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Argument Driven Inquiry in Science Education: A Systematic Literature Review

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Abstract: The purpose of this study is to identify the trends in the literature about the Argument Driven Inquiry learning approach for science education. This kind of study uses the PRISMA method in conjunction with the Systematic Literature Review (SLR) strategy. To locate pertinent material, we searched Google Scholar, Education Resources Information Center (ERIC), and Scopus databases. This study, which included 27 papers, concentrated on works published in respectable journals throughout the previous eight years, from 2018 to 2024. The results indicate that the nations that have carried out the most research in this field are Thailand, Indonesia, Turkey, and the United States, with high school students serving as the subjects of most studies. The review of the literature revealed that ADI learning models were effectively incorporated into several science fields, with chemistry seeing the greatest amount of ADI research aimed at enhancing scientific argumentation abilities. While there are many advantages to integrating ADI into science education, there are also drawbacks. Teachers have to deal with issues including time management, curriculum alignment, and the requirement for professional development while putting ADI into practice.

Keywords: Argument driven inquiry; Argumentation; Science education

1. INTRODUCTION

Enhancing students' critical thinking, conceptual comprehension, and scientific argumentation skills is a major task in science education. The capacity for critical thought and the ability to provide compelling scientific arguments are becoming increasingly crucial in this era of knowledge. Nevertheless, many the conventional teaching strategies still widely used in classrooms do not give pupils to develop these abilities efficiently. A novel approach to addressing this difficulty in science education is Argument Driven Inquiry (ADI), which combines the processes of scientific inquiry with debate.

Social constructivist theory, which considers both social and individual educational processes, is the foundation of the ADI model. The social process implies that information is constructed via interaction with others, whereas the personal process entails creating individual knowledge and understanding. Students have opportunity to actively participate in the science process through the social process in the ADI learning paradigm. According to Walker et al., students are encouraged to participate and feel victorious by the ADI learning model's components (argument development, discussion of findings, and scientific writing). In this environment, students can conduct fundamental scientific research with their peers and receive feedback on their work, which helps them feel more capable of doing science and, ultimately, sparks their interest in the (Eymur, 2019; Erenler, Cetin, & Eymur, 2024; Eymur, 2019).

Sampson et al. (2012) state that the ADI model is an integrated learning and inquiry development approach that incorporates science-related skills such as writing, analyzing, reasoning, and exploring (Walker et al., 2012). Task identification, data collection, argumentative creation, argumentation interaction session, investigation report preparation, report review, and report modification are the seven learning processes of the ADI model (Walker et al., 2012). A learning approach called Argument-Driven Inquiry (ADI) incorporates debate sessions into the process of teaching and learning. This paradigm highlights the value of argumentation, which can help foster critical thinking abilities. ADI consistently offers support for its execution in the form of helpful inquiries. Compared to traditional learning, which frequently does not push students to think critically, this helps to strengthen students' critical thinking abilities. As a result, pupils frequently struggle to understand Top of Form material (Purwandari & Wijaya, 2023).

The researcher gives each student a handout at the start of the activity that includes items needed for the investigation, pertinent information about the investigation, and guiding questions for the inquiry. To address the leading questions, it was expected of the students to plan and carry out an investigation. Students then determine the type of data they require and the method for gathering it. They decide how to interpret and analyze the data after it has been collected. Students formulate a preliminary argument that incorporates a claim in order to respond to the guiding question. Students improve the evidence and offer reasoning for it after developing a claim and responding to the guiding question. Using a huge whiteboard, each student group presents the claim, supporting details, and

reasoning for the supporting details to the entire class. A class-wide argumentation session starts when the groups display their giant whiteboards with their claims, supporting details, and arguments. Students present their ideas during this argumentation session by responding to prompts and contrasting them with the arguments of other groups. Following this argumentation session using the ADI approach, the researcher clearly and thoughtfully guided the conversation (Eymur, 2018).

The ADI learning model has been the subject of numerous investigations. A few of these have to do with how well the ADI model works to enhance scientific writing and argumentation abilities (Sampson & Walker, 2012; Walker & Sampson, 2013). According to some research, ADI can help students in biology and chemistry classes become more scientifically literate (Strimaitis et al., 2017). In addition to these research, Walker et al. (2016) demonstrated that students may use fundamental concepts and scientific methods to solve issues or explain scientific phenomena when they are involved in ADI learning models (Eymur, 2018). Penelitian terdahulu menyatakan bahwa model pembelajaran ADI berpengaruh terhadap kemampuan metakognitif dan berpikir kritis siswa (Siahaan, Liliasari, & Hernani, 2019; Utami, Aisyah, & Affifah, 2022). According to earlier studies, the ADI learning paradigm has an impact on students' critical and metacognitive thinking abilities (Çetin dan Eymur, 2017; Çetindkk., 2018). The body of research suggests that ADI can raise students' critical thinking and reasoning abilities, which in turn can lead to an improvement in science literacy.

The ADI learning paradigm will be examined from several angles in this systematic literature review, along with the opportunities and problems that come with applying it to science education. It will also point out any gaps or restrictions in the current literature and make suggestions for further research to deepen our understanding of ADI in science education. Ultimately, this should give light on the ADI learning paradigm and its capacity to revolutionize science education practices.

2. METHODS

This kind of study employs the Systematic Literature Review (SLR) method and is qualitative. A systematic literature review is a method for producing topic-specific knowledge by analyzing the body of current literature. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 standards were used in this investigation. (Page and others, 2021). This manual serves as a reference for carrying out and documenting literature reviews. The databases Scopus, Springer, Google Scholar, and Education Resources Information Center (ERIC) were employed in this study. From March to May of 2024, the search was carried out. "Argument Driven Inquiry" and "ADI" were the search terms used to make sure the articles were covered completely. The recovery of publications published between 2018 and 2024 was our main goal.

Reviewing the research on the Argument Driven Inquiry learning model in scientific education is the goal of this study. Consequently, we excluded papers that did not meet these criteria and only included studies that looked into this topic. We eliminated the duplicate research after discovering some that were identical. Language limitations and studies that had no bearing on our investigation led us to eliminate several of them as well. A variety of journals, including Asia-Pacific Science Education, International Journal of Science and Mathematics Education, Science & Education, Journal of Turkish Science Education, International Journal of Research in Education and Science, Journal of Indonesian Biology Education, Journal of Indonesian Chemical Education, and Journal of Science Education, were among those that included the selected articles. These journals were indexed by SINTA and scopus. Theses, books, literature reviews, and conference reviews were not included in this study; the journals that were chosen were open-access, written in the English language, and contained journal articles. Each study's data were taken out and put into a data extraction table specifically created for this review. A total of 195 publications were retrieved from the database, comprising 160 articles from Scopus and 35 papers from Springer, ERIC, and Google Scholar. The target sample consisted of 27 articles that were retrieved after the screening and extraction process.

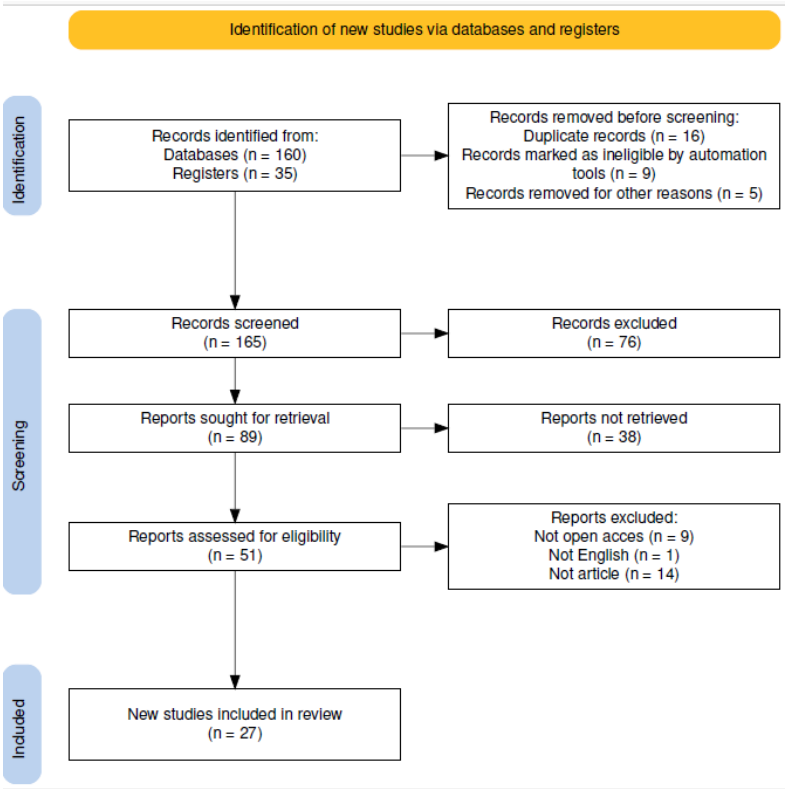

Figure 1. PRISMA Argument Driven Inquiry Method (2018-2024)

3. FINDINGS AND DISCUSSION

3.1. Geographical Distribution of Research

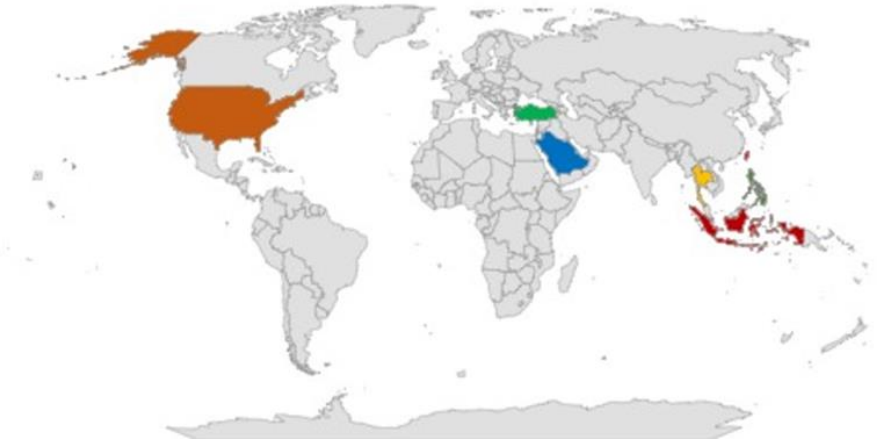

Figure 2. Geographical Distribution of Research

The distribution of research using the Argument Driven Inquiry learning approach across nations from 2018 to 2024 is depicted in Figure 1. With eleven studies, Indonesia has the most, according to the data, suggesting that the nation is heavily focused on incorporating ADI into its scientific education system. Enhancing students' argumentation abilities, critical thinking abilities, learning outcomes, conceptual comprehension, and HOTS across a range of educational levels is the main focus of research in Indonesia. The effectiveness of this paradigm in improving students' Nature of Science, Self-efficacy, Nature of Scientific Inquiry (NOSI), metacognitive, scientific writing, and argumentation skills was demonstrated in five studies conducted in Turkey. Four studies conducted in the United States have consistently shown how the ADI learning model helps students develop their critical thinking and reasoning skills. Three studies from Thailand were also included. The Thai studies provided

evidence of the model's efficacy in a range of educational contexts by demonstrating notable gains in students' capacity for argumentation and creative thinking. These studies demonstrate that ADI can be successfully modified to fit the requirements of Thai schoolchildren.

There is less research conducted in Taiwan, Saudi Arabia, or the Philippines, but the findings still need to be more encouraging. According to a Taiwanese study, participants in ADI laboratory activities with explicit reflective discussion significantly improved their grasp of the Nature of Scientific Inquiry (NOSI) using a modified ADI model (Metin Peten, 2022). Similarly, research from Saudi Arabia highlighted the potential of ADIs in improving argumentation skills (Alfarraj et al., 2023). According to two studies conducted in the Philippines, students' conceptual understanding and reflective thinking abilities were greatly enhanced by the ADI learning model when it was paired with metacognitive techniques (Ronilo P. Antonio & Prudente, 2021; Ronilo Palle Antonio, 2020). Overall, the geographic distribution of ADI research shows how broadly applicable and effective it is in a variety of educational settings and cultural contexts. Although the United States, Indonesia, and Turkey have produced the most studies, promising findings from Thailand, Taiwan, Saudi Arabia, and the Philippines also point to the model's influence on science education around the world. To maximize ADI's potential benefits globally, more research is required to examine its long-term impacts and adaptability to various educational environments.

3.2. Distribution of ADI Research Publications

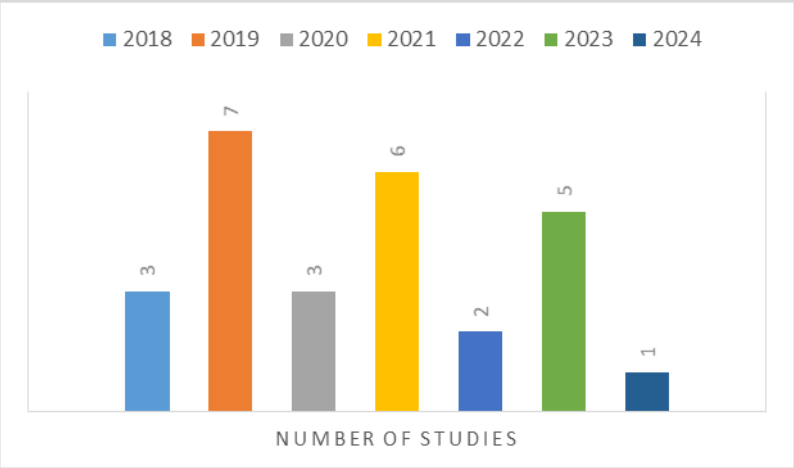

Figure 3. Distribution of ADI Research Publications (2018-2024)

Research on the Argument Driven Inquiry (ADI) learning model revealed important trends and advancements from 2018 to 2024. Three investigations were conducted in this first phase in 2018, which was the first time ADI was used in educational research. With seven studies in 2019, this number rose dramatically, indicating the growing interest and encouraging first results that spurred additional research into the usefulness of ADI in improving scientific inquiry and argumentation abilities. Nevertheless, in 2020, there were only three studies, most likely as a result of the worldwide COVID-19 epidemic upsetting research and education systems as universities concentrated on adjusting to remote learning. Six papers were published in 2021, showing a rebound from the pandemic's effects and fresh efforts to substantiate the advantages of ADIs. The number of studies decreased to two in 2022, maybe as a result of the pandemic's aftereffects or the timing of analysis and the release of earlier results. The number of investigations rose to five in 2023, demonstrating the ADIs' ongoing relevance and continuous interest in scientific education. Even though there has only been one study published thus far in 2024, ongoing research indicates that ADIs are still of interest.

3.3. Type of Research

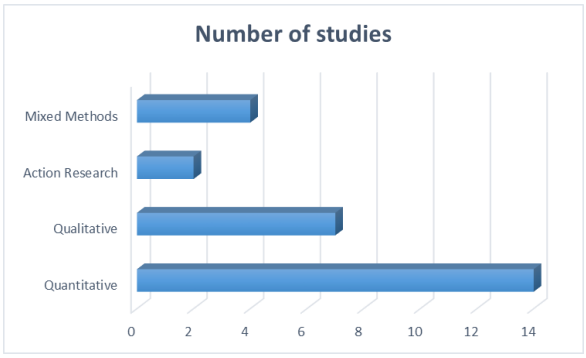

Figure 4. Type of Research

A range of methodological approaches have been used in research on the Argument Driven Inquiry (ADI) learning model, and each one offers a different perspective on the paradigm's efficacy and suitability for use in science teaching. According to the study data (Figure 4), quantitative research predominates, with 14 studies measuring the effect of ADI on learning outcomes, conceptual understanding, argumentation abilities, critical thinking, and Nature of Science (NOS). These studies used statistical methodologies. The effectiveness of ADIs was validated and causality shown by the use of experimental or quasi-experimental procedures in many of these research. Furthermore, seven qualitative studies employ interviews, observations, and content analysis to investigate the contextual and experiential aspects of ADI implementation. These studies offer comprehensive and intricate accounts of students' scientific aptitude, argumentation abilities, critical thinking, concept comprehension, and nature of scientific inquiry (NOSI) toward science. Two studies exemplified action research, emphasizing a participatory approach in which researchers worked with teachers to implement and evaluate ADIs on students' capacity for scientific inquiry, conceptual understanding, and creative thinking. This allowed for ongoing improvement based on direct feedback. In order to give a thorough examination of ADIs on argumentation skills, the nature of scientific inquiry (NOSI), students' conceptual understanding, and reflective thinking abilities, the other four research included quantitative and qualitative methodologies in mixed methods. By validating results through a variety of perspectives, this mixed methods approach provided for a comprehensive understanding of the effects of ADIs. The diversity of the research highlights the significance of an integrative approach to maximize the comprehension and advantages of ADI in education and reflects the complexity of the educational environment and the multidimensional nature of ADI implementation.

3.4. Subject Research

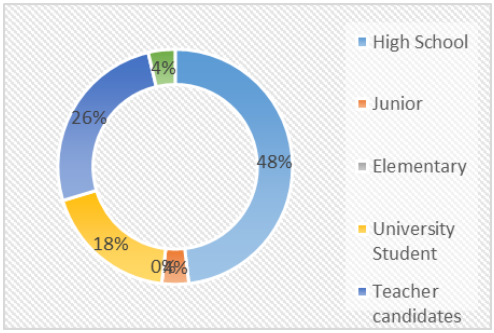

Figure 5. Subject Research

The Argument Driven Inquiry (ADI) learning approach has been extensively researched over a broad spectrum of educational levels and participant groups, indicating its broad applicability and impact across many educational stages. Thirteen studies by ADI have been devoted to high school pupils as their primary subject. This noteworthy figure suggests that there is a great deal of interest in learning more about how ADIs might improve students' critical thinking, scientific reasoning, and argumentation abilities at a critical juncture in their academic careers. Senior high school is a perfect area to deploy and research ADI learning

approaches since it is a critical time when students solidify their comprehension of complicated scientific subjects. One study focused on junior high school pupils, suggesting a possible topic for future investigation. Junior high school is a crucial transitional year for students as they advance from fundamental to more advanced scientific ideas. Furthermore, five of the research were student-focused, demonstrating a strong interest in the ways that ADIs might enhance higher education. ADIs are frequently used at this level to help students become more proficient in conducting independent research, making scientific arguments, and applying scientific concepts in more complex and specialized situations. Research on college students usually focuses on their depth of knowledge as well as their capacity to formulate and support scientific arguments—two things that prospective scientists and professionals need to be able to do.

The significance of educating aspiring teachers to apply ADI learning strategies in their own classrooms was underscored by seven research that concentrated on this population. These studies frequently looked into how ADI might help aspiring teachers develop their pedagogical abilities, such as their capacity to lead scientific discussions, create courses that involve inquiry, and assess student arguments. An in-depth understanding of how science teachers modify and implement the ADI model in their instructional strategies is provided by research in this field (Sengul et al., 2021). Since there is only one study that focuses on teachers, it appears that there hasn't been much research done on how the ADI learning paradigm directly affects teachers. This field of study looks at the challenges that educators have when attempting to integrate scientific argumentation—specifically, ADI—and inquiry-based learning strategies into science classroom instruction (Alfarraj et al., 2023). Especially in light of ADI and scientific argumentation, this study significantly adds to the body of knowledge on science education. It's interesting to note that no study examined elementary school pupils, which represents a huge research vacuum. Early exposure to ADI in primary education can lay a solid basis for scientific inquiry and critical thinking. Future studies should look at the advantages of early exposure to this instructional style in the long run and how ADIs can be modified for younger pupils.

3.5. Research Field

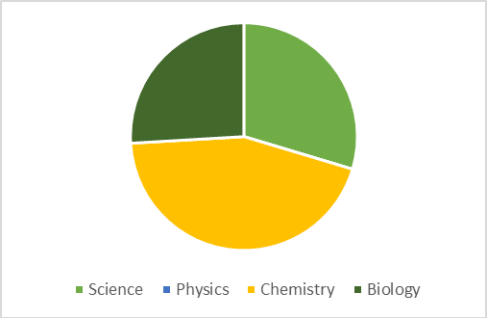

Figure 6. Research Field

The Argument Driven Inquiry (ADI) learning approach has been extensively researched across a broad spectrum of disciplines, indicating its adaptability and broad applicability in science teaching. There are eight studies that concentrate on the scientific domain, spanning multiple disciplines without focusing on any one area in particular. The emphasis was on using ADIs to enhance scientific reasoning abilities and conceptual comprehension on a variety of science-related themes, including climate change (Erenler et al., 2024). In the area of ADI, chemistry is the most explored field; thirteen studies demonstrate how ADI can help students better understand difficult chemical concepts like thermochemistry (Purwandari & Wijaya, 2023), acid base (Hosbein et al., 2021; Utami et al., 2022); (Anjamputra, Embisa et al., 2019), salt hydrolysis (Sunarya et al., 2022), reaction rate (Wulandari et al., 2021; Safitri et al., 2020) and environmental chemistry. These studies demonstrate how ADI aids in students' development of the capacity to create and support scientific arguments based on empirical evidence and reasoned reasoning. Seven research in the field of biology show how ADI may be used to analyze biological processes and life. These investigations span issues including excretory (Riyanti et al., 2023), anti-microbial resistance (Ronilo P. Antonio & Prudente, 2021), environment (Songsil et al., 2019). According to these

studies, ADIs can aid students in acquiring the reasoning abilities required to comprehend and elucidate intricate biological processes.

It's interesting to note that no study explicitly addressed the topic of physics, indicating a potential void in the literature on ADI research. With its frequently extremely complex and mathematical notions, physics stands to gain a great deal from an ADI approach. Subsequent investigations may delve into the potential of ADI in enhancing students' comprehension of physics and their capacity for debating physical phenomena. Chemistry is the most investigated field, followed by biology and science, according to the distribution of ADI research. There may be room for more investigation given the dearth of studies with a physics concentration. According to ADI research, the method works well for enhancing scientific reasoning abilities and conceptual comprehension in a variety of scientific fields. Expanding the study to include physics could offer a more thorough understanding of the ADI learning model's potential for science education in general.

3.6. Variable Research

Tabel 1. Variable Research

No	Reference	Varible	Number of studies
1.	(Purwandari & Wijaya, 2023); (Howitz et al., 2023); (Wulandari et al., 2021); (Hasnunidah et al., 2019); (Safira et al., 2021)	Critical thinking	5
2.	(Eymur, 2019)	Nature of Science	1
3.	(Eymur, 2018);	Self Efficacy	1
4.	(Hosbein et al., 2021); (Utami et al., 2022); (Sunarya et al., 2022); (Songsil et al., 2019); (Alfarraj et al., 2023); (Riyanti et al., 2023); (Yuliyanti et al., 2023); (Songsil et al., 2019); (Walker et al., 2019); (Almeida et al., n.d.)	Argumentation	10
5.	(Kumdang et al., 2018)	Creative Thinking	1
6.	(Safitri et al., 2020)	Learning Outcomes	1
7.	(Anjamputra, Embisa et al., 2019); (Ronilo P. Antonio & Prudente, 2021);	Student Conceptual Understanding	2
8.	(Metin Peten, 2022); (Erenler et al., 2024);	Nature of scientific inquiry (NOSI)	2
9.	(Amin et al., 2019);	HOTS	1
10.	(Erenler & Cetin, 2019)	Meta cognitive	1
11.	(Ronilo Palle Antonio, 2020)	Reflective Thinking	1
12.	(Sengul et al., 2021)	Unknown	1

Studies on the Argument-Driven Inquiry (ADI) learning paradigm have demonstrated a number of educational benefits, chief among them being the enhancement of students' critical thinking abilities, argumentation, and conceptual knowledge, as well as their NOS and NOSI. Through discussion and evidence-based inquiry, students can acquire scientific thinking and argumentation abilities through the use of scientific arguments as a teaching and learning tool (ADI). Studies on ADI demonstrate how this paradigm can greatly enhance pupils' critical thinking abilities. Five studies have shown that ADI aids students in developing their critical thinking abilities (Purwandari & Wijaya, 2023); (Howitz et al., 2023); (Wulandari et al., 2021); (Hasnunidah et al., 2019); (Safira et al., 2021). To prepare students for the problems of the real world, where the capacity for critical thought and evidence-based decision-making is highly appreciated, critical thinking skills enhancement is essential.

Additionally, the ADI learning paradigm helps students comprehend the Nature of Science (NOS). According to Eymur (2019), students' comprehension of the Nature of Science (NOS) can be greatly enhanced by the application of explicit science instruction integrated within the Argument-Driven Inquiry (ADI) technique (Eymur, 2019). In contrast to traditional laboratory education, research by Eymur (2018) indicated that the implementation of the ADI learning model can improve students' self-efficacy, their views of inquiry skills, and laboratory skills. Students that have higher levels of self-efficacy may be more eager to participate in the learning process and to have greater faith in their academic (Eymur, 2018). Ten studies have documented the impact of

argumentation, making it the most explored variable in the context of ADI. Studies conducted by (Hosbein et al., 2021; Utami et al., 2022; Sunarya et al., 2022); and others have demonstrated that ADI successfully enhances students' capacity to formulate and present compelling, evidence-based arguments. The teaching of science and other topics requiring analytical and critical thinking benefits greatly from the development of these reasoning skills. Studies indicate that ADI can enhance pupils' capacity for creative thought as well. An investigation carried out by Kumdang and colleagues (2018) demonstrated a rise in innovative thinking abilities through the utilization of the ADI model. Kumdang claimed that students' capacity for original thought was enhanced more when the Argument-Driven Inquiry (ADI) paradigm was used to the study of the chemical (Kumdang et al., 2018). The use of the ADI Model in the subject of the chemical environment successfully incorporates curiosity, originality, fluency, imagination, elaboration, and flexibility in addition to enhancing students' creative thinking abilities (Kumdang et al., 2018). For kids to be ready to take on difficulties in a world that is becoming more complex and changing quickly, they need to develop these creative thinking abilities. Additionally, ADI improves the learning results of students. According to a study by Safitri et al. (2020), students who used ADI learning outperformed traditional learning strategies in terms of learning outcomes (Safitri et al., 2020). This shows that ADI improves comprehension and retention of subject matter in addition to strengthening critical thinking and reasoning skills.

Through ADI, students' conceptual knowledge also increased. In comparison to traditional learning methods, students utilizing ADI demonstrated a higher knowledge of scientific topics (Anjamputra, Embisa et al., 2019; Ronilo Palle Antonio, 2020). It takes this profound conceptual grasp to lay a strong scientific foundation. Through ADI, one's understanding of the nature of scientific inquiry is also improved. Students became more familiar with the scientific method and the process of scientific inquiryDua studi oleh Metin Peten (2022) dan Erenler et al. (2024) menunjukkan bahwa siswa menjadi lebih paham tentang proses penyelidikan ilmiah dan pentingnya metode ilmiah dalam penelitian (Capkinoglu et al., 2022; Erenler et al., 2024). Students are better able to appreciate and use the scientific method in both academic and real-world settings when they have this understanding.

Studi oleh Amin et al. (2019) menemukan bahwa ADI dapat meningkatkan keterampilan berpikir tingkat tinggi (HOTS) pada siswa, yang mencakup kemampuan analisis, evaluasi, dan penciptaan. Keterampilan HOTS ini sangat penting dalam pendidikan modern yang menekankan pada pemecahan masalah dan pemikiran kritis (Amin et al., 2019). According to research by Erenler et al. (2019), ADI can help students become more metacognitive—that is, more conscious of how they think and how to efficiently organize their learning. Both academic achievement and lifetime learning depend on these metacognitive skills (Erenler & Cetin, 2019).

According to Ronilo Palle Antonio's research, ADI also fosters the growth of reflective thinking (2020). When using ADI, students are more adept at analyzing their own arguments' advantages and disadvantages as well as how they learned them. These abilities are critical for both career and personal growth. Sengul et al.'s (2021) study was one of the few that did not name any factors but did highlight the benefits of ADI in a broader learning environment. This implies that ADI may improve learning in a number of areas that the present research may not have thoroughly examined (Sengul et al., 2021). The research at hand indicates that the Argument-Driven Inquiry (ADI) learning approach is efficacious in enhancing a variety of student competencies and comprehension, such as critical thinking, argumentation, and conceptual understanding. This study backs up the application of ADI as a potent educational strategy in scientific education and other subjects where solid reasoning and critical thinking are necessary. As a result, ADI is a useful teaching strategy in contemporary education.

3.7 ADI Learning Model Research Challenges

Despite the established advantages of the ADI model, there are a number of obstacles when using it in educational settings. A primary concern was that certain individuals lacked prior laboratory experience, which would have impacted their capacity to adhere to the ADI paradigm, which necessitates active participation in laboratory procedures. Participants also disagreed on the group work atmosphere. Some participants expressed a preference for working alone, and while there were options for working alone in studies using traditional learning methodologies, these opportunities were not available with ADI exercises. They therefore found it challenging. On the other hand, a few individuals said that collaborating in groups was beneficial and instructive. The idea that the ADI approach is unsuitable for students with little experience is one of its criticisms. Participants expressed concern that students who are ill-prepared may find the approach challenging; in fact, they suggested that teachers focus more on safety and support pupils who require it when there are ill-prepared children. Another unfavorable comment was that since the reports were written after class, peers' evaluations of the students' reports lacked

objectivity (Hakkikadayifci & Ayseyalcin-Celik, 2016). An innovation is required to address the limits on the ADI model, particularly the shortage of time in the argument production stage, as stated by Effendi-Hasibuan et al. (2019) (Fitri et al., 2022).

4. CONCLUSION

Between 2018 and 2024, there will be a wide range of uses for Argument Driven Inquiry (ADI) in natural science education, according to research. With a particular focus on high school students, this distribution of research includes a wide range of educational themes, including aspiring teachers, working teachers, university students, and high school students. These research demonstrated how well ADIs work to enhance students' capacity for scientific reasoning, conceptual comprehension, and critical thinking. With thirteen studies, quantitative research was the most common type, followed by action, mixed, and qualitative research. Every research kind has something special to offer, from contextual insights and the development of instructional techniques to empirical confirmation. According to the distribution of research areas, chemistry was the most studied field, followed by science and biology. No studies were conducted in the field of physics. This implies that there may be room for more research on the use of ADI in physics. Overall, ADI research demonstrates that the method works well to improve scientific inquiry and critical thinking abilities in a variety of school settings. To obtain a more thorough grasp of the possibilities of ADI, additional research in physics and research to the primary school level are necessary. Increasing the scope of this study will aid in optimizing the use of ADI to improve science instruction in all subject areas and educational settings.

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