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Research Trends: Argument Driven Inquiry (ADI) Model in Science Learning

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Abstract: This study aims to analyze research trends regarding the Argument-Driven Inquiry (ADI) model in science education. A Systematic Literature Review (SLR) was conducted using the Scopus database, following PRISMA 2020 guidelines. From an initial 20 records identified, 11 high quality original articles published between 2019 and 2025 met the strict inclusion criteria. The findings indicate that while publication numbers appear to fluctuate, this is largely attributed to ongoing data indexing for the year 2025 rather than a decline in academic interest. The ADI model is most frequently implemented at the secondary school level, particularly in Physics and Chemistry. Results demonstrate that ADI significantly enhances scientific argumentation, conceptual mastery, and critical thinking. Furthermore, technical modifications such as *rADI* and *MADI* have proven effective in addressing diverse student needs and classroom constraints. In conclusion, ADI serves as a robust framework for 21st-century science learning, though future research must prioritize long-term sustainability studies and teacher professional development to ensure successful implementation across broader educational contexts.

Keywords: ADI; Science learning; Systematic literature review

Introduction

Science education in the 21st century faces the critical challenge of equipping students with higher-order thinking skills, specifically critical thinking, problem-solving, and scientific argumentation (Yunita et al., 2025). In an era of rapid technological advancement, traditional pedagogical approaches—which rely heavily on rote memorization and one-way knowledge transmission are increasingly seen as inadequate for preparing students to navigate complex real-world issues (Meizar et al., 2025). Theoretically, modern scientific literacy demands a shift from mere content acquisition to participating in the discursive practices of science (Osborne, 2010; Driver et al., 2000). While Inquiry-Based Learning (IBL) has long been promoted as a solution to encourage active knowledge construction, many standard inquiry models in practice still fall short in fostering deep analytical skills (Neni et al., 2024). These models often emphasize "following a recipe" during experiments, focusing on procedural compliance rather than the cognitive process of using evidence to justify scientific claims (Eymur & Çetin, 2024; Sampson & Grooms, 2010). This gap highlights a significant educational need for a model that transcends simple discovery and explicitly fosters the ability to construct and critique scientific arguments (Salsabila et al., 2019).

The Argument-Driven Inquiry (ADI) model addresses this limitation by centering the learning experience on evidence-based argumentation (Sampson et al., 2011). Theoretically, ADI is grounded in social constructivism and the communicative nature of science, where learning occurs through discourse, negotiation of meaning, and peer critique (Vygotsky, 1978; Walker & Sampson, 2013). Unlike basic inquiry, ADI integrates investigative processes with structured social requirements, such as peer review and rigorous

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evidence-based justification (Admoko et al., 2021). This alignment with modern frameworks such as the Next Generation Science Standards (NGSS) and Indonesia's Kurikulum Merdeka positions ADI as a vital bridge between "doing science" and "thinking scientifically" (Syafitri et al., 2025; Murphy et al., 2018). Research indicates that ADI can significantly shift students' skills from low-level participation to higher levels of scientific reasoning by engaging them in reflective and collaborative stages (Admoko et al., 2021; Erduran & Jimenez-Aleixandre, 2007).

However, despite the growing body of literature, the current research landscape remains fragmented and largely anecdotal (Rosidin et al., 2019). Most existing studies focus on isolated classroom implementations or specific scientific topics, resulting in a lack of high-level synthesis regarding ADI's long-term scalability and cross-disciplinary effectiveness (Songsil et al., 2019; Cavagnetto, 2010). Furthermore, implementation continues to be hindered by systemic barriers, including limited teacher training, resistance to pedagogical change, and a lack of standardized instructional resources (Kaçar & Balım, 2021; Grooms et al., 2014). Teachers often face cognitive constraints in shifting their roles from information providers to facilitators of productive argumentation (Siswa & Akademik, 2018). Without a structured evaluation of these scattered findings, it remains difficult for educators and policymakers to determine the most effective conditions for ADI's success across diverse educational contexts or how to mitigate the cognitive load students face during argumentation (Siahaan et al., 2019; Walker et al., 2012).

Therefore, this study conducts a systematic literature review (SLR) to analyze global research trends in the implementation of the ADI model (Page et al., 2021). There are several compelling logical reasons for conducting this research. First, there is an urgent need to synthesize results from 2019–2025 to provide a clear, evidence-based picture of ADI's effectiveness beyond individual "success stories" (Studi & Biologi, 2024). Second, this research identifies the crucial evolutionary transition from "standard" ADI to modified versions like rADI, MADI, or ADI-SETS that have emerged to meet diverse classroom needs and technological shifts (Songsil et al., 2019; Chen et al., 2019; Pan et al., 2021). Third, it is essential to identify specific variables—such as cognitive style, gender, and technological integration 8that influence the model's impact on academic achievement and personal epistemology (Rahayu et al., 2020; Ping et al., 2020). By providing a structured overview of ADI's evolution, this study offers a strategic roadmap for developing more robust, evidence-based science curricula that bridge the gap between theoretical potential and practical sustainability (Su et al., 2025; Nurhidayati & Masykuri, 2023). Ultimately, this synthesis serves to clarify how ADI fosters scientific literacy more effectively than traditional structured inquiry (Eymur & Çetin, 2024).

Method

This study employs a Systematic Literature Review (SLR) to analyze the implementation and impact of the Argument-Driven Inquiry (ADI) model in science education. The review process follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement to ensure transparency, replicability, and validity in selecting relevant studies (Page et al., 2021). The results of the selection process are presented in accordance with the PRISMA procedure in Figure 1.

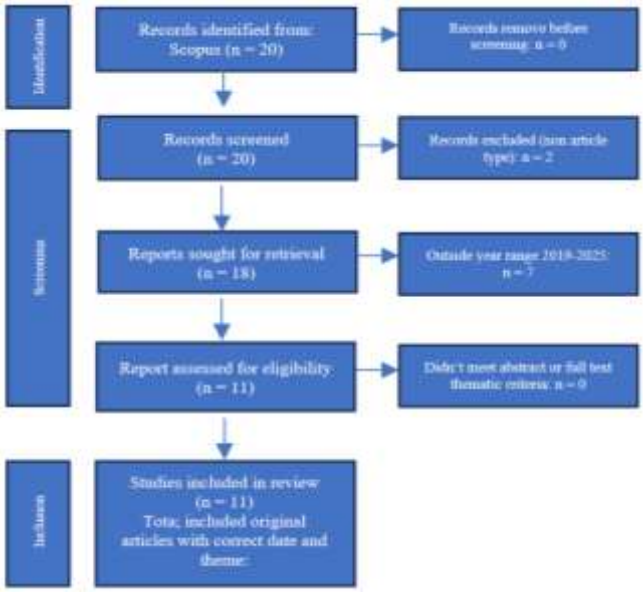

Figure 1. Prism Diagram

The literature search was conducted through the Scopus database to ensure the quality and international standing of the indexed journals. The search string utilized was ("ADI" AND "Science Learning"). This initial search identified 20 documents. In the first screening stage, all 20 records were evaluated based on document type; 2 documents were excluded because they were not original research articles (e.g., reviews or book chapters) leaving 18 articles for further evaluation.

The selection process was then guided by specific eligibility criteria. A temporal filter was applied to include only articles published between 2019 and 2025 to reflect the most recent advancements. This stage resulted in the exclusion of 7 articles that fell outside the specified year range. Finally, the remaining 11 articles were assessed based on the suitability of their abstracts and full-text content with the research theme. Since all remaining articles met the thematic criteria, a total of 11

studies were included in the final qualitative synthesis and review.

Result and Discussion

RQ1: Publication Trends of the ADI Approach in Science Learning

The systematic literature review (SLR) conducted on the Argument-Driven Inquiry (ADI) model in science education yielded several key findings. Based on the rigorous selection process of research involving students as primary subjects, the distribution of publications by year is illustrated in Figure 2.

Figure 2 delineates the volume of articles focusing on the ADI model in science education from 2019 to 2025. Data analysis shows that 2019 marked the peak of publication activity within this timeframe, with seven articles identified. In contrast, 2020, 2021, 2024, and 2025 each recorded one publication meeting the inclusion criteria. It is important to note that the years 2022 and 2023 yielded no articles that utilized students as research samples; during this period, ADI research primarily shifted toward teacher professional development and pedagogical training, which fell outside the specific scope of this review.

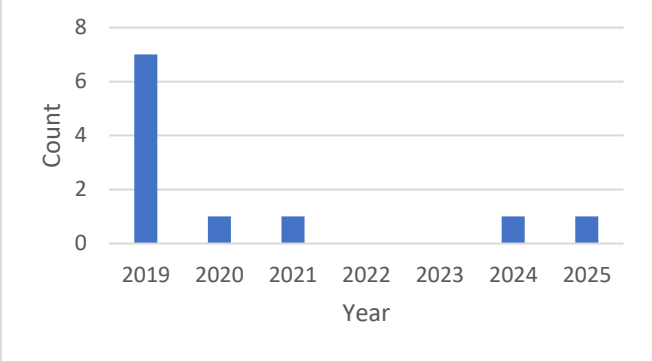

Figure 2. Distribution of Articles by Year

While the data might suggest a fluctuating or declining trend after 2019, the lower count in 2025 is likely due to the ongoing nature of data collection and journal indexing processes for that year, rather than a definitive decrease in research interest. Overall, these 11 selected articles provide a comprehensive foundation for identifying the most recent information and practical advancements regarding the application of the ADI model in science education.

Table 1. Selected articles provide a comprehensive foundation

Author	Subject/ Education,Level	Science Topic	Research Result
Su et al. (2025)	5th Grade Primary School Students	General Science	Significantly improved argumentation performance, especially for rural students in 'Claim' and 'Evidence' dimensions.
Chen et al. (2019)	Elementary School Students	General Science	Effectively enhanced engagement and argumentation quality while bridging the gender gap.
Rosidin et al. (2019)	Middle School Students	General Science	Improved critical thinking skills across different academic levels, genders, and personality types.
Siahaan et al. (2019)	Senior High School Students	Generic Science Skills	Successfully boosted students' generic science skills and their mastery of scientific concepts.
Songsil et al. (2019)	10th Grade Students	Socio-scientific Issues	Developed students' ability to enact scientific argumentation strategies in a supportive classroom environment.
Rahayu et al. (2020)	11th Grade Students	Chemistry (Equilibrium)	Cooperative-ADI resulted in higher student learning motivation compared to collaborative discussions.
Kaçar & Balım (2021)	7th Grade Students	Science (Electric Energy)	ADI significantly improved students' conceptual understanding of series and parallel circuits.
Eymur & Çetin (2024)	8th Grade Students	Scientific Literacy	ADI was more effective than structured inquiry in promoting scientific literacy and personal epistemology.
Pan et al. (2021)	Senior High School Students	Chemistry (Buffer Solution)	Significantly improved concept mastery and argumentation skills, particularly for reflective students.
Admoko et al. (2021)	High School Students	Physics (Newton's Law)	Successfully shifted students' scientific argumentation skills from low levels (1 & 2) to higher levels (3 & 4).
Salsabila et al. (2019)	Junior High School Students	Science (Global Warming)	Proven more effective in promoting students' concept mastery compared to the standard inquiry model.

RQ2: The Potential of ADI Approaches in Science Learning

The potential of the Argument-Driven Inquiry (ADI) model in science education has proven to be highly significant, encompassing improvements in the cognitive and affective domains, as well as the development of essential 21st-century skills. Fundamentally, Argument-Driven Inquiry (ADI) excels

in improving students' scientific argumentation skills, with studies showing the success of this model in encouraging students to construct more complex and comprehensive arguments, marked by the achievement of high levels of argumentation (Levels 3 and 4), including the ability to provide counterclaims. This potential extends to the deeper cognitive realm of conceptual understanding, where evidence-based argumentation forces students to analyze data and connect practical findings with scientific theory, ultimately significantly improving their mastery of concepts.

Furthermore, Argument Driven Inquiry (ADI) plays an important role in developing critical thinking and scientific literacy skills; students who learn with Argument Driven Inquiry (ADI) consistently show higher results on scientific literacy tests compared to groups that use the usual structured inquiry model, confirming the role of Argument Driven Inquiry (ADI) as an effective tool for training evidence evaluation and scientific reasoning. Beyond cognitive aspects, Argument Driven Inquiry (ADI) also has a significant impact on the affective domain, proven to increase student learning motivation (particularly in terms of attention, confidence, relevance, and satisfaction) through collaborative discussion and peer critique processes. Finally, this model shows high flexibility, being adaptable (rADI or MADI) to various levels of education and learning contexts, and proven to accommodate student diversity, including overcoming gender gaps in science engagement and being effective for students with various personality types.

Conclusion

This systematic literature review concludes that the Argument-Driven Inquiry (ADI) model is a highly effective instructional framework for enhancing students' scientific competencies in the 21st century. Synthesizing findings from 2019 to 2025, the results demonstrate that the ADI model consistently improves scientific argumentation skills, conceptual mastery, critical thinking, and scientific literacy. Based on the distribution of the 11 reviewed articles, the ADI model is most frequently implemented and tested at the secondary school level, particularly within the subjects of Physics and Chemistry. The analysis also reveals that modifications to the original model, such as *rADI* (Revised Argument-Driven Inquiry) and *MADI* (Modified Argument-Driven Inquiry), have emerged to better suit specific classroom constraints and diverse student needs, including addressing gender gaps and different cognitive styles. While this review highlights the immediate positive impact of ADI on learning outcomes within a single research cycle, there is currently limited empirical evidence regarding the long-term sustainability of these effects. Therefore, the implementation of ADI should be viewed as a high-impact intervention that requires consistent integration to yield lasting results. To ensure broader and more effective application, future research should focus on teacher professional development to overcome implementation barriers, such as limited instructional resources and the need for specialized pedagogical training.

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Conceptualization, A.M.P. and E.P.; methodology, A.M.P..; validation, E.P. and P.S.; formal analysis, A.M.P.; investigation, A.M.P.; resources, A.M.P.; data curation, M.I.I.; writing—original draft preparation, A.M.P.; writing—review and editing, A.M.P.; visualization, A.M.P.; project administration M.R.C and K.P.A.I.A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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