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THE CONVERGENCE OF ARGUMENT-DRIVEN INQUIRY AND STEM/STEAM: PATTERNS, TRENDS, AND RESEARCH GAPS

Za'ima Nabila Roshifa[1], Parno[1], Nuril Munfaridah[1]
[1]Universitas Negeri Malang, Malang, Indonesia
Corresponding author email: zaima.nabila.2103216@students.um.ac.id

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Abstract :
The integration of Argument-Driven Inquiry (ADI) with STEM and STEAM approaches has gained attention in recent years due to their shared emphasis on inquiry, collaboration, and real-world problem-solving. However, a comprehensive synthesis of how this integration has been researched is still lacking. This scoping review aims to map the trends, patterns, and gaps in studies focusing on the integration of ADI-STEM/STEAM in secondary science education. Following the PRISMA 2020 guidelines for scoping reviews, literature was collected from Scopus and Google Scholar using a range of relevant keywords. Thirteen eligible articles published up to April 2025 were analyzed based on publication type, country, research method, subject, and focus. Findings show that research on ADI-STEM/STEAM integration began in 2020 and is primarily concentrated in Indonesia. Most studies used mixed methods and focused on physics education, with key variables including conceptual understanding and argumentation skills. However, creative thinking, reflective thinking, scientific literacy, and self-efficacy remain underexplored—particularly within the ADI–STEAM context. Only one study was categorized as a development study, indicating opportunities for designing specialized instructional tools or media to support integration. This study is the first to systematically map ADI-STEM/STEAM research trends using a scoping review approach. Its novelty lies in providing a structured and visualized synthesis of an emerging field. The results offer important insights for educators and researchers seeking to expand innovative, interdisciplinary, and inquiry-based practices in science education.

Keywords: Argument-Driven Inquiry, STEAM, STEM

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INTRODUCTION

21st-century science education demands that students possess interdisciplinary thinking skills, collaborative abilities, and adaptability to technological developments. The STEM approach has become a trend because it enables students to engage with multiple perspectives and interdisciplinary integration. Initially, STEM was taught by addressing each element (science, technology, engineering, mathematics) separately without full integration. The development of integrated STEM (iSTEM) then

emerged by combining all elements within a single activity, for example, using engineering and technology as implementations of science and mathematics (Hebebci & Usta, 2022). Another development is STEAM, which integrates STEM with the arts element, aiming to promote emotions and spirituality alongside cognitive development, resulting in critical thinking, problem-solving, and creativity skills (Papadopoulou, 2024; Perignat & Katz-Buonincontro, 2018; Razi & Zhou, 2022).

Inquiry methods are popular in STEM classroom implementation due to their closeness to the scientific method in science (Tan et al., 2023). One model developed from the inquiry method is Argument-Driven Inquiry (ADI), which focuses on developing scientific argumentation skills through an inquiry-based approach. ADI consists of eight stages, including problem identification, investigation design, data collection and analysis, argument development and revision, as well as argument presentation and evaluation. This model encourages students to formulate claims based on valid evidence and to explain the logical reasoning behind them (Khalaf & Zin, 2018). The uniqueness of ADI compared to conventional inquiry methods lies in its emphasis on the argumentation process as the core of scientific practice, as well as its use of collaborative activities such as group discussions and peer review to enhance the quality of students' thinking (Antonio & Prudente, 2021). Due to its collaborative and evidence-based nature, ADI is considered relevant to the demands of 21st-century learning and holds great potential for integration with STEM or STEAM-based approaches (Hasançebi et al., 2021; Suganda et al., 2023).

Given the potential integration of ADI with STEM or STEAM approaches, as highlighted in various studies, it is essential to understand how research trends in this area have evolved. Although numerous studies and several reviews have focused individually on Argument-Driven Inquiry or STEM/STEAM approaches, comprehensive analyses that explore their integration are still limited. One literature review has examined the connection between ADI and STEM and how it impacts students' science literacy (Purnomo et al., 2023), but to date, no scoping review has systematically mapped the research landscape of ADI-STEM/STEAM integration. Therefore, this study aims to conduct a systematic scoping review to explore the patterns, trends, and gaps in such research, focusing on aspects such as research design, educational subjects, methods, countries involved, and academic focus The novelty of this study lies in its effort to systematically map and visualize research trends, patterns, and gaps in the integration of Argument-Driven Inquiry (ADI) with STEM/STEAM approaches. Unlike previous literature, such as Purnomo et al (2023) - which primarily discussed the conceptual alignment between ADI and STEM without a systematic review, this study applies a scoping review method to synthesize empirical evidence from the last seven years. This allows for a broader and more comprehensive understanding of how ADI-STEM/STEAM integration is implemented across various contexts, skills, and educational levels. The implication of this review is to provide a comprehensive overview of previous research developments and also to help identify gaps that can become focal points for future studies.

RESEARCH METHOD

Research Design

This study employed a systematic scoping review design (Peters et al., 2020) to explore broad questions within a focused domain—namely, the integration of Argument-Driven Inquiry with STEM/STEAM approaches. This design allows for summarizing the scope and nature of existing studies without conducting a critical appraisal of the effectiveness or quality of individual research (Campbell et al., 2023). Through this approach, the study aims to understand how research has been conducted and what themes are commonly discussed, making it suitable for topics that are still evolving. The purpose of this review is to identify patterns, trends, and research gaps related to the integration of ADI with STEM/STEAM. Due to reliance on search tools, potential geographic bias in article availability may exist. However, selection criteria focused on thematic relevance rather than origin.

Research Procedure

This scoping review was conducted by following the PRISMA 2020 guidelines for scoping reviews (Page et al., 2021; Tricco et al., 2018) to ensure transparency and methodological clarity. The main procedures followed are outlined below:

1. Database Search

   The literature was obtained from Scopus, a comprehensive and reliable scientific database (Klapka & Salby, 2018), and Google Scholar, which offers broad access to relevant literature searches (Chatterjee et al., 2021). The search was conducted in April 2025 using various keyword combinations, including ""Argument-Driven Inquiry" AND (STEM OR STEAM) AND (physics OR chemistry OR biology OR "science learning" OR "science class")", as well as more general keywords like "Argument Driven Inquiry; STEM," "Argument Driven Inquiry; STEAM," "ADI; STEM," "ADI; STEAM," "Argument Based Inquiry; STEM," "Argument Based Inquiry; STEAM," "ABI; STEM," and "ABI; STEAM."

   The use of the term Argument-Based Inquiry (ABI) instead of Argument-Driven Inquiry (ADI) was also included in the literature search. Although there is a difference in terminology, both contain comparable key components such as scientific argumentation activities, group discussions, scientific report writing, and student-led scientific investigations (Baydas et al., 2018; Cavagnetto et al., 2010). Therefore, literature discussing the integration of ABI and STEM/STEAM is considered relevant for analysis in the context of trends in integrating ADI with STEM/STEAM approaches.

2. Inclusion and Exclusion Criteria

   Articles were selected based on the following inclusion criteria: 1) relevance to the integration of ADI and STEM/STEAM based on title or abstract, 2) written in English or Indonesian (languages understood by the researcher), and 3) document type limited to journal articles or conference proceedings, excluding repositories. No publication year restriction was applied during the literature selection process in order to capture a comprehensive overview of the trends in the integration of ADI with STEM/STEAM approaches. However, publications from the year 2025 only include those published up to April, based on the timeframe in which the literature search was conducted.

3. Screening Process

   The total number of sources retrieved before screening was 1,064. These were then filtered using inclusion and exclusion criteria to ensure relevance and focus. The screening was conducted in two stages: first by title and abstract, and then by full-text review. After the screening process, 13 studies were identified as eligible for further analysis in the research trend mapping.

The full selection process is illustrated in the PRISMA flow diagram (Figure 1). The summary of included studies is presented in Table 1.

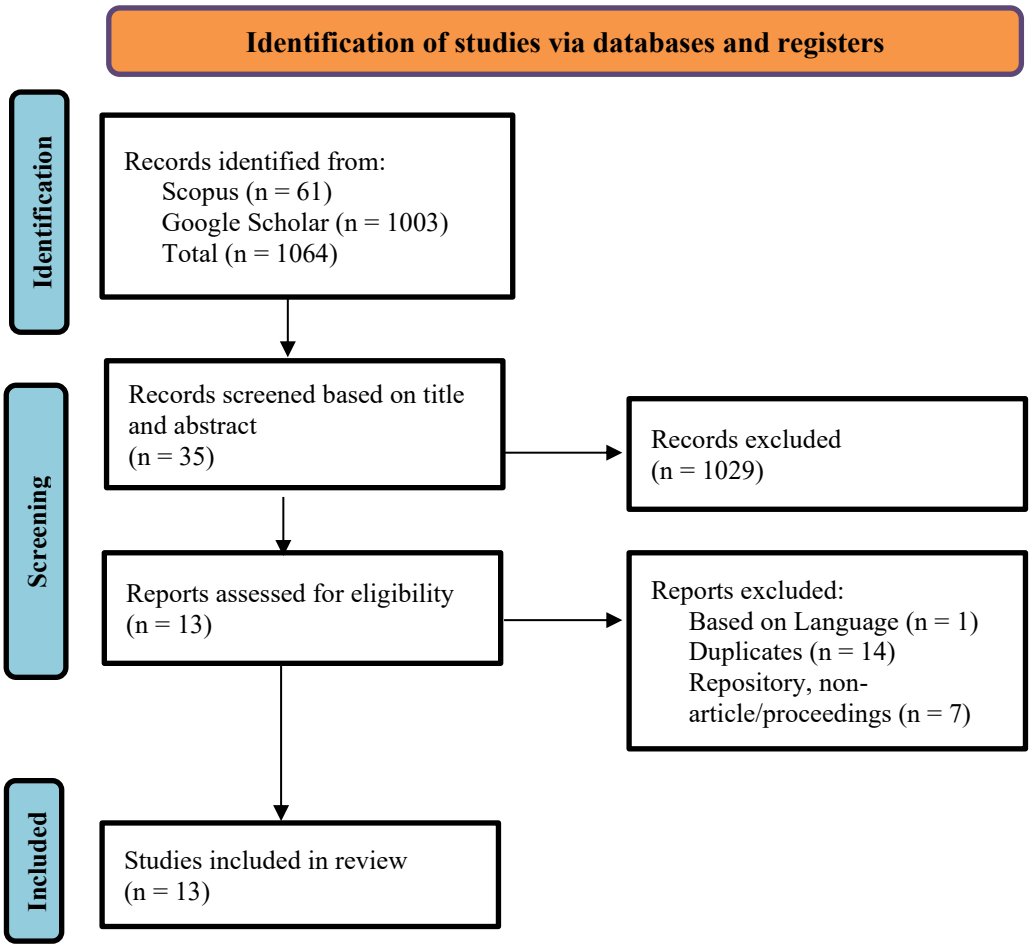

Figure 1. PRISMA 2020 flow diagram adapted for scoping review following PRISMA-ScR guidelines

Data Collection and Analysis Technique

Data were extracted manually from the 13 included articles using a structured spreadsheet (Microsoft Excel). The extracted information included: author(s) and institutional affiliation; year of publication; article title; research subject (e.g., physics, biology); research variables; research design/method; country or region of study. These fields were selected to support the mapping of patterns, trends, and research gaps in studies related to the integration of ADI or ABI with STEM/STEAM approaches.

The extracted data was analyzed using a combination of descriptive qualitative techniques and basic quantitative mapping. Categorical data were grouped and summarized using frequency counts, which were then visualized in the form of tables and charts to highlight publication trends, methodological preferences, disciplinary distribution, and geographic spread of the research. No statistical testing or critical appraisal was performed, in accordance with the exploratory nature of scoping reviews.

RESULTS AND DISCUSSION

Included Studies

Table 1. List of included studies

Citation(s)	Tittle	Publication	Focus
(Bukifan et al., 2020)	Penguasaan Konsep Siswa Pada Materi Termodinamika Dalam Pembelajaran Argument Driven Inquiry for STEM Education	Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan	Conceptual Understanding
(Bukifan & Yuliati, 2021)	Conceptual Understanding Of Physics Within Argument-Driven Inquiry Learning For STEM Education: Case Study	International Conference on Progressive Education: ICoMSE 4th edition, published in AIP Conference Proceedings	Conceptual Understanding
(Atqiya et al., 2021)	Argument-Driven Inquiry For STEM Education In Physics: Changes In Students' Scientific Reasoning Patterns	International Conference on Progressive Education: ICoMSE 4th edition, published in AIP Conference Proceedings	Scientific Reasoning
(Mochsif et al., 2021)	Pengaruh Model Argument-Driven Inquiry-STEM-EFA terhadap Peningkatan Scientific Reasoning Skills Siswa	Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan	Scientific Reasoning
(HASANÇEBİ et al., 2021)	Impact Of STEM Integrated Argumentation-Based Inquiry Applications On Students ' Academic Success, Reflective Thinking, And Creative Thinking Skills	Participatory Educational Research (PER)	Conceptual Understanding, Reflective Thinking, Creative Thinking Skills
(Suganda et al., 2023)	Building Students' Scientific Argumentation Skills Through The Model ADI Integrated STEM Approach And Formative Assessment	International Conference on Progressive Education: ICoMSE 8th edition, published in AIP Conference Proceedings	Argumentation Skills
(Suganda et al., 2023)	Improving Students' Critical Thinking Ability Through Model Argument-Driven Inquiry (ADI) Integrated STEM	International Conference on Progressive Education: ICoMSE 5th edition, published in AIP Conference Proceedings	Critical Thinking
(Purnomo et al., 2023)	Effectiveness Of ADI-STEM To Improve Students' Science Literacy Skills	IJORER: International Journal of Recent Educational Research	Science Literacy Skill
(Suganda, Parno, & Sunaryono, 2023)	Building Critical Thinking Skills Through the ADI Model with STEM and Formative Assessment	International Conference on Progressive Education: ICOPE (4th edition), published in Atlantis Press	Critical Thinking
(Hikmah et al., 2023)	Validity of Student Worksheets Based on Model Argument-Driven Inquiry Integrated by STEM to Train Students' Argumentation Ability and Self-Efficacy in Chemical Equilibrium Material	IJORER: International Journal of Recent Educational Research	Argumentation Skills, Self-Efficacy
(Nurhidayati	Pengaruh Model Pembelajaran	Inkuiri Jurnal Pendidikan	Argumentation

et al., 2023)	Argument Driven Inquiry (ADI) Dengan Pendekatan STEM Terhadap Keterampilan Argumentasi Pada Materi Cahaya dan Alat Optik	Fisika	Skills
(Mochsif et al., 2024)	The Effect Of The ADI Model With STEM Approach And Formative Assessment (ADI-STEM-FA) For Increasing Students' Concept Acquisition On Heat Material	International Conference on Progressive Education: ICoMSE 6th edition, published in AIP Conference Proceedings	Conceptual Understanding
(Epriliyani & Deta, 2025)	The Influence of the Argument-Driven Inquiry Learning Model in Physics Learning with the STEAM Approach on the Scientific Argumentation Ability	Inovasi Pendidikan Fisika	Argumentation Skills

Research Publication

The types of publications analyzed in this study include journal articles and seminar proceedings. Both contribute significantly to mapping the trend of integrating the Argument-Driven Inquiry (ADI) approach with STEM/STEAM in secondary science education. Proceedings are often used to present preliminary findings and initiate scholarly discussion, while journal articles typically reflect more mature studies that have undergone rigorous peer review and deeper theoretical development (Day & Gastel, 2006).

Figure 2 shows that publications on the integration of ADI and STEM/STEAM are nearly evenly distributed, with journal articles accounting for 54% and seminar proceedings for 46%. This suggests that research in this area is still relatively new. Researchers may prefer to present their preliminary findings in seminar forums before developing them further into journal articles.

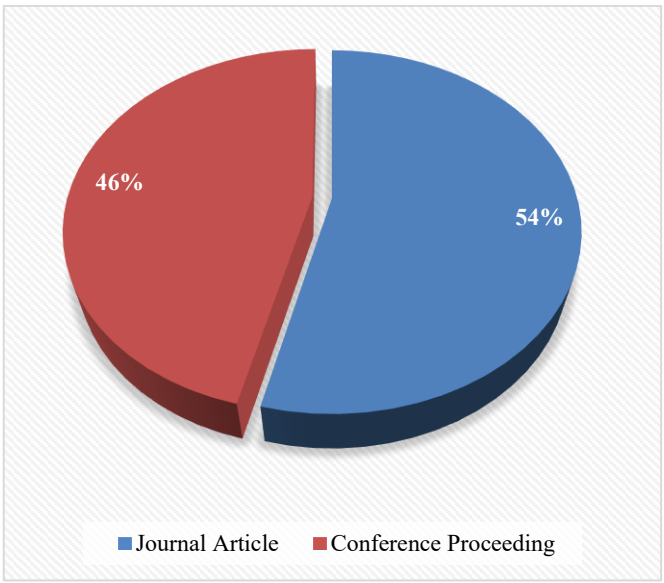

Figure 2. Percentage of journal articles and conference proceedings

Table 2 provides more detailed information about the publications, listing the names of journals or seminars along with their frequency, indexing status, and the country of publication (which also corresponds to the origin of the study). A total of 12 out of 13 articles, or approximately 92%, were conducted in Indonesia. Considering that all proceedings came from conferences hosted within the country, the integration of ADI and STEM/STEAM appears to be a prominent and emerging trend in Indonesian educational research. This finding aligns with the growing body of STEM-related research in Indonesia. Studies on STEM and STEAM in Indonesia began to emerge around 2015 and

have increased significantly in the 2020s (Ardwiyanti et al., 2021; Farwati et al., 2021; Maulidiyah et al., 2023). In parallel, Indonesia has also become one of the active contributors to research on scientific argumentation skills and the implementation of the ADI model (Admoko et al., 2025; Utami et al., 2024).

To support the development of 21st-century skills among students, STEM has become one of the recommended approaches in Indonesian curricula. The previous national curriculum, *Kurikulum 2013*, already shared similarities with STEM by integrating concepts across scientific disciplines (Purnomo et al., 2023). The current *Kurikulum Merdeka* places even stronger emphasis on the 4Cs—critical thinking, creativity, communication, and collaboration—as well as on problem-solving, making STEM/STEAM approaches increasingly relevant to Indonesian education (Langoday et al., 2024). As a result, educators and researchers have increasingly experimented with combining various learning models with STEM/STEAM, including ADI.

Although ADI may not yet align directly with the current educational priorities in Indonesia, there is potential for its integration with STEM/STEAM to become highly relevant in the near future. A recent shift in *Kurikulum Merdeka* focuses on "Deep Learning," which encourages students to actively collaborate with learning partners both within and beyond the school environment to engage in real-world learning experiences (Kementerian Pendidikan Dasar dan Menengah Republik Indonesia, 2025). The argumentation skills central to ADI—such as constructing claims, supporting them with evidence, and participating in structured dialogue—are essential for effective public communication and collaborative problem-solving, particularly in interdisciplinary and real-life contexts.

Although a large proportion of the included studies originates from Indonesia, the research topic—the integration of ADI with STEM/STEAM approaches—addresses global concerns in science education, particularly in fostering scientific argumentation, creativity, and inquiry-based learning. These are skills emphasized not only in Indonesia's curriculum but also in international frameworks such as NGSS (USA), OECD learning frameworks, and 21st-century competencies globally.

Furthermore, the studies reviewed reflect broader educational shifts in developing countries aiming to align national curricula with global standards. Thus, despite the geographic clustering, the findings and gaps identified in this review can inform similar educational reforms and practices in other contexts.

Table 2. Distribution of literature based on the seminars/journals' names

Country	Status	Ceminar/Journal	Quantity
Indonesia		International Conference on Progressive Education: ICoMSE (4th, 5th, 6th, 8th editions), published in AIP Ceminar Proceeding	5
		International Conference on Progressive Education: ICOPE (4th edition), published in Atlantis Press	1
	Grade 2 (Sinta 2) accredited	IJORER: International Journal of Recent Educational Research	2
	Grade 3 (Sinta 3) accredited	Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan	2
	Grade 4 (Sinta 4) accredited	Inovasi Pendidikan Fisika	1
		Inkuiri Jurnal Pendidikan Fisika	1
Turkey	Scopus Q3 indexed	Participatory Educational Research (PER)	1

This topic can also be categorized as a recent trend, as illustrated in Figure 3. Research on the integration of ADI with STEM/STEAM began to appear in 2020, with a peak in 2023. These findings highlight the continuing potential of this topic for further exploration, particularly in the context of publication in reputable and international journals.

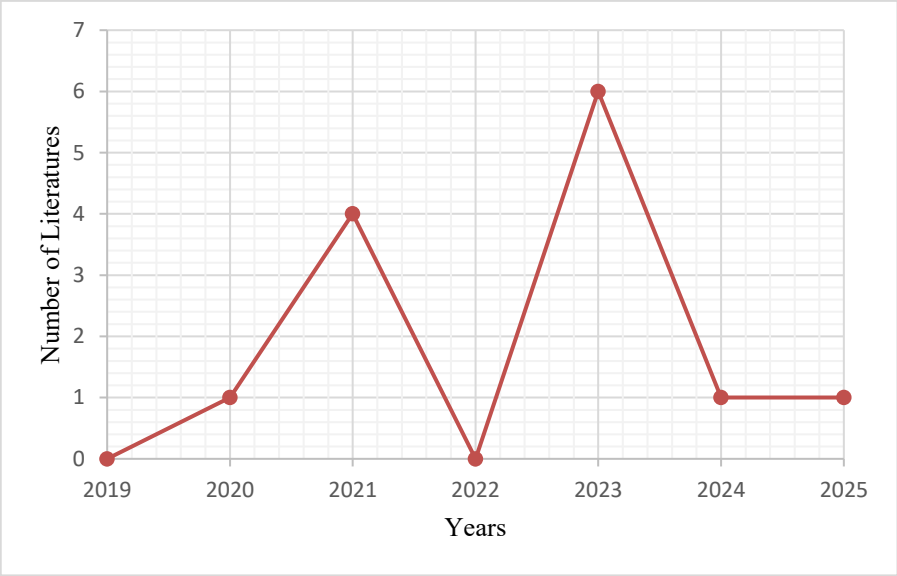

Figure 3. Distribution of literature published annually

Research Author and Affiliation

To further understand the research landscape on the integration of ADI with STEM/STEAM, this section examines the authors and institutional affiliations of the analyzed publications. Identifying the most frequently appearing authors and their affiliations helps to map out key contributors and potential research hubs within this emerging field. Figure 4 presents the frequency of author appearances in publications related to ADI-STEM/STEAM integration, including both first and co-authors. The size of the squares represents the frequency of appearances, while the color indicates the author's institutional affiliation. It is evident that Universitas Negeri Malang leads in this research area, followed by Universitas Negeri Surabaya.

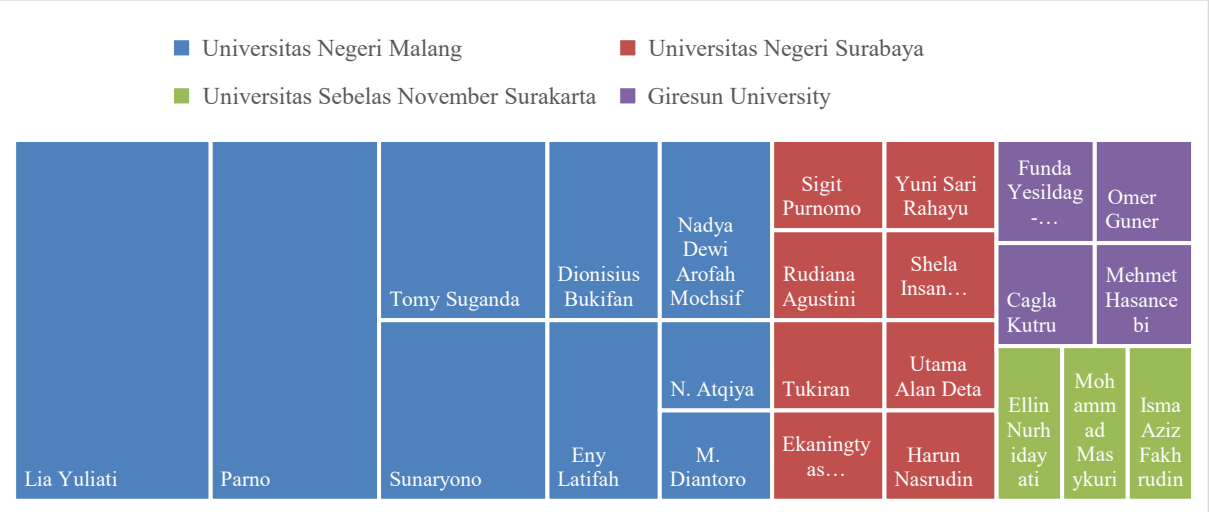

Figure 4. Frequency of authors and institutional affiliation

The dominance of certain affiliations suggests that initiatives and development of ADI in STEM/STEAM contexts are still concentrated within a few higher education institutions. This highlights opportunities for cross-institutional collaboration and emphasizes the importance of broader dissemination, enabling this approach to be adopted more widely across regions.

Research Methods and Focus

Most studies on the integration of ADI with STEM/STEAM employed a mixed-methods approach (n = 9; 69%). The dominance of mixed methods approaches reflects a broader trend in science education research, where researchers not only aim to investigate the effects of integration but also seek to capture measurable impacts and process-level insights from interventions (Creswell & Clark, 2017). Notably, this methodology was adopted both in Indonesian and Turkish studies.

Table 3. Research methods trend

Methods	Quantity
Quantitative	2
Qualitative	1
Mix Method	9
Research and Development	1

Other methodologies include quantitative methods with quasi-experimental design, qualitative reviews examining ADI and STEM separately, and research and development (R&D) studies using a 4D model. The presence of only one development study (n = 1; 8%) suggests opportunities for further research focused on designing instructional instruments or media. Considering that ADI was originally designed as a laboratory-based instructional model (Eymur, 2018; Sampson & Schleigh, 2012), and that STEM emphasizes investigation and problem-solving design (National Research Council, 2000) the integration of both requires supportive media, learning materials, and specialized instructional resources that also need to be developed.

In terms of the approach used, STEM is far more commonly integrated with ADI (n = 12; 92%) than STEAM. This highlights a research gap, especially considering that the sole study on ADI–STEAM integration was published in a national journal.

To further explore future research directions, Table 4 outlines the variables examined in existing studies. Most research emphasizes conceptual understanding and argumentation skills, which are indeed central to ADI. In Table 1, several studies included variables such as academic success and concept acquisition in their titles. In this review, both variables were merged under the broader category of Conceptual Understanding, reflecting how educators and researchers often interpret these outcomes. Both variables were investigated in studies conducted in Indonesia. The Indonesian science curriculum recognizes Conceptual Understanding as a key competency that contributes to both knowledge acquisition and academic achievement (Setiawan & Suwandi, 2022; Widiyatmoko & Shimizu, 2018).

Other variables that remain underexplored in ADI-STEM/STEAM research include reflective thinking, creative thinking skills, scientific literacy, and self-efficacy. In particular, creative thinking—a core focus of the "A" in STEAM—has only been examined within ADI-STEM contexts, not ADI-STEAM. This is notable because integrating the arts into STEM learning has been shown to enhance creative, real-world problem solving—an outcome that reflects authentic scientific practice (Perignat & Katz-Buonincontro, 2018). As such, future research should explore how ADI–STEAM integration may support creativity in science education.

Table 4. Research variable trends

Variabels	Frequency
Conceptual Understanding	4
Argumentation Skills	4
Scientific Reasoning	2
Critical Thinking	2
Reflective Thinking	1
Creative Thinking Skills	1
Science Literacy Skill	1
Self-Efficacy	1

The conceptual distinction between STEM and STEAM is not always clear in the literature. Although STEAM is often promoted for its potential to foster creativity, empirical evidence supporting this assumption remains limited (Aguilera & Ortiz-Revilla, 2021). This overlap may contribute to the scarcity of studies that meaningfully integrate ADI with STEAM, as many works treat STEAM and STEM as pedagogically interchangeable. The reviewed study on ADI-STEAM integration also fails to explain the impact of the 'art' component on the investigated variable (argumentation), resulting in no observable differences in either outcomes or processes compared to ADI-STEM studies on the same variable. Due to the limited availability and conceptual clarity of ADI-STEAM studies, especially those with measurable outcomes distinct from ADI-STEM, further investigation is needed to understand the unique contributions of the 'art' component.

Figure 5 shows the subject distribution across studies. Here, "science" is listed separately, referring to integrated science learning that combines biology, chemistry, and physics. Research is heavily dominated by physics education. Given the close relationship between physics and STEM fields (Seyranian et al., 2018) this makes ADI–STEM/STEAM integration in physics appropriate. Physics often serves as an entry point to STEM because of its history of incorporating engineering and technology components (Bao & Koenig, 2019; Bybee, 2013). However, it would be interesting to explore this integration in other subjects as well.

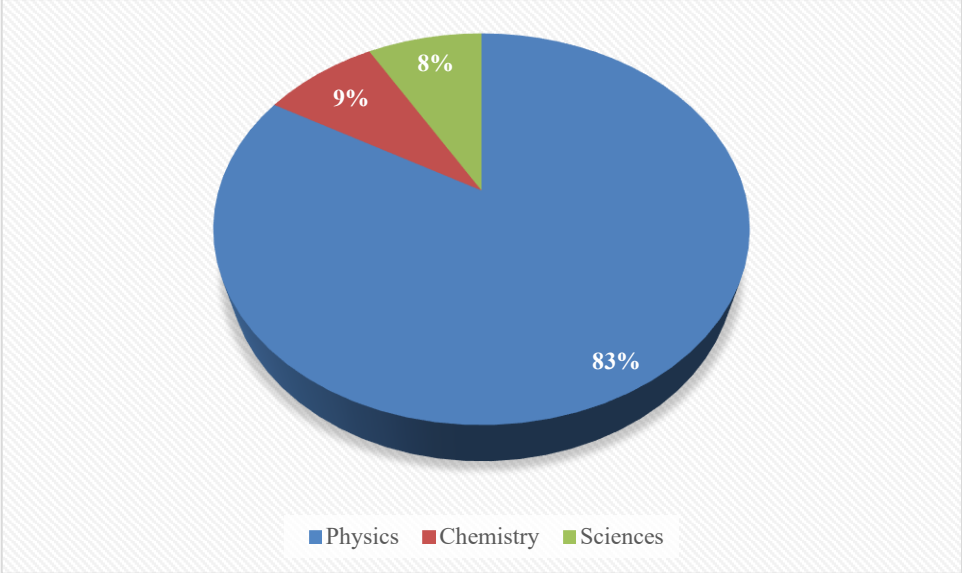

Figure 5. Subjects trend

Overall, the findings indicate that the integration of the Argument-Driven Inquiry (ADI) approach with STEM/STEAM in secondary science education is an emerging research topic, with a notable concentration in Indonesia. Although the number of studies is still limited, the identified patterns reflect a strong focus on enhancing conceptual understanding and argumentation skills, particularly within physics education through STEM-based strategies. These findings suggest a wide range of opportunities for further exploration—both in expanding toward interdisciplinary approaches, such as STEAM, and in developing instructional tools and variables, including creativity. Therefore, this study serves as an initial effort to map the current landscape and inform future directions in innovative, contextually relevant science education research.

CONCLUSION

This study aimed to map the trends and characteristics of research related to the integration of the Argument-Driven Inquiry (ADI) approach with STEM/STEAM in secondary science education. The analysis of 13 publications reveals that this topic is still emerging, with most studies originating from Indonesia and published in local conference proceedings or national journals.

Most studies employed mixed-methods designs, focusing on physics education, with conceptual understanding and argumentation skills as the most frequently investigated variables.

While integration with STEM is more common, research involving STEAM or targeting variables such as creativity and collaboration remains limited.

These findings highlight the significant potential for further exploration—both through interdisciplinary approaches and innovation in instructional design and learning tools. This study is expected to serve as a foundation for understanding current research directions and to encourage more diverse and contextually relevant investigations in the future

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