

Implementation of Argumentative Driven Inquiry in Science Learning 2009-2023: Bibliometric and Review Analysis

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DOI: <http://dx.doi.org/10.18592/tarbiyah.v13i1.12929>

Key Words:

argumentation driven inquiry
bibliometric analysis
science learning

Received : 30 May 2024

Revised : 11 June 2024

Accepted : 12 June 2024

Published : 30 June 2024

Abstract:

This research examines research trends in applying argumentation-driven inquiry (ADI) in science learning and its potential for future research. A literature review is used in this research method through bibliometric analysis. The data source was obtained from the Scopus database, which obtained 72 articles from 549 articles in 2009-2023 with the keyword "Argumentative Driven Inquiry." The results show that publications fluctuate every year, with some years seeing a significant increase in publications, while others show a decline. Articles on this topic mostly come from international journals indexed by Scopus with quartile 1. This is in line with sources that publish many articles on this topic. Similarly, the top authors based on publications also come from international journals indexed by Scopus with quartile 1. The US and Indonesia are the most productive countries on this topic. The visualization results are divided into 6 clusters. It can find specific keywords that have the potential to be further researched in the future.

To cite this article: Misbah, Hamidah, I., Sriyati, S., Samsudin, A. (2024). Implementation of Argumentative Driven Inquiry in Science Learning 2009-2023: Bibliometric and Review Analysis. *Tarbiyah: Jurnal Ilmiah Kependidikan*. Vol 13 (1), 91-104.

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Introduction

Argumentation-based inquiry (ADI) is a student-centered, writing-intensive laboratory teaching and learning model that emphasizes the role of argumentation and inquiry in science education (Çetin & Eymur, 2017; Sampson et al., 2013). ADI is designed so students can generate data, conduct investigations, use data to answer research questions, write, conduct group peer reviews of students' practicum reports, and revise their reports according to that review (Walker et al., 2011; Walker & Sampson, 2013a).

Implementing the ADI model in learning makes it easier for students to understand concepts because it emphasizes the construction and validation of knowledge through research activities, which can increase students' mastery of concepts (Anas et al., 2023). In addition, ADI learning improves students' mathematical comprehension skills (Hidayat & Aripin, 2019), mathematical creative reasoning skills (Hidayat & Prabawanto, 2018), and students' argumentation skills (Suminar et al., 2017).

Laboratory activities support science learning, physics, chemistry, and biology (Ekaputra & Widarwati, 2023; Farida et al., 2018; Hasnunidah, 2016; Putra et al., 2021). ADI is an alternative instructional learning model emphasizing argumentation and investigation's role in science education (Rizkia & Aripin, 2022). This ADI model is essential because it is inquiry-based learning, which was developed to provide opportunities for students to study science (learning science) by doing science (Marhamah et al., 2017). By implementing the ADI learning model, students must be able to make decisions and provide arguments when receiving lessons to avoid getting caught up in issues or incorrect information spreading in society. It also helps students understand how to make a scientific explanation and use data to answer scientific questions. Therefore, it is essential to research the application of ADI in science learning.

The ADI model has been used in macroeconomics courses (Anas et al., 2023) and mathematics learning (Hidayat & Aripin, 2019; Hidayat & Prabawanto, 2018). However, it must still be found in science learning, physics, chemistry, and biology. Given the importance of the impact obtained after ADI is applied in the learning process, it is necessary to conduct a comprehensive review of this ADI model in science learning. Therefore, bibliometric analysis and review of ADI research trends and opportunities in science learning in the period 2009-2023 was carried out based on (1) the number of publications each year, (2) document type, (3) publication sources, (4) authors based on the number of citations, (5) countries, and (6) co-occurrence analysis.

Research Method

This study is a review and bibliometric analysis. At this stage, the PRISMA method is used (Misbah et al., 2024; Pratiwi et al., 2022). Data obtained from the Scopus database as of March 13, 2024. Vosviewer is used to visualize the data obtained. The stages of PRISMA are presented in Figure 1.

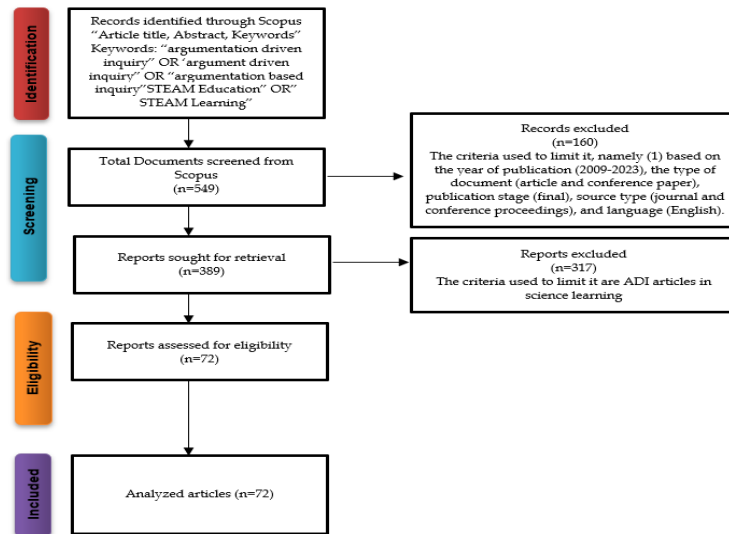


Figure 1. PRISMA Method on ADI Topics in Science Learning

Results and Discussion

1) The number of publications each year on ADI in science learning

Based on 72 articles analyzed from the Scopus database, the results are detailed based on (1) the number of publications each year, (2) document type, (3) publication source, (4) author based on the number of citations, (5) country, and (6) co-occurrence analysis. The number of ADI publications in science learning since 2009-2023 is shown in Figure 2.

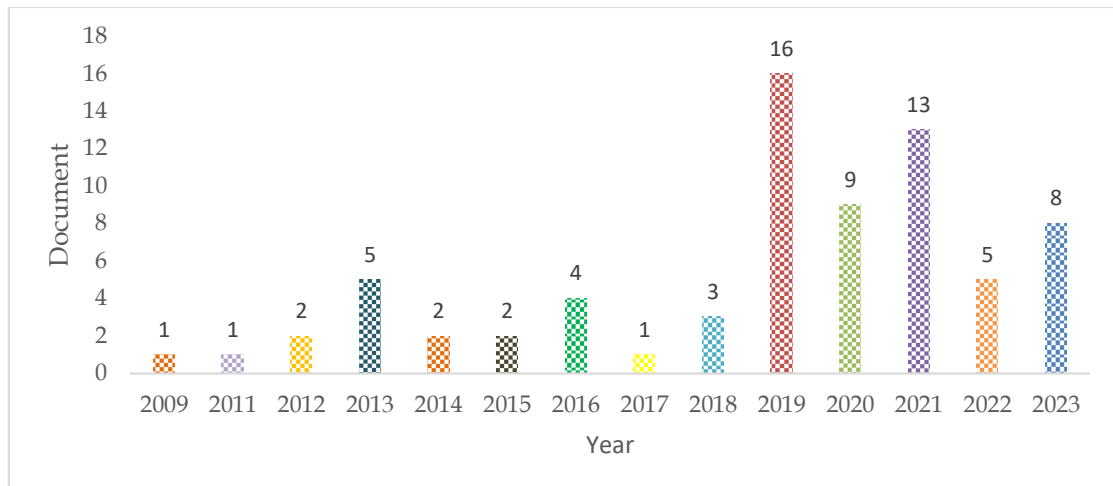


Figure 2. Number of ADI Publications in Science Learning

Figure 2 shows that ADI research in science learning fluctuates. However, this publication has increased in the last five years, especially in 2019. This aligns with several similar learning models that experience an increase in publications yearly, such as Project-Based Learning (Ahmad et al., 2023; Misbah et al., 2024) and discovery learning (Pratiwi et al., 2022).

2) The document type on ADI in science learning

Based on the 72 articles analyzed, the distribution based on document type is listed in Figure 3.

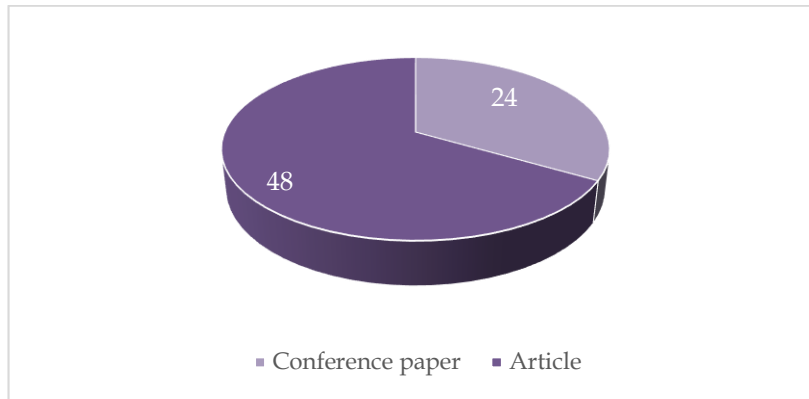


Figure 3. Document Types on the topic ADI in Science Learning

In Figure 3, research on ADI in science learning was dominated by articles from Scopus-indexed journals, totaling 48 articles.

3) The publication sources on ADI in science learning

The top 10 sources that publish many articles about ADI in science learning are listed in Figure 4.

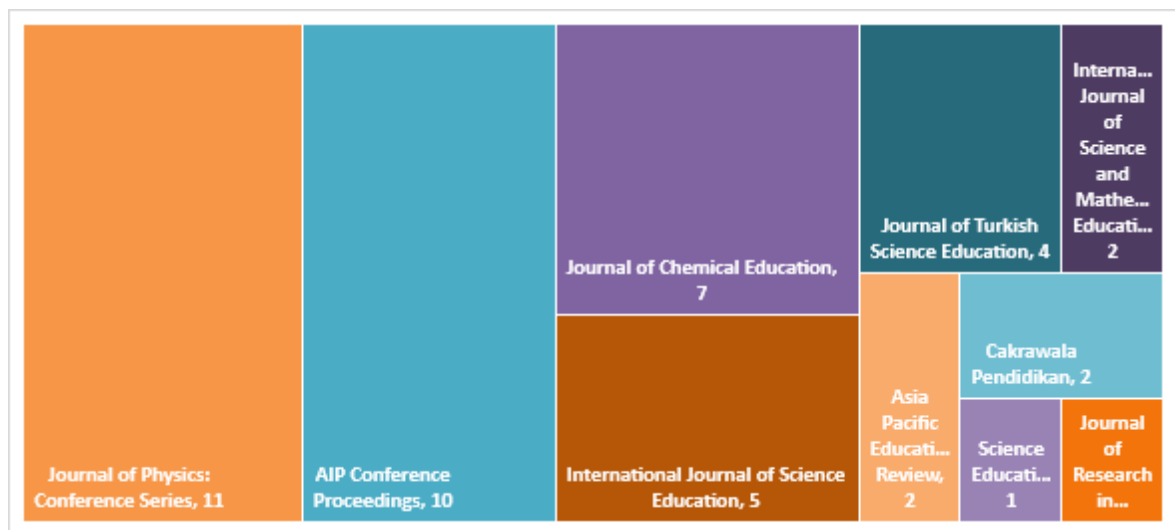


Figure 4. Top 10 Resources on ADI topics in Science Learning

In Figure 4, sequences 1 and 2 are obtained from conference proceedings, namely the Journal of Physics: Conference Series and AIP Conference Proceedings. Furthermore, eight other sources come from Scopus Indexed International Journals. Some journals, such as the Journal of Chemical Education and Science Education, include reputable international journals with Quartile 1 (Q1). Some of the studies published in the journal include Walker (Walker et al., 2011, 2019; Walker & Sampson, 2013a), who consistently examines ADI in Chemistry laboratory activities, and Sampson (Sampson et al., 2013), who examines ADI in science learning.

4) The authors based on the number of citations on ADI in science learning

The top 10 authors, based on the number of citations on the topic of ADI in science learning, are listed in Table 1.

Table 1. Top 10 Authors by Number of Citations on ADI Topics in Science Learning

Authors	SJR/ Quartile	Cited by	Abstract
Walker & Sampson (2013a)	1.882/Q1	117	Following the implementation of the ADI learning model's laboratory activities, students' written and spoken arguments showed notable improvements.
Sampson Vet al. (2013)	2.115/Q1	90	After using ADI learning, students' grasp of fundamental scientific concepts and their ability to write argumentative essays with a science focus both improve.
Walker et al. (2011)	0.555/Q1	86	Peer review and scientific debate are integrated into ADI learning.
Walker & Sampson (2013b)	0.555/Q1	75	The participants' abilities to write science articles significantly improved. Following the application of ADI, they were able to assess their peers' writing with a comparatively high degree of accuracy.
Sampson & Walker (2012)	1.003/Q1	70	The ADI model, which teaches writing skills, can benefit students who write to learn science and new directions for future study.
Walker et al. (2016)	0.711/Q1	47	For every student, the ADI portion of the practice exam had a far higher average score.
Demirbag & Gunel (2014)	0.244/-	40	Students in the group using the Argument-Based Science Inquiry approach fared much better in writing and argumentation assessments, and they outperformed students in the comparison group on science achievement tests.
Sampson & Gleim (2009)	0.241/Q4	39	The ADI paradigm enables biology instructors to effectively incorporate inquiry-based laboratory experiences into other academic disciplines, like writing and reading, to promote and enhance learning.
Demircioglu & Ucar (2015)	0.244/-	37	ADI is adaptable for use in various laboratory classrooms and effectively enhances students' academic achievement and science process abilities.
Songsil et al. (2019)	0.380/Q2	33	The revised ADI model could be helpful for teachers who want to help students in science classes become more adept at scientific argumentation.

Table 1 obtained authors with high citations, mostly from international journals indexed by Scopus with Quartile 1 or 2 (Q1 or Q2). This shows that articles published in international journals indexed by Scopus with Q1 have the potential to be cited more by other authors.

Figure 5 showcases the top authors in our study, whose expertise is evident in the significant number of documents they have published on the topic of ADI in science learning. Their contributions have undoubtedly shaped the discourse in this area.

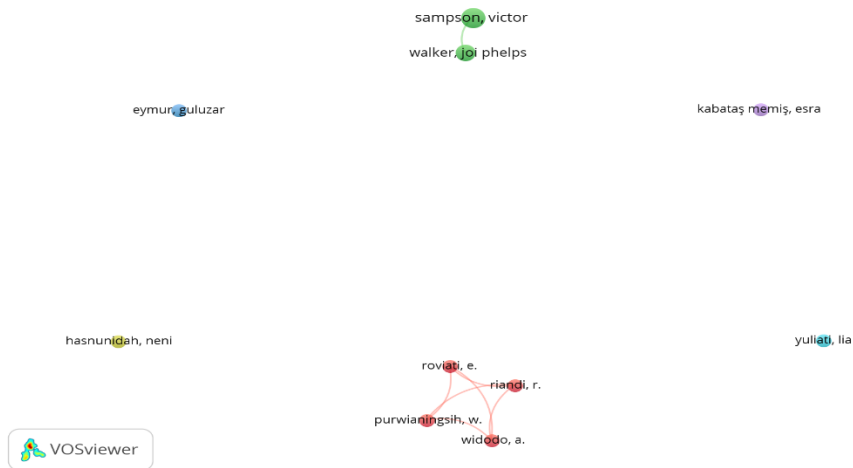


Figure 5. Top Authors by Number of Documents on ADI Topics in Science Learning

Figure 5 shows that the author with the highest number of documents on this topic is Sampson, followed by Walkers. This corresponds to the top 10 authors based on their number of publications, where these two authors have consistently researched ADI in chemistry learning for a long time. Then, in Figure 5, Indonesian writers such as Yuliati integrate ADI in STEM on sound and light waves (Bukifan & Yuliati, 2021; Suganda, 2014).

5) The countries on ADI in science learning

The top 10 countries that research a lot about ADI in science learning are listed in Figure 6.

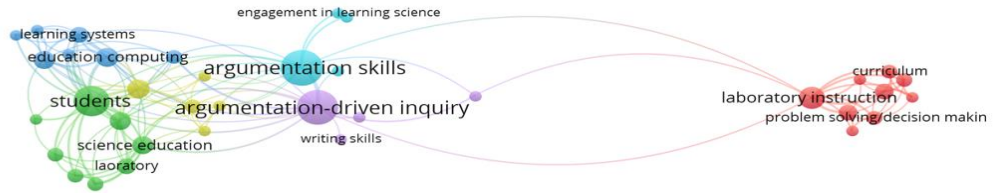


Figure 6. Top 10 Countries on the topic of ADI in Science Learning

In Figure 6, it is shown that Indonesia and the United States are countries whose researchers extensively discuss ADI in science learning. Many Indonesian researchers, such as Yuliati from the State University of Malang (Suganda, 2023, Bukifan, 2021), Roviati, Widodo, Purwianingsih, and Riandi from Universitas Pendidikan Indonesia (Roviati, 2017; Roviati, 2019), are involved in this topic.

6) Result co-occurrence analysis on ADI in science learning

Figure 7 lists the results of a co-occurrence analysis using VOSviewer on the topic of ADI in science learning.



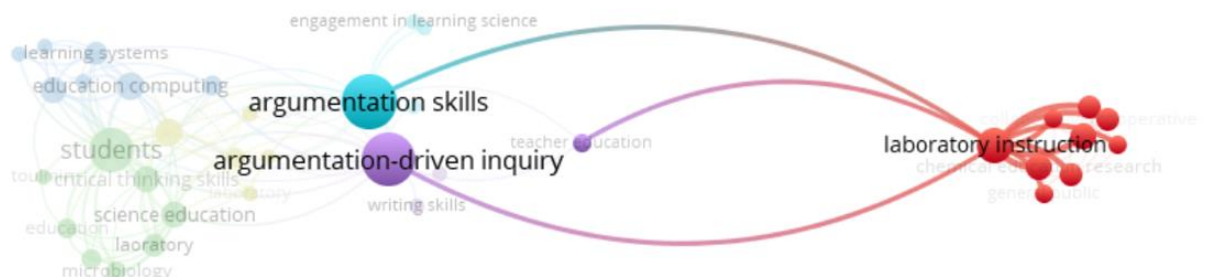
(a)



(b)



(c)



(d)



(e)\

Figure 7. Keyword Mapping Results Are More Specific to The Topics of a) ADI in Science Learning, b) ADI, c) Critical Thinking Skills, d) Laboratory Instruction, and e) Problem-Solving

Based on Figure 7, a network visualization of ADI topics in science learning was obtained into 6 clusters (red, green, yellow, light blue, blue, and purple). Table 2 presents the top 5 keywords in each cluster.

Table 2. Co-occurrence analysis of keywords (Top 5 keywords in the 5 clusters)

No	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
1	Laboratory Instruction (26)	Argument-Driven Inquiry (25)	Students (21)	Argumentation (25)	Education Computing (25)	Inquiry Learning (22)
2	Inquiry-Based/Discovery Learning (15)	Conceptual Understanding (10)	Science Education (11)	Critical Thinking Skills (14)	Learning Models (18)	Scientific Knowledge (12)
3	Collaborative/Cooperative Learning (13)	Teacher Education (4)	Laboratorial (10)	Engagement In Learning Science (4)	Learning Systems (18)	Instructional Model (6)
4	Curriculum (13)	Argumentation Skills (3)	Education (7)	Modified Argument-Driven Inquiry (4)	Quasi-Experiments (8)	Laboratory (6)
5	Problem Solving/Decision Making (11)	Practical Work (3)	Microbiology (6)	Abi (3)	Learning Process (7)	Content Analysis (4)

In Figure 7, it is found that ADI is closely related to scientific argumentation skills and critical thinking skills. This is in line with several existing studies that show that the application of ADI can improve these two competencies. In addition, ADI is also related to laboratory instruction; the name is still rarely discussed, seen from a long distance, as seen in Figure 7. In addition, problem-solving is only related to laboratory instruction; there is no direct relationship between problem-solving and ADI.

Scientific argumentation skills are necessary for students to communicate their viewpoints, make decisions, solve everyday problems, and explain scientific phenomena based on data and concepts learned (Fadillah & Deta, 2020; Songsil et al., 2019). The ADI model is designed to increase student engagement in scientific argumentation and investigative design (Admoko et al., 2021; Antonio & Prudente, 2021; Hasnunidah et al., 2023; Pan et al., 2021; Sunarya et al., 2022; Zheng et al., 2022), motivation (Rahayu et al., 2020), mastery of concepts (Salsabila et al., 2019), conceptual

understanding of students (Kaçar & Balım, 2021; Parno et al., 2021), scientific reasoning (Amelia et al., 2020; Atqiya et al., 2021), critical thinking skills (Kabataş Memiş & Çakan Akkaş, 2020; Sönmez et al., 2021; Undang et al., 2019; Wulandari et al., 2021), science process skills (Arslan et al., 2023), and science generic skills (Siahaan, 2019).

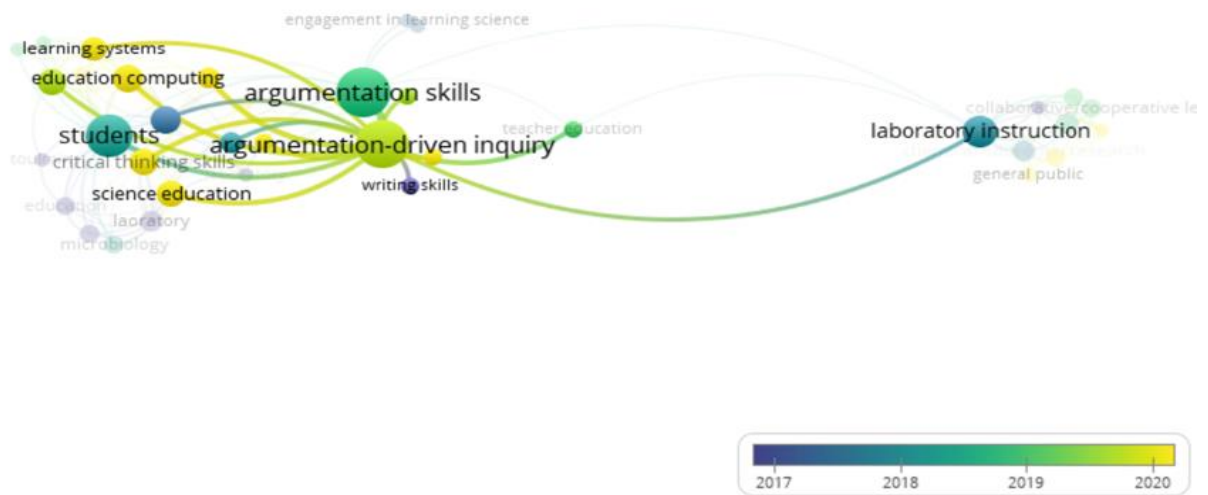
The ADI learning model combines inquiry activities with argumentation (Zheng et al., 2022). The ADI model is an instructional method used in laboratory courses to teach students scientific techniques, including science writing, argumentation and critique, data gathering and analysis, and investigative design. (Hosbein, 2020). The ADI model is intended to help construct arguments and support answers for research issues. To complete their investigations, students must plan and execute them, gather and evaluate data, present and defend their positions to others during interactive debating sessions, create investigative reports to share and record their work and, participate in peer evaluation. This procedure allows students to actively participate in their laboratory education (Sampson & Gleim, 2009). The ADI learning model is laboratory-based. Students must be able to collaborate in groups and present arguments that demonstrate a conceptual grasp to meet ADI requirements (Fadillah & Deta, 2020).

Implementing the ADI model in science learning is applied in several topics: chemistry, physics, biology, and science. Such as salt hydrolysis (Sunarya et al., 2022), chemical equilibrium (Rahayu et al., 2020), metal refining (Sari et al., 2019), chemical laboratory (Hosbein, 2020; Howitz et al., 2023; Sönmez et al., 2021; Yaman & Hand, 2022), buffer solution learning (Pan et al., 2021), Newton's laws (Admoko et al., 2021; Parno et al., 2021), the reaction rate (Amelia et al., 2020; Safitri et al., 2020), sound and light waves (Suganda et al., 2023), electrical energy (Kaçar & Balım, 2021), thermodynamics (Bukifan & Yuliati, 2021), temperature and heat (Priyadi et al., 2020), elasticity (Fadillah & Deta, 2020), force and reaction (Kabatas Memis & Ezberci Çevik, 2018), light (Inthaud et al., 2019), microbiology courses (Roviati et al., 2019), global warming (Salsabila et al., 2019), and environmental pollution (Taufik et al., 2019). However, from this, it can be seen that the application of ADI to physics learning, such as fluid topics, has not been found. This could be an opportunity for further research.

Overlay visualization using VOSviewer on the topic of ADI in science learning is listed in Figure 9.



(a)



(b)
Figure 8. Overlay Visualisation on topics (a) ADI in Science Learning andn (b) ADI

Figure 8 shows that in the last four years, ADI learning has been associated with learning systems, education computing, critical thinking skills, and science education. Figure 8 shows that the distance between ADI and science education and critical thinking skills is still far away. This relationship has begun to be researched in the last three years. Several studies show the application of ADI in science learning, both in physics (Inthaud et al., 2019; Kabatas Memis & Ezberci Çevik, 2018), chemistry (Hosbein, 2020; Howitz et al., 2023; Sönmez et al., 2021; Yaman & Hand, 2022), and biology (Roviati et al., 2019). Apart from that, implementing ADI can improve students' critical thinking skills (Kabataş Memiş & Çakan Akkaş, 2020; Sönmez et al., 2021; Undang et al., 2019; Wulandari et al., 2021).

Conclusion

Based on the results of the analysis, it was found that there has been an increase in the number of publications on the topic of ADI in science learning in the last five years. Articles published on this topic are dominated by articles from Scopus-indexed journals with quartile 1. This corresponds to sources that have published many articles on this topic and authors whose many citations come from these journals. Indonesia has become one of the most productive countries in this area. The visualization results are divided into 6 clusters marked with specific colors. Certain keywords were found that became opportunities for further research, such as critical thinking skills that have not been directly related to ADI in laboratory instruction. Similarly, problem-solving is directly connected to ADI. This has the potential to be further investigated in the future. This research's limitation lies in its data source, which only uses the Scopus database. In the future, this research can use databases from other credible sources, such as the Web of Science (WoS), or combine Scopus and WoS.

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