instruments. The Scientific Reasoning Test consisted of 20 multiple-choice items adapted from established instruments assessing formal reasoning abilities, including proportional reasoning, control of variables, and correlational reasoning. An example item required students to determine how changes in mass and temperature affect heat transfer outcomes. The instrument was validated through expert review and pilot testing, yielding acceptable reliability (Cronbach's $\alpha = 0.78$). The Scientific Argumentation Quality Test comprised open-ended questions prompting students to explain heat-related phenomena using scientific reasoning. For example, students were asked to justify why two objects with different masses but the same temperature may transfer different amounts of heat. Students' responses were analyzed using Toulmin's Argumentation Pattern (TAP), focusing on claims, supporting evidence, and rebuttals. Argument quality was categorized into five levels, from simple claims (Level 1) to well-structured arguments with coherent reasoning and valid rebuttals (Level 5). Two trained raters independently scored the responses, and strong inter-rater reliability was achieved (Cohen's $\kappa = 0.82$).

In addition to written assessments, qualitative data were collected from classroom discussions during ADI sessions. Group discussions were audio-recorded, transcribed, and analyzed using thematic discourse analysis based on the TAP framework. This analysis focused on students' use of evidence, reasoning coherence, and responsiveness to counterarguments, providing insight into their epistemic engagement during learning. Quantitative data analysis included the calculation of normalized gain (N-gain) scores to measure learning improvement from pretest to posttest. ANCOVA was then conducted on posttest scores using pretest scores as covariates to control for initial differences between groups. Qualitative findings from discourse analysis were used to complement and explain the quantitative results. The triangulation of quantitative and qualitative data enhanced the validity of the conclusions and provided a nuanced understanding of how the ADI model influences both the process and outcomes of physics learning.

Results

The data were collected from 72 students of a public senior high school in Central Sulawesi, Indonesia. The participants consisted of two intact classes selected from four available Grade XI science classes. One class (n = 36) was assigned as the experimental class and taught using the Argument-Driven Inquiry (ADI) model, while the other class (n = 36) served as the control class and received conventional instruction. The learning activities were conducted over four consecutive weeks. Students' scientific reasoning ability was measured using a validated Scientific Reasoning Assessment administered before and after the intervention. Table 1 presents the mean scores, standard deviations, and normalized gain (N-gain) values for both classes.

Table 1. *Students' Scientific Reasoning Pre-test, Post-test, and N-Gain Scores*

Group	N	Pre-test Mean	Post-test Mean	N-gain	Category
Experimental	36	54.72	81.36	0.68	High
Control	36	55.11	70.28	0.45	Medium

The results indicate that both groups experienced improvement in scientific reasoning after instruction. However, the experimental class achieved a higher post-test mean score and N-gain value, categorized as high according to Hake's (1998) criteria, while the control class showed a medium level of improvement. Students' argumentation quality was assessed using a Toulmin's Argumentation Pattern (TAP)-based rubric focusing on claim construction, evidence use, and reasoning. Descriptive statistics of argumentation performance are presented in Table 2.

Table 2. *Students' Argumentation Quality Pre-test, Post-test, and N-Gain Scores*

Group	N	Pre-test Mean	Post-test Mean	N-gain	Category
Experimental	36	2.87	4.10	0.72	High
Control	36	2.84	3.52	0.55	Medium

The data show that students in the experimental class demonstrated greater improvement in argumentation quality than those in the control class, reaching a high level of gain, whereas the control class attained a medium level. To examine whether these differences were statistically significant after controlling for initial ability, an Analysis of Covariance (ANCOVA) was conducted. The results revealed significant differences between the two groups in both scientific reasoning and argumentation quality. For scientific reasoning, ANCOVA yielded $F = 19.84$, $p < 0.001$, with a large effect size ($\eta^2 = 0.22$). Similarly, for argumentation quality, the analysis produced $F = 24.16$, $p < 0.001$, with a large effect size ($\eta^2 = 0.26$).

These findings indicate that the ADI model had a strong and significant impact on enhancing students' reasoning and argumentation skills compared to conventional instruction. Students' post-test argumentation performance was further analyzed using the TAP rubric, which classifies argumentation into five levels: Level 1 (Limited), Level 2 (Basic), Level 3 (Developing), Level 4 (Proficient), and Level 5 (Advanced). Figure 1 presents a bar chart illustrating the distribution of students across argumentation levels in both groups.

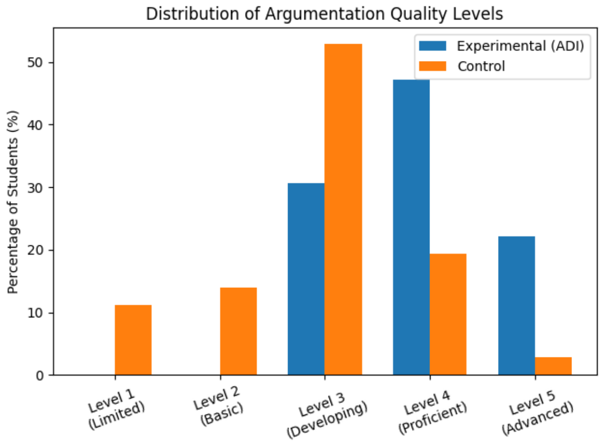

Figure 1. *Distribution of students' argumentation quality levels in the experimental (ADI) and control classes based on the Toulmin's Argumentation Pattern (TAP) rubric.*

As illustrated in Figure 1, students in the ADI class were more likely to reach higher argumentation levels (Levels 4–5), whereas control group students were predominantly concentrated at the Developing level (Level 3). The distribution shows clear differences between the experimental and control classes. In the experimental class, 47.2% of students reached the Proficient level (Level 4), and 22.2% attained the Advanced level (Level 5). Students at these levels were able to construct coherent, evidence-based claims and include rebuttals, reflecting mature scientific argumentation practices. In contrast, most students in the control class remained at the Developing level (Level 3; 52.8%), with only 19.4% reaching Level 4 and 2.8% achieving Level 5. A notable proportion of control students stayed at the Basic and Limited levels, indicating arguments dominated by unsupported claims and minimal reasoning.

From a pedagogical perspective, achievement at Levels 4–5 signifies students' ability to engage in authentic scientific practices, including evaluating evidence, justifying claims logically, and responding to alternative explanations. The higher proportion of students reaching these levels in the ADI class suggests that structured inquiry and argumentation activities effectively support the development of higher-order reasoning and scientific communication skills. Overall, the results consistently show that the ADI model led to higher learning gains, stronger argumentation structures, and more advanced levels of scientific reasoning than conventional instruction. These quantitative and categorical findings provide robust evidence of the effectiveness of ADI prior to further theoretical interpretation in the discussion section.

Discussion

The present study demonstrates that integrating the Argument-Driven Inquiry (ADI) model into physics instruction significantly enhances students' scientific reasoning and argumentation skills within a single high school context. Post-test results indicate substantial improvement, suggesting that students engaged more meaningfully in the scientific process—from formulating questions and designing investigations to analyzing data and constructing evidence-based arguments. These findings support the assertion that ADI provides an authentic learning environment that promotes not only conceptual understanding but also scientific communication through structured argumentation (Suganda et al., 2023).

Consistent with prior research the findings suggest that coupling inquiry with argumentation fosters higher-order cognitive engagement (Antonio & Prudente, 2021; Melta et al. 2024; Nurjannah et al. 2025). At the same time, it is important to acknowledge that this study was conducted in a single-school setting, which may limit the generalizability of the findings. However, this context-specific design offers valuable insight into how classroom dynamics, teacher facilitation, and students' prior inquiry experiences mediate the effectiveness of ADI in real instructional settings. Such insights are particularly relevant for adapting ADI to local conditions while maintaining its theoretical foundations.

The findings also corroborate theoretical expectations that reasoning and argumentation develop interactively when learners are given the autonomy to construct and justify claims. Drawing upon Toulmin's model of argumentation (2003), students' reasoning patterns reflected the systematic use of evidence–claim–warrant structures, which are essential for coherent scientific thinking. Moreover, peer discussion sessions encouraged critical evaluation of ideas, validating Vygotsky's social constructivist notion that cognitive development emerges through collaborative dialogue and negotiation of meaning.

The observed improvement in reasoning skills can be attributed to the explicit inquiry phases embedded within the ADI framework. Through iterative processes of problem identification, hypothesis formulation, data collection, and interpretation, students were required to test and refine ideas using empirical evidence. This aligns with Lawson's view that scientific reasoning develops through engagement in tasks requiring causal explanation and justification (Kamaluddin et al., 2023). Nevertheless, the relatively short intervention duration (four weeks) may have constrained the depth of reasoning development, suggesting that longer implementations could yield even stronger effects.

Regarding argumentation quality, the structured application of the Claim–Evidence–Reasoning (CER) framework within ADI discussions enabled students to establish logical connections between data and theory. Rebuttal and peer-review sessions encouraged epistemic dialogue, prompting students to critically evaluate and refine their explanations. This finding is consistent with previous studies emphasizing that scientific argumentation involves rational evaluation of knowledge claims rather than mere opinion exchange (Pan et al., 2021; Suliyanah et al., 2020). In this study, students demonstrated a shift from descriptive responses toward analytical reasoning, indicating a deeper understanding of the causal mechanisms underlying physical phenomena.

This progression contrasts with earlier findings reported who observed that students' arguments at the elementary level were predominantly descriptive and lacked explicit reasoning links between evidence and scientific concepts, highlighting the role of structured inquiry and argumentation scaffolds such as ADI in advancing argument quality (Pertiwi & Sinensis, 2019). Qualitative discourse analysis further reinforced these findings by revealing clear patterns of epistemic engagement. Students frequently referenced empirical data, articulated sources of error, and used scientific terminology accurately behaviors indicative of developing epistemic cognition and scientific literacy. These observations illustrate how collaborative discourse functioned as social scaffolding for advanced reasoning, consistent with Vygotsky's sociocultural framework.

Importantly, the relationship between scientific reasoning and argumentation skills in this study was supported by explicit statistical analysis, which revealed a strong positive correlation between the two constructs ($r = 0.65$, $p < 0.001$). This finding indicates that improvements in reasoning were systematically associated with higher-quality argumentation, rather than being inferred solely from qualitative interpretation. This interdependence supports the proposition that argumentation serves as a cognitive tool for reasoning, as it requires the coordination of evidence, justification, and evaluation of alternatives (Inthaud et al. 2019; Kaçar 2023). Within the ADI context, peer evaluation and reflective feedback promoted iterative refinement of reasoning, leading to more sophisticated argument structures.

Despite these strengths, the study has several limitations that should be considered. The quasi-experimental design, while suitable for authentic school contexts, did not allow for full randomization, potentially introducing selection bias. Additionally, the focus on a single school and a specific physics topic (heat and temperature) limits the extent to which findings can be generalized across different contexts and content domains. These limitations suggest caution in extrapolating the results and underscore the need for broader, multi-site, and longitudinal studies. From a pedagogical perspective, the findings highlight important implications for physics instruction. The successful implementation of ADI in a resource-constrained setting demonstrates that meaningful reasoning and argumentation can be fostered through intentional instructional design. Moreover, the integration of inquiry and argumentation not only strengthens conceptual understanding but also enhances students' communication, critical evaluation, and collaborative skills key competencies for 21st-century scientific literacy.

The teacher's role as a facilitator of questioning, evidence analysis, and discourse regulation emerges as a critical factor in sustaining productive inquiry environments. Overall, this study contributes empirical support to the growing body of literature positioning ADI as an effective instructional model in secondary science education. By framing knowledge as something to be constructed, debated, and refined through evidence-based discourse, ADI promotes intellectual rigor and reflective inquiry. Consequently, students develop not only physics content knowledge but also the scientific habits of mind essential for lifelong learning and informed decision-making.

Conclusion

This study demonstrates that the Argument-Driven Inquiry (ADI) model has a significant positive impact on students' scientific reasoning and argumentation skills in physics learning. Quantitative findings show that students in the ADI group achieved higher post-test scores and learning gains in both scientific reasoning (N-gain = 0.68, high) and argumentation quality (N-gain = 0.72, high) compared to the control group, with large effect sizes confirmed by ANCOVA ($\eta^2 = 0.22$ for reasoning; $\eta^2 = 0.26$ for argumentation). Performance-level analysis further indicates that a substantially greater proportion of ADI students reached proficient to advanced levels of argumentation, reflecting stronger abilities in constructing evidence-based claims and rebuttals. Despite these encouraging results, several limitations should be acknowledged. The study involved a single school with a relatively small sample size and focused on one physics topic over a limited instructional period. In addition, the quasi-experimental design, while appropriate for school settings, restricts full randomization and generalizability. These factors suggest that the findings should be interpreted with caution. From a practical perspective, the results highlight the value of integrating ADI into physics instruction as a means of promoting higher-order thinking, scientific discourse, and meaningful conceptual understanding. Physics teachers can apply the ADI model to shift classroom practices from procedural problem solving toward inquiry-based learning that emphasizes reasoning and argumentation. Future research is recommended to implement ADI across diverse contexts, topics, and longer time spans, as well as to incorporate longitudinal and in-depth qualitative analyses to further examine the sustainability and cognitive mechanisms underlying students' reasoning development.

Acknowledgment

-

References

Amelia, D., Asrial, & Effendi-Hasibuan, M. H. (2021). The effectiveness of argument-driven inquiry in promoting students' argumentation skills about colloids*. In Proceedings of the 3rd Green Development International Conference (GDIC 2020)* (pp. 328–335). Atlantis Press. https://doi.org/10.2991/aer.k.210825.058

Antonio, R. P., & Prudente, M. S. (2021). Metacognitive argument-driven inquiry in teaching antimicrobial resistance: Effects on students' conceptual understanding and argumentation skills. *Journal of Turkish Science Education, 18(2),* 192–217. https://doi.org/10.36681/tused.2021.60

Arini, W. 2020. "Implementation of Scientific Approach in Physics." *Thabiea : Journal of Natural Science Teaching* 3(2):151–61.

Baharsyah, A. I., & Admoko, S. (2020). Analisis kemampuan argumentasi ilmiah siswa berbasis pola Toulmin's argument pattern (TAP) menggunakan model argument-driven inquiry dan diskusi pada pembelajaran fisika SMA. **Inovasi Pendidikan Fisika, 9*(3),* 318–324. https://ejournal.unesa.ac.id/index.php/inovasi-pendidikan-fisika/article/view/35092

Faize, F. A., Husain, W., & Nisar, F. (2018). A critical review of scientific argumentation in science education. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(1), 475–483. https://doi.org/10.12973/ejmste/80353.

Inthaud, K., Bongkotphet, T., & Chindaruksa, S. (2019). Argument-driven inquiry instruction to facilitate scientific reasoning of 11th grade students on light and visual instrument topics. *Journal of Physics: Conference Series, 1157*, Article* 032014. https://doi.org/10.1088/1742-6596/1157/3/032014

Kaçar, S. (2023). The Effect Of Cognitive Apprenticeship Enriched Argument-Driven Inquiry Method On Pre-Service Teachers' Academic Achievement And Scientific Research Skills. *The Universal Academic Research Journal, 5(3),* 232-253. https://doi.org/10.55236/tuara.1349197

Kamaluddin, K., Sani, N. K., Darmadi, I. W., & Nurgan, N. (2023). Analysis of students' scientific reasoning ability and its correlation with cognitive ability in physics learning. *Jurnal Penelitian Pendidikan IPA,* 9*(11), 10173–10179. https://doi.org/10.29303/jppipa.v9i11.5657*

Kuki, A. D., Agustini, R., & Azizah, U. (2023). Analysis of the effectiveness of argument-driven inquiry to improve students' argumentation skills and conceptual understanding. *International Journal of Recent Educational Research, 4(3), 329–342. https://doi.org/10.46245/ijorer.v4i3.316*

Melta, D., Azhar, M., Arsih, F., & Razak, A. (2024). Argument-driven inquiry learning model to improve students' argumentation skills in science learning: A systematic literature review.

Edu Sains: Jurnal Pendidikan Sains dan Matematika, 12(1), 55–63. *https://doi.org/10.23971/eds.v12i1.5843*

Nurhidayati, E., Masykuri, M., & Fakhrudin, I. A. (2023). Pengaruh model pembelajaran argument-driven inquiry (ADI) dengan pendekatan STEM terhadap keterampilan argumentasi pada materi cahaya dan alat optik. INKUIRI: Jurnal Pendidikan IPA, 12(3*), 171–182.* *https://doi.org/10.20961/inkuiri.v12i3.79317*

Nurjannah, N., Sani, N. K., Haeruddin, H., Kade, A., & Khuzaimah, A. U. (2025). Enhancing cognitive and argumentation skills through integration of argument-driven inquiry and the scientific method in physics education*. Jurnal Pendidikan Fisika, 13(3), 291–307.* *https://doi.org/10.26618/9h25w918*

Pan, M. A., Marfu'ah, S., & Dasna, I. W. (2021). The effect of argument-driven inquiry (ADI) based on science, environment, technology, and society (SETS) on students' conceptual understanding and scientific argumentation skills in buffer solution learning*. AIP Conference Proceedings, 2330, 020038.* *https://doi.org/10.1063/5.0043621*

Pertiwi, R. P., & Sinensis, A. R. (2019). Profile of elementary students' argument ability on the energy topic. *Journal of Physics: Conference Series, 1157(2), Article 022010.* *https://doi.org/10.1088/1742-6596/1157/2/022010*

Sani, N. K., Paloloang, M. F. B., Rahmawati, D., & Aras, F. (2024). Guided inquiry meets audiovisual media: Elevating cognitive and scientific reasoning skills*. Jurnal Penelitian Pendidikan IPA, 7(3), 1121–1130.*

Satriya, M. A., & Atun, S. (2024). The effect of argument-driven inquiry learning models on scientific argumentation skills and higher-order thinking on acid–base topics. *Jurnal Penelitian Pendidikan IPA, 10(5), 2663–2673.* *https://doi.org/10.29303/jppipa.v10i5.6834*

Shofiyah, N., Afrilia, I., & Wulandari, F. E. (2020). Scientific approach and its effect on students' scientific literacy. *Journal of Physics: Conference Series, 1594(1), 012015. https://doi.org/10.1088/1742-6596/1594/1/012015*

Suganda, T., Parno, & Sunaryono. (2023). *Building critical thinking skills through the argument-driven inquiry model with STEM and formative assessment. In *Proceedings of the 4th International Conference on Progressive Education 2022 (ICOPE 2022)* (pp. 726–742).* Atlantis Press. https://doi.org/10.2991/978-2-38476-060-2_66

Suliyanah, Fadillah, R. N., & Deta, U. A. (2020). The process of developing students' scientific argumentation skill using the argument-driven inquiry (ADI) model in senior high school on the topic of elasticity. *Journal of Physics: Conference Series, 1491(1),* Article 012046. https://doi.org/10.1088/1742-6596/

Toulmin, S. (2003). *The uses of argument* (Updated ed.). Cambridge University Press.