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Implementation of the Argument-Driven Inquiry (ADI) Model in Physics Learning of 2012-2021: Bibliometric Analysis

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ABSTRACT

Argumentation is a core practice of scientific discourse. One of the problems in learning science is the low level of argumentation skills of students. Efforts to improve argumentation skills include implementing the Argument-Driven Inquiry (ADI) learning model. This study aims to identify the contribution and find out the trend of applying ADI in physics learning in 2012-2021. The method used in this research is a bibliometric analysis based on Scopus data with the help of MS Excel and VOSviewer to visualize the metadata obtained. The results of this study obtained 100 documents. The development of ADI every year does not have a significant increase in the number of publications produced. Research visualization using VOSviewer produces 14 clusters and is closely related to argumentative learning, guided inquiry, and so on. Based on the results of this study, it can be concluded that the ADI has several contributions to science learning, mostly done in Chemistry, and it is still rare in Physics, so it can be an opportunity for further research. It is hoped that further research can discuss more deeply the ADI learning model, which is applied to physics learning to improve students' argumentation skills.

INTRODUCTION

The root of the problem in learning science, especially physics, is the weak argumentative ability of students. Most students today still lack skills in writing scientific arguments and less effective learning methods (Muslim, & Suhandi, 2012). Most teachers still dominate in explaining science material in several schools, so this has an impact on the weakening of argumentation skills by students. The argumentative ability of students is becoming weaker. Because of that, the student's ability to understand the material is decreasing. The weakness of students in arguing is caused by the lack of students' ability to prove evidence and support their arguments. A good argument can be judged by how students understand the material, express opinions that are understood, and are able to convince the interlocutor to accept what is conveyed by him (Sarira et al., 2019). Therefore, the importance of teachers in teaching students to argue in the current century. According to Muhali (2019), the view of education in the 21st century is different from the previous century, which is characterized by developing literacy and collaborating with data, technology, and information.

The advancement of information technology in the 21st century has led to a learning model called the 4c model: critical thinking, collaborative, creative and innovative, and communicative (Sunardi & Doringin, 2020). According to (Gunawan et al., 2017), the 2013 curriculum emphasizes more on several aspects, namely creative, active, innovative, effective, and fun. Skills in conveying arguments, creative thinking, and skilled in Communicating these four aspects must be possessed by students to live life in the 21st century easily (Andrian & Rusman, 2019). Learning with the Argument-Driven Inquiry (ADI) model has some special emphasis on implementing it. The Argument-Driven

Inquiry (ADI) model is a learning model that aims to emphasize learning by facilitating students and investigating in order to understand the concept of learning Natural Sciences, especially physics (Rahayu et al., 2019). The involvement of students in arguing about a process and physics concept is very important and relevant, especially in the 21st century today, so that it can help them in learning after (Ping & Osman, 2019).

The application of the ADI learning model is important because it teaches students the epistemology of knowledge. In this model, students are required to test the truth of knowledge through an argumentative discussion based on the evidence of the data and facts they have. The ADI learning method supports the development of student's ability to argue for the better (Demircioğlu & Uçar, 2012; Hidayat, 2017; Marhamah et al., 2017). Meanwhile, according to Sampson, the importance of ADI model because it can influence students to be able to increase their level of scientific argumentation skills and be able to participate properly.

There are several studies discussing the ADI model, for example from (Hanifah & Admoko, 2019) on the application of the argument-driven inquiry (ADI) learning model to train high school students in scientific argumentation skills. However, no articles have been found that discuss the bibliometric analysis of the implementation of the ADI learning model, especially its relation to thinking skills. Bibliometric analysis is a useful application to get a new picture/idea about the current scientific situation, and research in a particular field and allocate researchers to identify and conduct new research of various kinds (Zyoud et al., 2014). In this study, bibliometric indicators are used to explain the results of physics research around the world over the last ten years(Amiruddin et al., 2022; Kahl, 2015). Therefore, this researcher will conduct a bibliometric analysis of ADI in the last ten years (2012-2021). This research is expected to find out patterns, search trends, novelty, and education in the future. Specifically, the core objects of this research are as follows:

1. How are the year-wise distribution and document type related to the ADI learning model in the last ten years?
2. How are the top source titles, top subject areas, and top keywords related to the ADI learning model in the last ten years?
3. Who are the top productive authors from the top 10 papers and top countries based on the origin of the Author from the ADI learning model?
4. Who were the top affiliates over the last ten years in the ADI learning model?
5. What is the trend of visualization of ADI models in the last ten years?

RESEARCH METHOD

This research utilizes many sources like journals, conferences, proceedings, and books and uses bibliometric analysis to describe the results of all the sources (Admoko et al., 2021a). This study uses bibliometric analysis to describe the results of journal publications (Amielia et al., 2018; Farida et al., 2018). Bibliometric analysis is a technique that can be used to provide a structure that refers to several questions, the main topics in a particular science, how topics can relate to each other, and how topics can evolve over time. The bibliometric analysis is intended to obtain descriptive data and findings on various issues of publication of the ADI learning model. With this analysis, it is hoped that a comprehensive and accurate picture of publication trends or the development of publications and collaborations between authors in their respective subject areas can be obtained. This research is a type of literature study using bibliometric analysis method.

The approach used in this study is a qualitative approach. Bibliometrics can be used to measure or analyze books and literature with the help of statistical and mathematical approaches (Diodato & Gellatly, 2013). The data used in this study is in the range of 2012-2021, which is secondary data from the Scopus database, which was accessed in May 2022. Based on the Scopus database obtained, then stored in the form of Ris processed using the VOSviewer application until further analysis (Effendy et al., 2021; Tupan, 2016). One of the free programs that can be used to visualize and explore bibliometric knowledge maps is VOSviewer (Leydesdorff & Rafols, 2012; Hidaayatullaah et al., 2021). The stage of visualizing raw data so that it becomes tables, graphs, and maps can use Microsoft Excel applications. Figure 1 is a bibliometric research flowchart.

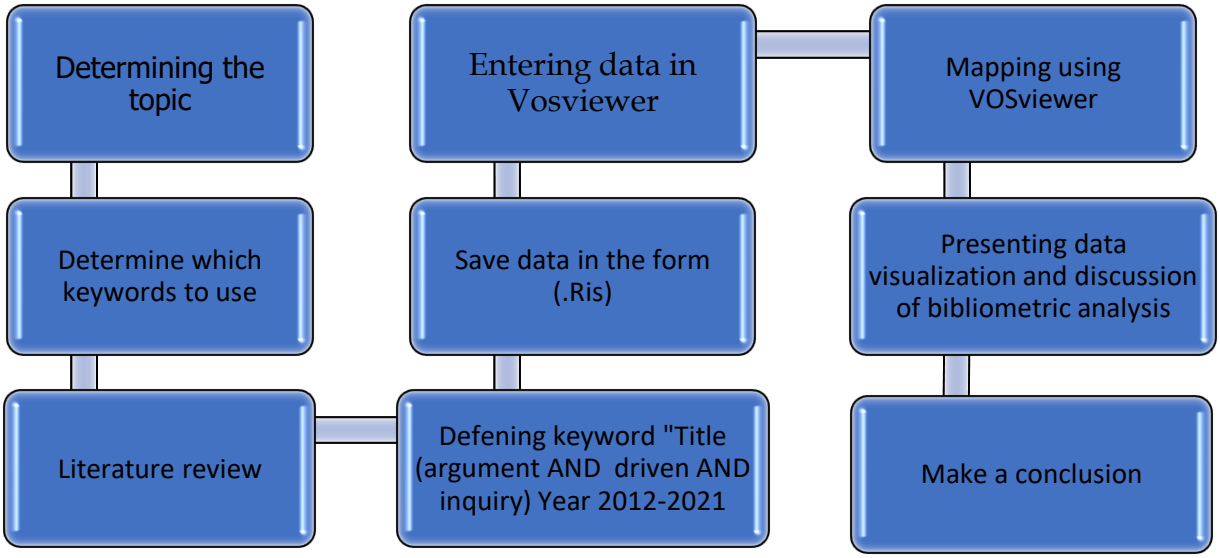


Figure 1. Flowchart research (Dewi & Jauhariyah, 2021; Suliyanah et al., 2021).

The researcher conducted an online search on May 14, 2022. The topic the researcher chose was the bibliometric analysis of argument-driven inquiry models in physics learning with the keywords argument and driven and inquiry. Then the researchers got the results of 100 documents after sorting them according to keywords that met the criteria for 2012-2021. The data is documented in the form (.Ris), and then the data is entered into the VOS viewer. Vosviewer is used to map the data and get the results of data visualization and discuss bibliometric analysis. After obtaining data that fits the criteria, researchers can make conclusions.

RESULTS AND DISCUSSION

Year-wise Distribution and Document Type

Research publications on Argument-Driven Inquiry during the last ten years can be seen in Figure 2. It can be seen that in the number of Argument-Driven Inquiry research each year, there is no significant increase in the publications produced. The year 2019 was the year with the most publications, with 18 publications, and the least occurred in 2012, with five publications. Seen in 2020-2021 there was a slight increase from 16 publications to 17 publications. However, in 2018-2019 where the increase in the number of publications was high by 12. In 2013-2014 there was a decrease from the initial nine publications to 6 publications. Meanwhile, the same thing happened in 2016-2017 and 2019-2020, where

there was a decrease of 5 and 1 publication. These results are in accordance with research (Hakim, 2020) which also found that 2019 was the year with the most publications.

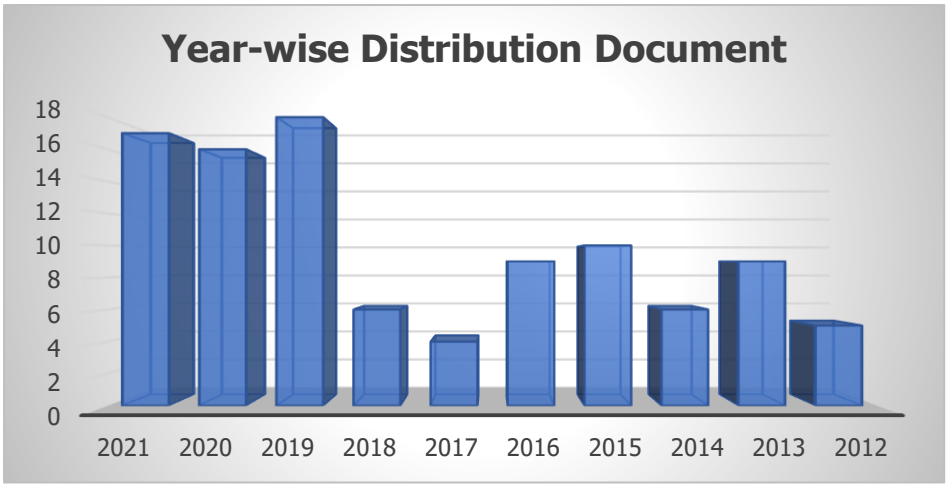


Figure 2. Year-wise distribution document on argument-driven inquiry.

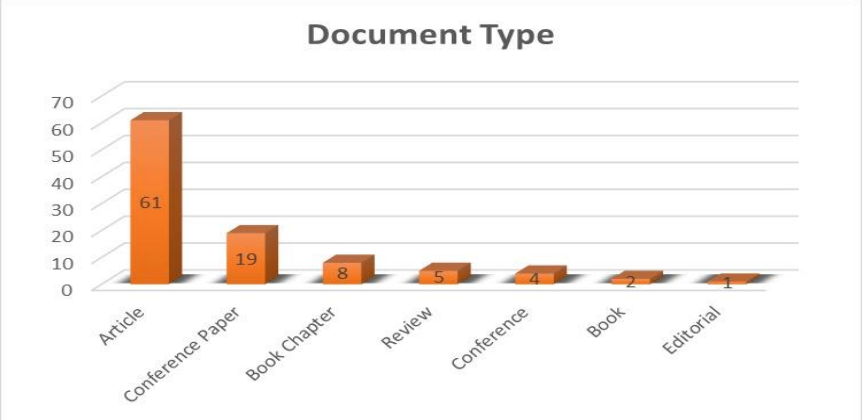


Figure 3. Document type of argument-driven inquiry.

Sources of documents in the Argument-Driven Inquiry research for the last ten years can be seen in Figure 3. Based on the results shows that there are 100 documents related to the Argument-Driven Inquiry research in the Scopus database, including 7 document sources (editorial, book, conference, review, book chapter, conference papers, and articles). From the figure, it can be seen that the types of documents are dominated by articles with 61 documents, then 19 documents conference papers, 8 book chapters, 5 review documents, 4 conference documents, 2 books, and 1 editorial document. This result is in accordance with research (Ulya, 2019) which also found that the type of document is dominated by articles.

Source Title, Subject Area, and Keyword

Table 1. Top 10 Source title, subject area, and keywords during the last ten years.

Top Source		Top Subject Area		Top Keyword	
Source Title	**Total**	**Subject Area**	**Total**	**Keyword**	**Total**
Journal Of Physics Conference Series	10	Social Sciences	70	students	12
Journal Of Chemical Education	8	Physics and Astronomy	18	Argumentation	11
AIP Conference Proceedings	7	Arts and Humanities	12	Argument-driven Inquiry	9
International Journal Of Science Education	5	Chemistry	10	Laboratory Instruction	9
Journal Of Turkish Science Education	3	Psychology	9	Chemical Education Research	8
Horizons of Education	2	Mathematics	6	Education Computing	5
Chemistry Education Research And Practice	2	Computer Science	5	Conceptual Understanding	4
Childhood And Philosophy	2	Business, Management, and Accounting	3	Problem-Solving/Decision Making	4
Communications In Computer And Information Science	2	Nursing	3	Argument-Driven Inquiry	3
International Journal Of Research In Education And Science	2	Decision Sciences	2	First-Year Undergraduate/General	3

Table 1. shows the top 10 source titles, subject areas, and keywords used in the last ten years. In ADI, the highest source title is "Journal of Physics Conference Series" with ten documents, followed by "Journal of Chemical Education" with eight documents, "AIP Conference Proceedings" with seven documents, and so on. Meanwhile, the highest subject area is Social Sciences (70), followed by Physics and Astronomy (18), Arts and Humanities (12), and so on. The Journal of Physics Conference Series is closely related to the progress of articles discussing ADI in physics learning, such as research (Admoko et al., 2021b)

In the distribution of the top 10 subject areas used in the last ten years, the highest subject area was achieved by Social Sciences (70), followed by Physics and Astronomy (18), Arts and Humanities (12), Chemistry (10), Psychology (9), Mathematics (6), Computer Science (5), Business, Management, and Accounting and Nursing (3). Meanwhile, Decision Sciences (2) is in last place. Furthermore, Table 1 describes the distribution of the top 10 keywords used in the article for the last ten years. The highest keywords from the Argument-Driven Inquiry publication are students (12), then the next order is argumentation (11), Argument-driven Inquiry (9), Laboratory Instruction (9), Chemical Education Research (8), Education Computing (5), Conceptual Understanding (4), Problem Solving/Decision Making (4). Meanwhile, Argument-Driven Inquiry (3) and

First-Year Undergraduate/General (3) are in last place. The keyword "Chemical Education Research" is included in the top 10 keywords; this shows that the research on the application of the ADI model is mostly done in Chemistry lessons. Meanwhile, the "physics" keyword did not appear in the top 10 keywords, and this shows that the application of the ADI learning model in physics lessons has not been widely researched. The student keyword is closely related to ADI because in the sample research tested, there are students, such as research (Hasnunidah et al., 2015).

Top 10 Authors Based on Author Productivity

Table 2 shows the top 10 authors based on the number of the document. In the ADI, the highest ranking authors were Walker, JP with seven documents, followed by Sampson, V. and Eymur, G. with four documents, Schwartz, RS, Enderle, PJ, Diantoro, M. and Cetin, PS in position next with three documents, and finally, Chen, HT, Budiasih, E. and Antonio, RP are in the last position with two documents.

Table 2. Top 10 authors during the last ten years.

Author	Document	Countries
Walker, JP	7	Australia
Sampson, V.	4	United States of America
Eymur, G.	4	Turkey
Schwartz, RS	3	Australia
Enderle, PJ	3	United States of America
Diantoro, M.	3	Indonesia
Cetin, PS	3	Turkey
Chen, HT	2	United States of America
Budiasih, E.	2	Indonesia
Antonio, RP	2	Brazil

In Table 2, the top 10 countries based on author productivity with the highest level is the United States with a total of 3 authors, then followed by Indonesia, Turkey, and Australia with two documents, then for the last position is Brazil with 1 document. For more clear, it can be seen in Figure 4.

Figure 4. Visualization of top 10 authors.

Affiliation

Figure 5. depicts the top 10 affiliates during the last ten years. Based on affiliation, it ranks at the top with a total of 9 published articles. Then followed by Florida State University and East Carolina with a total of 5 published articles. Furthermore, Bolu Abant Izzet Baysal University, University of Indonesia Education, and Giresun University with a total of 4 article publications. The next position was followed by Georgia State University and Tallahassee Community College, with a total of 3 article publications, and the last position was occupied by Pennsylvania State University and Universiti Kebangsaan Malaysia, with a total of 2 article publications. The State University of Malang is the highest affiliate because it has a great influence on ADI in physics, such as research (Jauwad et al., 2021).

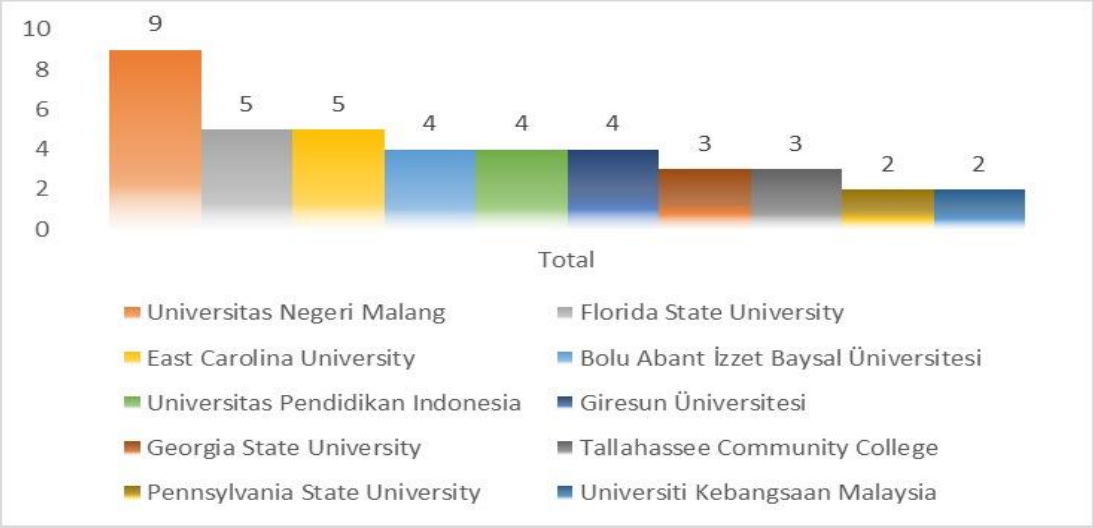


Figure 5. Top 10 affiliates during the last ten years.

Vosviewrs analysis

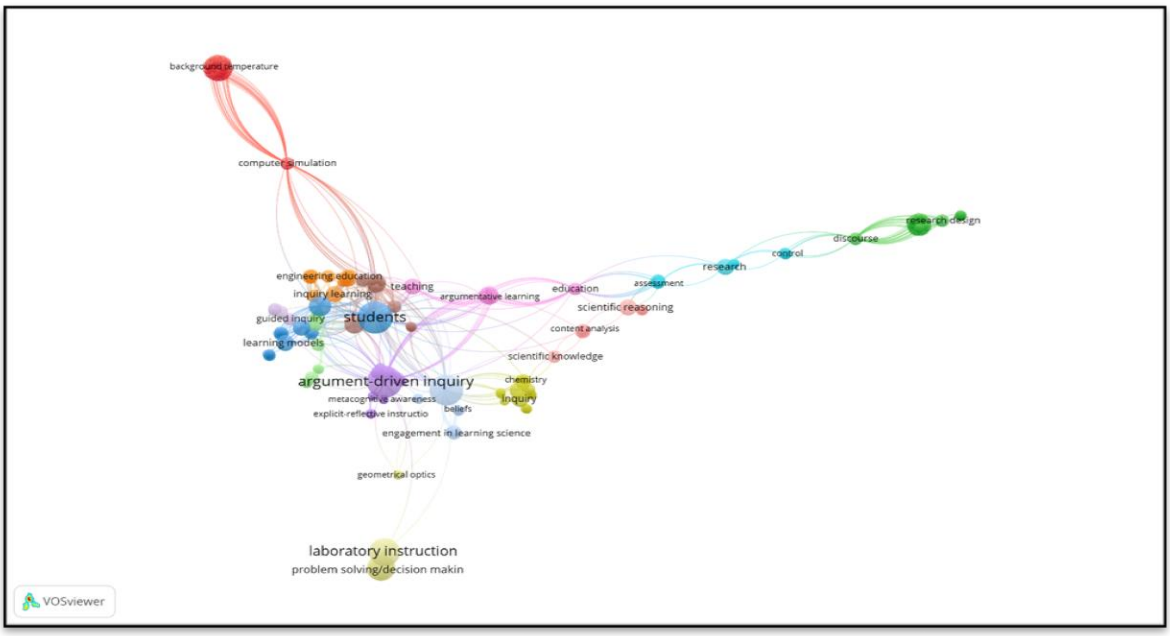
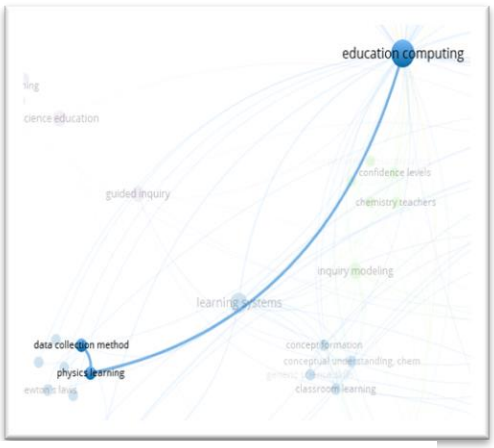


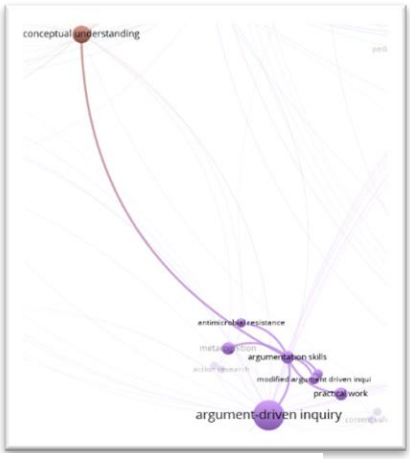
Figure 6. Mapping result visualization of argument-driven inquiry.

Figure 6 shows the results of the visualization of argument-driven inquiry in VOSviewers. The visualization of ADI, relates to argumentative learning, guided inquiry, learning models, education, and so on. Visualization of argument-driven inquiry there is 14 clusters. The first cluster (n=28 items) consists of background temperature, collective instability, computer simulation, convection, double diffusion, and so on. The second cluster (n=27 items) consists of complexity, conceptual framework, design, and so on. The third cluster (n=20 items) consists of classroom learning, concept formation, conceptual understanding of data collection methods, education computing, and so on. The fourth cluster (n=20 items) consists of argument, attitude, chemistry, chemistry education, chemistry proficiency, and so on. The fifth cluster (n=18 items) consisted of action research, antimicrobial resistance, argument-driven inquiry, argumentation skills, basic biological concepts, and so on. The sixth cluster (n=18 items) consists of assessment, content knowledge, control, disenchantment, doctoral education, and so on. The seventh cluster (n=18 items) consists of control groups, direct transfer, engineering education, experimental groups, global warming, etc. Cluster eight (n=17 items) consisted of computational experiments, computer-aided instruction, conceptual understanding, epistemological beliefs, experiments, and so on. The nine clusters (n=15 items) consist of argumentative learning, argumentative skills, big6 models, classroom teachers, curriculum, and so on. The ten clusters (n=15 items) consist of content analysis, curiosity, data handling, exploration, information analysis, and so on. Eleven clusters (n=14 items) consist of academic abilities, chemistry teachers, community-based resource management, confidence levels, critical thinking skills, and so on. In cluster twelve (n=14 items) consisting of argumentation, beliefs, collaborative discussion, cooperative discussion, elementary school children, and so on. The thirteenth cluster (n=13 items) consists of chemical education research, communication/writing, first-year undergraduate/general, the general public, geometrical optics, and so on. The fourteen clusters (n=8 items) consist of: evaluated data, guided inquiry, mathematics education, mathematics learning, primary school, and so on.

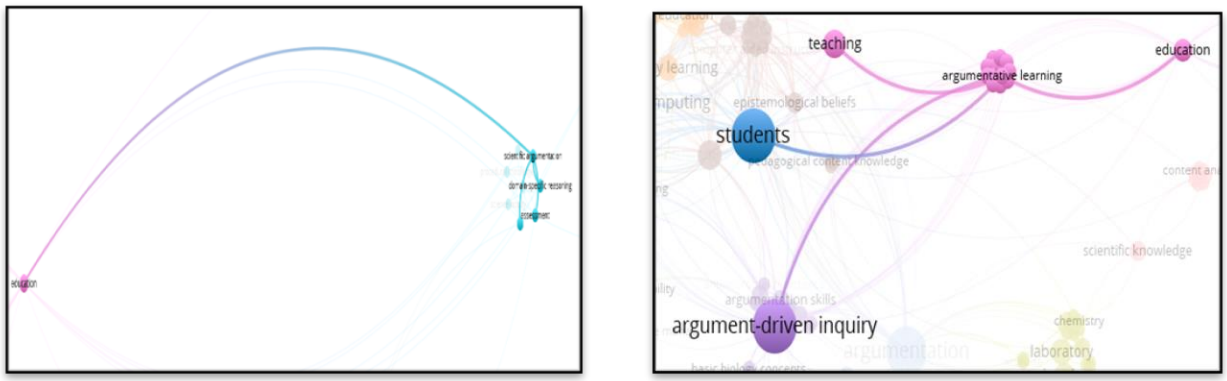
Figure 7(a) shows that physics learning is closely related to data collection methods and education computing. Then in Figure 7(b) shows that Argument-Driven Inquiry skills are closely related to conceptual understanding, modified argument-driven inquiry, and others. Figure 7(c) shows that scientific argumentation is closely related to domain-specific reasoning, education, and others. Figure 7(d) shows that argumentation learning is closely related to argument-driven inquiry, students, education, and others.



(a)



(b)



(c) (d)

Figure 7. Some examples of more specific Argument driven inquiry Mapping results on the topic of (a) physics learning, (b) argument-driven inquiry skills, (c) scientific argumentation, and (d) argumentation learning.

Contribution of Argument-Driven Inquiry to Learning Physics

To find out in more detail how ADI contributes to science learning, especially physics, it is necessary to review several articles that discuss its application in science learning so that the information obtained is truly valid. The review results are shown in Table 3.

Table 3. ADI's contribution to learning science

Title	Author	Citation	Findings	Suggestion
Writing to learn by learning to write during the school science laboratory: Helping middle and high school students develop argumentative writing skills as they learn core ideas (Sampson et al., 2013)	Sampson, V., Enderle, P., Grooms, J., Witte, S.	71	Learning outcomes students can be measured using scientific assessments and special scientific argumentative writing and are carried out at the beginning, middle, and end of the school year. Students show a change in performance on the two assessments over time.	Further research is needed on the identification of ADI elements that can be changed according to teacher adaptation and elements that cannot be changed.
Argument-driven inquiry: Using the laboratory to improve undergraduates' science writing skills through meaningful science writing, peer-review, and revision (Walker & Sampson, 2013)	Walker, JP, Sampson, V.	58	The results of quantitative and qualitative analysis derived from reports and reviews provide evidence that participants get an increase in writing skills in science and be able to evaluate the quality of their colleagues' writing	recommended that writing assignments emphasize ideas and increase arguments, not only emphasize the writing mechanism because it can help students understand the content of the writing.

Title	Author	Citation	Findings	Suggestion
The influence of the explicit nature of science instruction embedded in the Argument-Driven Inquiry method in chemistry laboratories on high school students' conceptions of nature (Eymur, 2019)	Eymur, G	11	The results of the study showed significant differences between the pre- to post-test scores for the explicit group in terms of NOS view. However, the post-instruction views of the implicit group showed no difference from their previous NOS views. But it can be believed that the explicit nature of science instruction embedded in the ADI method has real potential and aims to improve secondary school students' views on NOS.	This study shows that the explicit nature of science instruction embedded in the ADI method is effective for developing NOS conceptions in eleventh graders. The ADI model of instruction provides opportunities for students to develop arguments that include explanations for research questions. By doing this, students need to develop their own methods for collecting and analyzing data, discuss and verify their ideas in argumentation sessions, write investigative reports to represent their ideas in scientific writing, and engage in peer review.
Argument-driven inquiry for STEM education in physics: Changes in students' scientific reasoning patterns (Atqiya et al., 2021).	Atqiya, N., Yuliati, L., Diantoro, M.	0	ADI for STEM Education into argument-based inquiry learning. Can help students to apply the engineering process (investigating problems, making solutions, and identifying them)	ADI for STEM learning is recommended to be innovative learning that can cause a good sense of scientific thinking.

Based on the results of a review of articles on the application of the ADI learning model in science education, positive impacts were obtained including: increasing learning achievement based on student assessment results (Sampson et al., 2013), improving students' written argumentation skills and the ability to evaluate writing quality (Walker & Sampson, 2013), improving science process skills: collect data, analyze data, verify ideas and engage in peer review (Eymur, 2019), improve conceptual understanding (Atqiya et al., 2021) and encourage scientific thinking (Bukifan & Yuliati, 2021). The results of this review are in line with what was stated by Driver, who stated that the main role of argumentation in science education is to develop conceptual understanding, develop competence in conducting investigations, understand the epistemology of science and understand science as a social practice (Driver et al., 2000). Based on these findings, the application of argumentation-based learning, such as the ADI model, is

needed in science education, especially physics learning, which teaches a lot of concepts. Further application of the ADI model is recommended to be combined in STEM learning (Atqiya et al., 2021; Bukifan & Yuliati, 2021) and emphasizes more on emphasizing the emergence of ideas and improving the quality of argumentation, not just a mechanism in arguing so that students can understand the content discussed in more depth (Walker & Sampson, 2013). This recommendation will open further research opportunities in the application of the ADI learning model in physics learning to improve students' argumentation skills and develop conceptual understanding, develop competence in conducting investigations, understand the epistemology of science and understand science as a social practice.

CONCLUSION

Based on the results of the analysis and discussion, it is known that the development of ADI articles in 2012-2021 every year does not have a significant increase in the number of publications produced. The year 2019 was the year the most documents were produced, with as many as 18 publications, and the year the least occurred in 2012, with five publications. Then the document type section is dominated by articles with a total of 61 documents. Research visualization using VOSviewers produces 14 clusters and is closely related to argumentative learning, guided inquiry, learning models, education, and so on. Visualization of "physics" in VOSviewers shows that the relationship is very limited; physics learning is closely related to data collection methods and education computing. The keyword "Chemical Education Research" is included in the top 10 keywords. This shows that the research on the application of the ADI model is mostly done in Chemistry lessons. Meanwhile, the "physics" keyword did not appear in the top 10 keywords, this shows that the application of the ADI learning model in physics lessons has not been widely researched. Review articles on the application of the ADI in science education have positive impacts, including increasing learning achievement, improving students' written argumentation skills and the ability to evaluate writing quality, improving science process skills, improving conceptual understanding, and encouraging scientific thinking. Based on the results of this study, it can be concluded that the ADI has several contributions to science learning, mostly done in Chemistry, and it is still rare in Physics, so it can be an opportunity for further research. So, it is hoped that the next research can be discussed more deeply the ADI learning model, which is applied to physics learning to improve the argumentation skills of students.

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