International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 4, August 2024, pp. 2126~2138
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i4.26374

Scientific argumentations research for last 10 years: analysis bibliometric

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Article Info

Article history:

Received Dec 24, 2022
Revised Mar 23, 2023
Accepted May 19, 2023

Keywords:

Bibliometric
Education
Research trends
Science
Scientific argumentation

ABSTRACT

The topic of scientific arguments is crucial to discuss because it is one of the basic sciences that has close links with other topics. Moreover, this science has a close relationship with the skills of the 21st century today. This study aims to reveal the current trends in the scientific argumentation field for the last 10 years based on the Scopus database. This study uses quantitative research through bibliometric studies with the keyword scientific argumentation year. The results of this study indicate that the number of article publications during the years 2012 to 2021 on the topic of scientific argumentation has increased on average. However, the most visible increase was in 2018-2021. The United States, Indonesia, and Germany dominated the publication of scientific argumentation topics from 2012 to 2021. As for the top authors were from the United States and Germany. Furthermore, in scientific argumentation, dominated by subject areas based on science, keywords used are argumentation, students, and scientific argumentation. There were several suggestions for the research, namely: i) the need for further research, especially on the differences and similarities of each argumentation; ii) the need to discuss the appropriate scope of argumentation at the appropriate learning level; iii) collaboration between universities that have a focus on this argumentation field. It is highly recommended that the research be more robust; and iv) future research must adapt to the current development of arguments so that the topic does not decline but continues to become the basis for studying other sciences.

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1. INTRODUCTION

Scientific argumentation skills are essential skills in the 21st century. This follows the 21st-century goals, which require society, especially students, to master 21st-century skills, namely collaborations, communication, critical thinking, and creativity (4c) [1]–[4]. Critical thinking is closely related to scientific argumentation skills. In line with previous research, scientific argumentation influences critical thinking skills [5]–[8]. In addition, it turns out that scientific arguments also have a relationship with communication skills. This is proven by the results of several researches [9]–[12], which stated that researchers use communication skills to convey the results of their research that scientific arguments in their presentation must accompany. The adaptations from Erduran's book [13] are potential contributions to the argument. Figure 1 presents how argumentation exists between scientific argumentation, argumentation theory, and 21st skills.

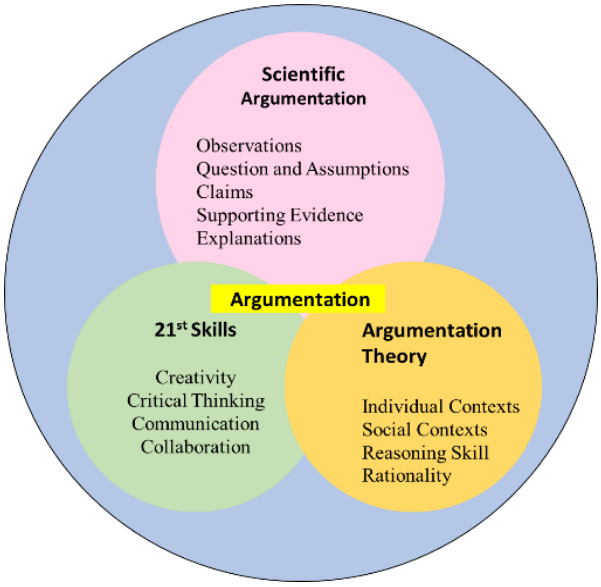


Figure 1. Potential contribution from argumentation

Scientific argumentation can help the community, especially students, to improve argumentation skills and achieve the demands of the 21st century. Based on Figure 1, the potential contribution of argumentation is very linear with the demands of the 21st century. However, improving scientific argumentation skills takes work. This requires a variety of ways to improve these skills. According to several researches [5], [14], [15], to improve scientific argumentation, students must use many appropriate ways, including carrying out a learning approach, structured teaching, using contextual issues, and providing clear goals for the argument itself. In addition, the results of previous research [16]–[18] stated the need for an instructional approach with a learning model to train students' argumentation. In addition, previous studies in Indonesia [19]–[21] showed that the results of the argumentation of students obtained are still in the low category. Moreover, based on research conducted in Thailand and harmonized with the program for international student assessment (PISA) database showed that literacy skills decrease along with the decline in students' scientific argumentation skills [22]–[24]. This indicates a close relationship between scientific argumentation and 21st-century skills.

Furthermore, based on the previous discussion, scientific argumentation is critical to learn. This is because the contribution of scientific argumentation is needed, especially in the 21st century [25]–[27]. However, based on Scopus data as of April 20, 2022, publications indexed internationally throughout the year related to scientific arguments only contain 290 documents. After that, it was again limited to 2012 to 2021, which contained 229 documents. In this case, Scopus publications indexed at the international level are certainly not young because they require different research topics than before. In line with previous studies [28]–[30], to increase publication, one way that can be used is to follow the current developing trend.

Based on the description, this topic of scientific argumentation becomes essential to discuss. This is because scientific argumentation has a close relationship with 21st-century skills, so it is necessary to identify the similarities and existing contributions of scientific argumentation to assist future research. This research has a specific objective: to identify and explore research trends related to argumentation over the last 10 years. That way, it can become basic information and focus on future research related to topics that are under scientific arguments. Therefore, there are several questions to help answer trends related to the topic of scientific argumentation over the last 10 years:

Q1: How many publications on scientific arguments have been published in Scopus for 10 years?
Q2: How is the pattern of publication of the on-based 10 years of scientific argumentation top 100 cited?
Q3: What are the types of publications of argumentation for 10 years?
Q4: Who has been the most active writer on scientific argumentation for 10 years?
Q5: What is the level of productivity of countries in the world on the topic of scientific argumentation for 10 years?
Q6: How is the map to visualize scientific arguments for 10 years?
Q7: How are the findings and recommendations of top 5 cited in scientific argumentation during 10 years?

2. RESEARCH METHOD

The type of research is quantitative, with bibliometrics following the steps of several studies [31]–[33]. The data source was obtained from the Scopus database with the keyword "scientific argumentation" search within the article title. The search was started twice throughout the year and then narrowed to the last 10 years. The data was taken on April 20, 2022, from the Scopus database.

Afterward, the data obtained will be stored and analyzed using Microsoft Excel and VOSviewer software to help visualize the retrieved data. The use of Microsoft Excel and VOSviewer will help in finding the most solid topics related to scientific arguments [34]–[36]. After that, the data that has been obtained and visualized will be described in detail. To provide a simple and understandable overview, Figure 2 presents the research flowchart.

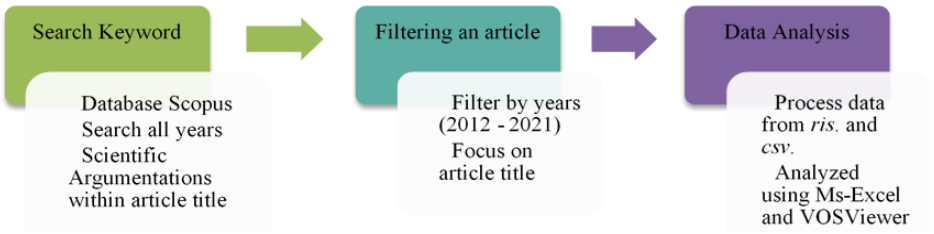


Figure 2. Flowchart of filtering and data collection

3. RESULTS AND DISCUSSION

3.1. The last publication by year

Based on the Scopus database with the keyword scientific argumentation in the article title, 229 documents were obtained throughout the year. Up and down of publications in a field will occur, this is as shown in the topic of scientific argumentation. Figure 3 presents data per year from 2012 to 2021.

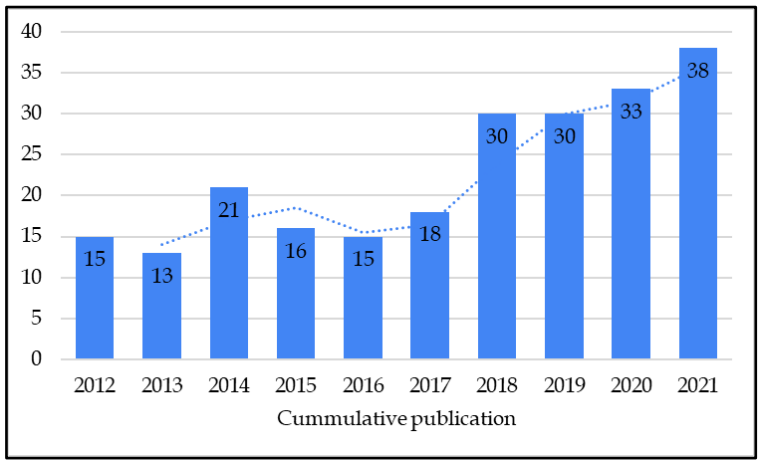


Figure 3. Trend publication on scientific argumentation

Figure 3 shows a graph of cumulative publications throughout the year for scientific argumentation research topics obtained based on the Scopus database. In this case, the number of publications every year for the last 10 years can be seen. From 2012 to 2017, the number of documents published still needed to be consistent. In this case, there is an increase in the number of publications in that year. Based on the results of more profound observations, one of the causes of the ups and downs of publications was that the trend of research topics that year needed to focus on scientific argumentation. While the number of publications in 2018 to 2020 is relatively the same. In addition, in 2018 to 2021, relative increase in the number of publications. This can happen because, in recent years, scientific argumentation has become one of the essential topics to support the achievement of 21st-century educational skills targets [37]–[39].

After exploring further information from the Scopus database obtained in 2012 and 2013, the most widely discussed subject areas are social sciences, arts and humanities, and computer science. In 2014, the most frequently discussed subject areas were social science, computer science, and psychology. In 2015, the most frequently discussed subjects were social sciences, computer science, and agricultural and biological sciences. In 2016, the most frequently discussed subject areas were social science, arts and humanity, and chemistry. The most frequently discussed subject areas in 2017, 2019, and 2020 were social sciences, physics and astronomy, and computer science. In 2018, the most frequently discussed subject areas were social sciences, computer science, and mathematics. In 2021, the most frequently discussed subject areas were social sciences, physics and astronomy, and art and humanities. Thus, the most widely discussed subject area is related to social science. Social sciences are too important because they are closely related to humans and their behavior [40]–[42].

3.2. The distribution of scientific argumentation year based on top 100 cited

The data reveals that the number of publications discussed in Figure 3 differs significantly from those based on top citations. In this case, a large number of publications is only sometimes followed by many citations. Table 1 shows distributions of scientific argumentation based on the top 100 cited for the last 10 years. Based on top citations in the last 10 years, the highest number of documents was in 2018 (20 documents). Then followed in 2015 (13 documents) and 2014 and 2019, respectively (12 documents).

If examined more closely, the highest number of papers was found in 2018. However, the highest number of citations was in 2012. Furthermore, based on the number of citations, the highest number of citations was in 2012 with the number of citations 540 cited, followed by 2014 as many as 393 cited, and 2015 with 367 cited. Under the results of research [43]–[45], it says that the number of citations is identical to the quality of the article. Based on this, many publications only affect the number of citations.

Table 1. Distribution of scientific argumentation

Year	Paper	Cited	Average citation per paper	Average citation per paper per year	Citable years
2012	10	540*	54.00*	5.40*	10
2013	7	300	42.86	4.76	9
2014	12	393	32.75	4.09	8
2015	13	367	28.23	4.03	7
2016	7	147	21.00	3.50	6
2017	8	62	7.75	1.55	5
2018	20*	298	14.90	3.73	4

*= the highest number

3.3. The document type, source type, source title, and subject area

Research topics related to scientific argumentation in 2012 to 2021 based on the Scopus database are presented in Figure 4 for the document type, Figure 5 for the source type, Table 2 for the source title, and Figure 6 for the field of science. From this, it can be known how the types of documents, sources, titles, and fields of science have the most relationship with scientific argumentation. That way, the information presented can be a new picture for the future.

Figure 4 presents the results of document types on scientific argumentation for the last ten years. Based on the data, the document type is dominated by articles (135 documents), conference papers (73 documents), book chapters (15 documents), books (2 documents), reviews (2 documents), and editorials (1 document). Thus, most publications on research topics based on the Scopus database are articles. Usually, scientific articles will discuss a discovery from what already exists. In addition, articles undergo a fairly rigorous process before being published so that the originality of the article can be trusted. Moreover, of course, they are closely related to the source type as shown in Figure 5.

Figure 5 presents the source type of scientific argumentation research topics during the last 10 years based on the Scopus database. Based on the data, the highest number is output from journals (143 documents), conference proceedings (64 documents), books (16 documents), and book series (6 documents). A large number of published articles come from journal sources.

Table 2 presents source titles of scientific argumentation research topics (2012 to 2021). Based on the Scopus database described in Table 2, it can be seen that the source title is dominated by the Journal of Physics Conference Series, followed by AIP Conference Proceedings and the International Journal of Science Education. This is proven based on the data that has been discussed previously that the most significant number of publications comes from publications in journals. Furthermore, Figure 6 shows the most subject areas use scientific arguments.

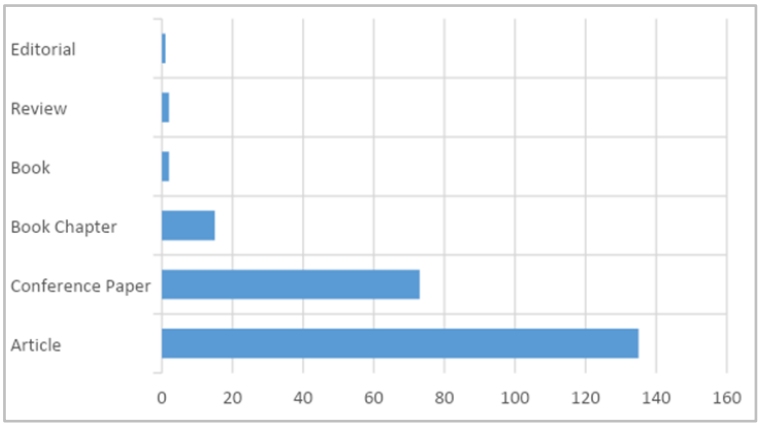


Figure 4. Document type on scientific arguments

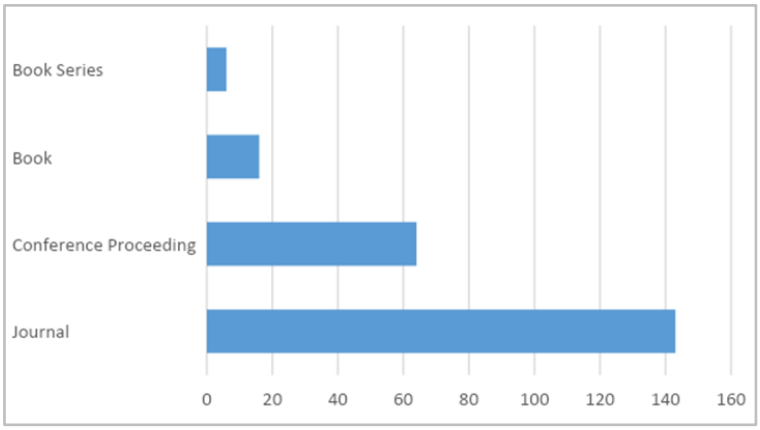


Figure 5. Source type of scientific argumentation

Table 2. Source title on scientific arguments

Source title	Total
Journal of Physics Conference Series	22
AIP Conference Proceedings	13
International Journal of Science Education	13
Journal of Research in Science Teaching	7
Proceedings of International Conference of The Learning Sciences	7
Eurasia Journal of Mathematics Science and Technology Education	6
Perspectives on Scientific Argumentation Theory Practice and Research	6
Coeur Workshop Proceedings	5
Scientific Reasoning and Argumentation the Roles of Domain-Specific and Domain-General Knowledge	5
Computer-Supported Collaborative Learning Conference	4

Figure 6 presents the most widely used subject areas in scientific argumentation research topics from 2012 to 2021. In this case, the subject area is dominated by social sciences (52%), followed by computer science (14%), and physics and astronomy (11%). However, it is entirely dominated by science-based subjects. This is because the role of scientific argumentation for science is enormous [46]–[48].

3.4. Top country, affiliation, author, and keyword

Scientific argumentation research topics based on the Scopus database in the years 2012 to 2021. Searches related to top countries, affiliations, and keywords are necessary and can provide deeper information on the topics studied. For more details, Table 3 presents the top countries and affiliations, Table 4 presents the top authors, and Table 5 presents the keywords.

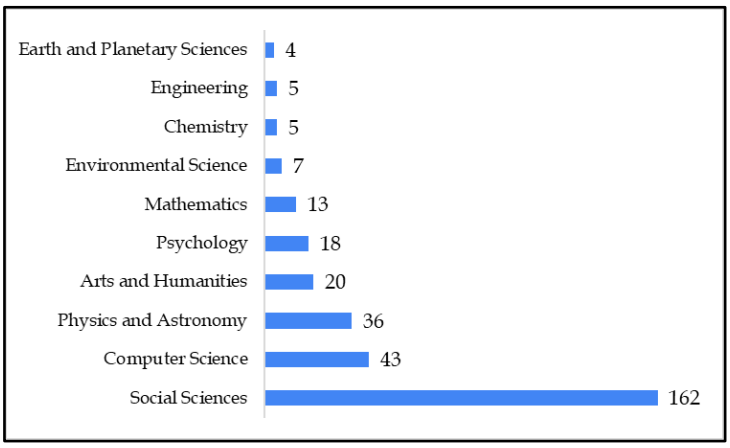


Figure 6. The subject area of scientific arguments

Table 3 shows the top 10 countries and affiliations in scientific arguments for the last 10 years. If we look at the data, the country that ranks first in the field of scientific argumentation over the past island years is the United States (66 documents), Indonesia ranks second (39 documents), Germany ranks (22 documents), and others can be seen in Table 3. Then for affiliates, the first rank is Boston College (12 documents), the second rank is Ludwig-Maximilians-Universität München (11 documents), and the third rank is Universitas Negeri Malang (11 documents). For the others, it can be seen in Table 3. From the description data, it can be seen that top county no and top affiliation are not always the same. This is because, in a country, there are certainly so many targets, respective.

Table 3. Top 10 countries and affiliates

Country	Total	Affiliation	Total
United States	66	Boston College	12
Indonesia	39	Ludwig- Maximilians-Universität München	11
Germany	22	Universitas Negeri Malang	11
Turkey	14	Stanford University	8
Taiwan	10	Indonesian Education Universities	7
China	9	University of California	6
Spain	9	The University of Texas at Austin	6
Colombia	8	Arizona State University	5
Brazil	7	Khon Kaen University	5
Thailand	7	Universidad de Los Andes	5

The top 10 authors in the field of scientific arguments are presented in Table 4. The table shows the first rank with 10 papers belongs to McNeill (Lynch School of Education, USA), the second rank with seven papers belongs to Fischer (Ludwig Maximilians University of Munich, Germany), third place with six papers each belongs to González-Howard (Lynch School of Education, USA) and Lee (University of California, USA), and the rest can be seen in Table 4. These authors' contributions indicate that they all have a focus on the topic of scientific argumentation.

Table 4. Top author in scientific arguments

Author	Paper	Country
McNeill, KL	10	Lynch School of Education, Boston College, Chestnut Hill, United States
Fischer, F	7	The Ludwig Maximilian University of Munich, Department of Psychology, Germany
González-Howard, M	6	Lynch School of Education, Boston College, Chestnut Hill, MA, United States
Lee, HS	6	University of California, Santa Cruz, CA, United States
Archila, PA	5	Universidad de Los Andes, Bogotá, Colombia
Loper, S	5	University of California, Berkeley, Berkeley, CA, United States
Molina, J	5	Universidad de Los Andes, Bogotá, Colombia
Osborne, J.	5	Stanford University, United States
Widodo, A.	5	Universitas Pendidikan Indonesia, Bandung, Indonesia
Deta, UA	4	Universitas Negeri Surabaya, Indonesia

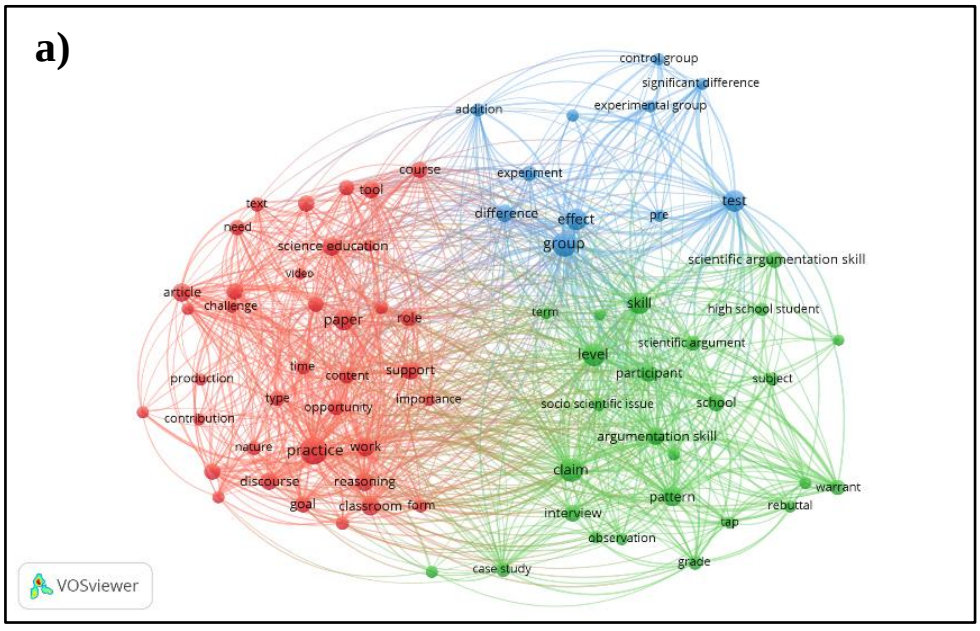
Table 5 presents the most frequently used keywords in scientific argumentation research during 2012 to 2021. The first rank keyword is argumentation, with a total of 51 with a total link strength of 112. The second rank is students, with a total of 51 and a total link strength of 43. The third rank of scientific arguments with a total of 38 and a total link strength of 1 and the rest can be seen in Table 5. Based on the information in Table 5, it can be seen that argumentations and scientific arguments are two different keywords. This is because the keyword argumentations are a basic word while the keyword scientific arguments are a development of the word argumentations and are usually used in science learning [49]–[52].

Table 5. Keyword research on scientific argumentation

Keyword	Total	Occurrence	Total link strength
Argumentation	51	51	112
Students	51	51	43
Scientific argumentation	38	38	17
Science education	18	18	28
Education	12	12	26
Socio-scientific issues	11	11	14
Teaching	11	11	30
Education computing	10	10	34
Learning systems	10	10	26
Scientific literacy	10	10	19

3.5. Visualization of trends in scientific argumentation years

In 2012 to 2021, there were 229 documents related to the topic of scientific argumentation within the article title. After that, the researcher visualized the trends using the help of VOSviewer. The visualization results can be seen in Figure 7 and Figure 8. Figure 7(a) shows trends in scientific argumentation topics over the last 10 years 2012 to 2021 based on bibliographic. The results of the visualization that has been carried out produce cluster assignments with red, blue, and green colors. The red cluster consists of practice, work, reasoning, classroom, form, goal, discourse, nature, opportunity, contribution, type, importance, support, content, time, production, role, paper, challenge, article, video, science education, need, text, tools, and courses. The blue cluster consists of group, effect, pre, test, difference, experiment, Addition, experimental group, significant difference, and control group. The green color cluster consists of level, term, skill, case study, interview, observation, grade, tap, pattern, rebuttal, warrant, claim, argumentations skill, socio-scientific, issue, school, participant, scientific argument, subject, high school student, and scientific argumentation skills. Through these cluster relationships, we can find updates in that field [53]–[56].



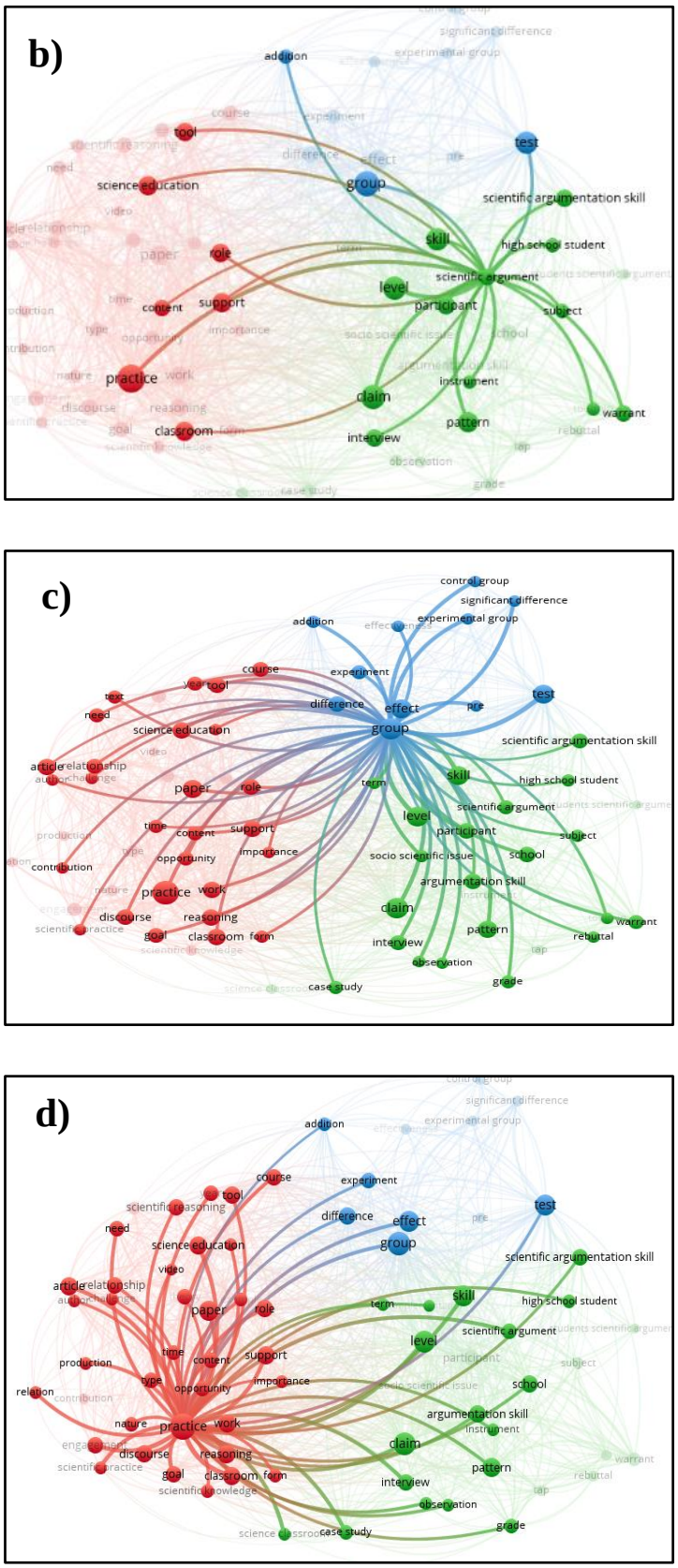


Figure 7. Network visualization (based on bibliographic) in (a) scientific argumentation year 2012 to 2021, (b) connection of the word scientific argument, (c) connection of the word group, (d) connection of the word practice

Then, from the three clusters, one word most related to this study's purpose was chosen by adjusting from each of these clusters. In the green-colored cluster as shown in Figure 7(b), the word scientific arguments are chosen, and then the relationship with the other clusters is seen. In this case, the scientific argument is closely related to the word skill. Furthermore, in the blue color cluster as shown in Figure 7(c), the word group with a close relationship with others is selected. The word group itself has something to do with effect, difference, pre, test, experiment, addition, experimental group, significant difference, control group, term, skill, level, scientific argumentation skill, high school student, scientific argument, participant, subject, school, socio-scientific issues, argumentation skill, claim, interview, observation, pattern, grade, rebuttal, warrant, case study, form, classroom, reasoning goal, discourse, practice, work, importance, opportunity, support, content, time, contribution, role, paper, article, science educations, need, text, year, tool, and course. Then, the red color cluster as shown in Figure 7(d) selected the word practice which has a close relationship with other words, namely, knowledge, classroom, form, goal, reasoning, work, discourse, nature, opportunity, type, relation, production importance, content, time, paper, role, video, article, science education, need, scientific reasoning, year, tool, course, addition, experiment, difference, effects, group, term, level, skill, case study, interview, observation, grade, pattern, argumentation skill, instrument, school, scientific argument, high school student, and scientific argumentation skill. Based on a series of connected words, there are research opportunities in it. This is supported by research from several studies [57]–[61]. Words that are connected using VOSviewer visualization have a relationship that can be used as an option for further research.

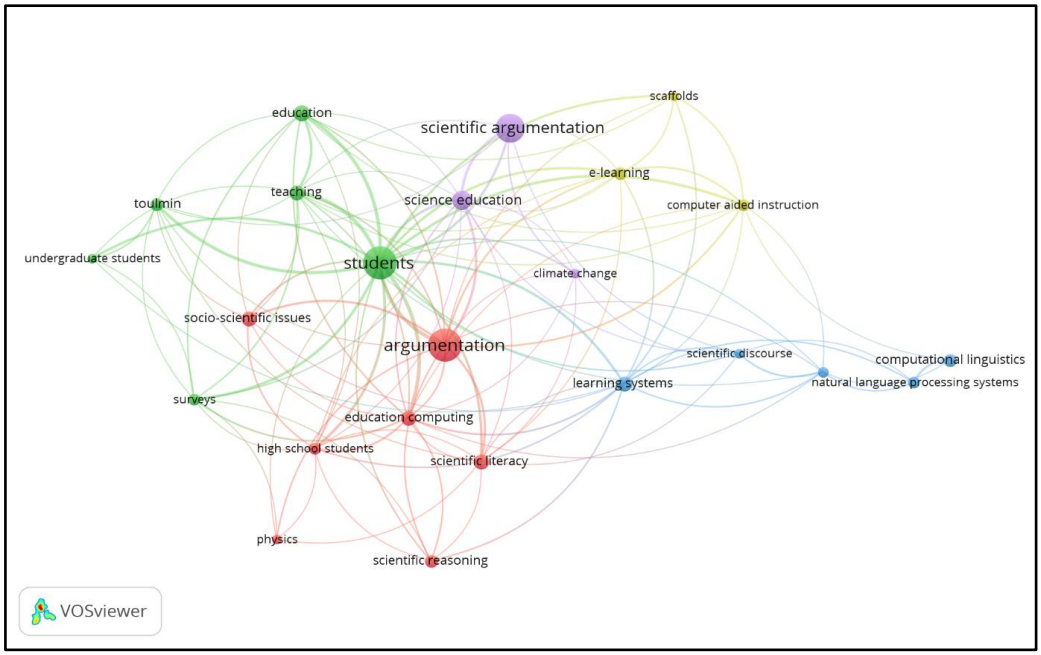


Figure 8. Network visualization (based on text data) in scientific argumentation year 2012 to 2021

Figure 8 presents visualization results from the scientific argumentation year 2012 to 2021 based on text data. The visualization results show that five clusters are obtained, namely red clusters, blue clusters, green clusters, yellow clusters, and purple clusters. The red cluster consists of argumentation, education computing, scientific literacy, scientific reasoning, physics, high school students, and socio-scientific issues. The blue cluster consists of learning systems, scientific discourse, natural language, processing systems, and computable linguistics. The green cluster consists of students, surveys, undergraduate students, Toulmin, teaching, and education. The yellow cluster consists of e-learning, scaffolds, and computer-aided instruction. Finally, the purple cluster consists of scientific argumentation, science education, and climate charge. In this case, these four words cannot be separated from an argument someone will carry out, whether orally or in writing. This is because every argument that is thrown requires reasoning, skill, and step-by-step to make a good claim [62]–[66].

3.6. Review top 5 papers cited in scientific argumentation (2012 to 2021)

Reviewing the top 5 articles that have the most citations is one that needs to be known further. This is because we can take lessons from these articles for writing and information in the field of scientific argumentation studies. By reviewing, we can know the right results and suggestions for future research to be better than before. The following review results are presented in Table 6.

Table 6. Article review of top 5 papers cited in scientific argumentation

No	Author	Finding	Recommendations
1	[67]	This study provides a solution perspective related to students' arguments in answering the question of when and how	This research is still only a perspective on responding to an argument and making it. The author suggests applying this argument so that students answer questions in a structured manner.
2	[68]	This study describes how the deficit of reasoning and argumentation is used in higher education.	Education reasoning and grounding further research in the form of a conceptual framework with several appropriate modes.
3	[69]	This study reveals how the lack of student participation in authentic arguments is one of the causes of the lack of opportunity and understanding of teachers regarding the argument itself. This is evidenced through interviews conducted by researchers.	In the future, in conducting learning that has to do with argumentation, the teacher must make the material before learning. That way, it will make learning more meaningful and valuable without miscommunication and can achieve the goals of learning.
4	[70]	Results This Research uses how to align conceptually with argumentation support in scientific practice.	Further research is expected to make argumentation a basis in scientific activities carried out by participants' students and develop and maintain an epistemic culture in the classroom.
5	[71]	However, several challenges need to be analyzed in more depth.	The difference in teacher levels must be discussed in further research so that the argumentation design proposed follows the needs of the students going forward.

4. CONCLUSION

This study shows that the number of article publications from 2012 to 2021 on scientific argumentation has increased on average. However, the most visible increase was in 2018-2021. Publications on scientific argumentation topics from 2012 to 2021 were dominated by the United States (66 docs), followed by Indonesia (39 docs), and Germany (22 docs). Meanwhile, the top authors came from the United States (McNeill), Germany (Fischer), and the United States (González-Howard). Furthermore, the topic argumentation of science dominated by subject areas based on science keywords used is argumentation (51), students (51), and scientific argumentation (38). Research trends during 2012 to 2s021 were primarily papers and proceedings and book and book series from the published conference proceedings and the International Journal of Science Education, respectively (13 docs). The data that has been analyzed is all taken from the database Scopus with the 2012 to 2021 string scientific AND argumentation within the article title. It is hoped that in the future, it will be necessary to find an appropriate learning model to practice arguments developed orally and in writing.

In this research, there are several limitations, namely: i) the keywords used are limited to other search sources, namely in the article titles, to focus more on the objectives to be achieved; ii) this research focuses on trends in scientific argumentation research topics over the past 10 years; and iii) the search only used the Scopus database with the keyword “Scientific Argumentation”.

REFERENCES

[1] Z. Hidayatullah, I. Wilujeng, N. Nurhasanah, T. G. Gusemanto, and M. Makhrus, “Synthesis of the 21st century skills (4C) based physics education research in Indonesia,” *JIPF (Jurnal Ilmu Pendidikan Fisika)*, vol. 6, no. 1, p. 88, 2021, doi: 10.26737/jipf.v6i1.1889.

[2] T. X. Yu and W. M. R. Wan Mohammad, “Integration of 21st century learning skills (4C Elements) in interventions to improve English writing skill among 3K class students,” *International Journal of Contemporary Education*, vol. 2, no. 2, p. 100, 2019, doi: 10.11114/ijce.v2i2.4498.

[3] H. D. Sipayung, R. A. Sani, and W. Bunawan, “Collaborative inquiry for 4C skills,” *Proceedings of the 3rd Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2018)*. Atlantis Press, 2018. doi: 10.2991/aisteel-18.2018.95.

[4] V. Erdogan, “Integrating 4C skills of 21st century into 4 language skills in EFL classes,” *International Journal of Education and Research*, vol. 7, no. 11, pp. 113–124, 2019.

[5] V. Giri and M. U. Paily, “Effect of scientific argumentation on the development of critical thinking,” *Science and Education*, vol. 29, no. 3, pp. 673–690, 2020, doi: 10.1007/s11191-020-00120-y.

[6] R. Perdana, J. Jumadi, and D. Rosana, “Relationship between analytical thinking skill and scientific argumentation using PBL with interactive CK 12 simulation,” *International Journal on Social and Education Sciences*, vol. 1, no. 1, pp. 16–23, 2019, [Online]. Available: https://interactives.ck12.org/simulations/physics.html.

[7] A. R. Hakim, W. Widodo, and T. Sunarti, “Profile of Toulmin’s scientific arguments students and technological utilities in global warming topic,” *JPPS (Jurnal Penelitian Pendidikan Sains)*, vol. 12, no. 1, pp. 85–99, 2022, doi: 10.26740/jpps.v12n1.p85-99.

[8] V. Yossyana, N. Suprapto, and T. Prastowo, "5E learning cycle in practicing written and oral argumentation skills," *IJORER: International Journal of Recent Educational Research*, vol. 1, no. 3, pp. 218–232, 2020, doi: 10.46245/ijorer.v1i3.53.
[9] G. J. Kelly, J. Regev, and W. Prothero, "Analysis of lines of reasoning in written argumentation," in *Argumentation in Science Education*. Springer Netherlands, 2007, pp. 137–158. doi: 10.1007/978-1-4020-6670-2_7.
[10] L. K. Berland and K. L. McNeill, "A learning progression for scientific argumentation: understanding student work and designing supportive instructional contexts," *Science Education*, vol. 94, no. 5, pp. 765–793, 2010, doi: 10.1002/sce.20402.
[11] H. Hunaidah, "Validity and effectiveness lesson plan of physic learning argument driven inquiry (ADI) model assisted by lectora inspire software to improve the skills of scientific argumentation of high school students," *JPPS (Jurnal Penelitian Pendidikan Sains)*, vol. 8, no. 2, p. 1722, 2019, doi: 10.26740/jpps.v8n2.p1722-1726.
[12] M. Z. Bin Amiruddin, E. P. D. N. Sari, W. Q. L. Arrafi', M. S. Ma'arif, and S. Admoko, "The development of student worksheet based on stem integrated blended learning to improve student's science argumentation skills in the Covid-19 pandemic era," *Berkala Ilmiah Pendidikan Fisika*, vol. 10, no. 1, p. 135, 2022, doi: 10.20527/bipf.v10i1.12657.
[13] S. Erduran and M. P. Jiménez-Aleixandre, *Argumentation in science education*. Dordrecht: Springer, 2007. doi: 10.1007/978-1-4020-6670-2.
[14] A. R. Cavagnetto, "Argument to foster scientific literacy: a review of argument interventions in K-12 science contexts," *Review of Educational Research*, vol. 80, no. 3, pp. 336–371, 2010, doi: 10.3102/0034654310376953.
[15] L. Ke, T. D. Sadler, L. Zangori, and P. J. Friedrichsen, "Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues," *Science & Education*, vol. 30, no. 3, pp. 589–607, 2021, doi: 10.1007/s11191-021-00206-1.
[16] J. P. Walker, V. Sampson, and C. O. Zimmerman, "Argument-driven inquiry: an introduction to a new instructional model for use in undergraduate chemistry labs," *Journal of Chemical Education*, vol. 88, no. 8, pp. 1048–1056, 2011, doi: 10.1021/ed100622h.
[17] M. A. Pan, S. Marfu'ah, and I. W. Dasna, "The effect of the argument-driven inquiry (ADI) based on science, environment, technology, and society (SETS) to students' concept understanding and scientific argument skill in buffer solution learning: Studied from cognitive style," *AIP Conference Proceedings*, vol. 2330. AIP Publishing, 2021. doi: 10.1063/5.0043621.
[18] W. Songsil, P. Pongsophon, B. Boonsoong, and A. Clarke, "Developing scientific argumentation strategies using revised argument-driven inquiry (rADI) in science classrooms in Thailand," *Asia-Pacific Science Education*, vol. 5, no. 1, pp. 1–22, 2019, doi: 10.1186/s41029-019-0035-x.
[19] M. Miaturrohmah and W. Fadly, "Looking At a portrait of student argumentation skills on the concept of inheritance (21st century skills study)," *INSECTA: Integrative Science Education and Teaching Activity Journal*, vol. 1, no. 1, p. 17, 2020, doi: 10.21154/insecta.v1i1.2056.
[20] R. R. Sukardi and Y. V Agustrianti, "Analysis of students' argumentation skill and conceptual knowledge in friction force lesson through argumentative task," *Proceedings of the 2016 International Conference on Mathematics and Science Education*. Atlantis Press, 2017. doi: 10.2991/icmsed-16.2017.18.
[21] S. Admoko, N. Hanifah, N. Suprapto, E. Hariyono, and M. Madlazim, "The implementation of argument driven inquiry (ADI) learning model to improve scientific argumentation skills of high school students," *Journal of Physics: Conference Series*, vol. 1747, no. 1, p. 12046, 2021, doi: 10.1088/1742-6596/1747/1/012046.
[22] C. Yuenyong, "Enhancing scientific literacy in Thailand," *Global Studies of Childhood*, vol. 3, no. 1, pp. 86–98, 2013, doi: 10.2304/gsch.2013.3.1.86.
[23] J. Pimvichai and K. Buaraphan, "A case study of helping in-service science teacher to teach with the science-technology-society approach and its influence on students' scientific argumentation," *International Journal of Education and Practice*, vol. 7, no. 4, pp. 391–403, 2019, doi: 10.18488/journal.61.2019.74.391.403.
[24] Y.-C. Chang and A. Bangsri, "Thai students' perceived teacher support on their reading ability: mediating effects of self-efficacy and sense of school belonging," *International Journal of Educational Methodology*, vol. 6, no. 2, pp. 435–446, 2020, doi: 10.12973/ijem.6.2.435.
[25] National Research Council, *Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Academies Press, 2012.
[26] T. Demircioğlu, "The effect of online argumentation in open-ended physics experiments on academic achievement and the change in argumentation abilities," *International Journal of Curriculum and Instruction*, vol. 14, no. 2, pp. 1561–1577, 2016.
[27] B. Minasny, D. Fiantis, B. Mulyanto, Y. Sulaeman, and W. Widyatmanti, "Global soil science research collaboration in the 21st century: time to end helicopter research," *Geoderma*, vol. 373, p. 114299, 2020, doi: 10.1016/j.geoderma.2020.114299.
[28] X. Chen, D. Zou, G. Cheng, and H. Xie, "Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: a retrospective of all volumes of Computers & Education," *Computers and Education*, vol. 151, p. 103855, 2020, doi: 10.1016/j.compedu.2020.103855.
[29] Y. Li, K. Wang, Y. Xiao, and J. E. Froyd, "Research and trends in STEM education: a systematic review of journal publications," *International Journal of STEM Education*, vol. 7, no. 1, 2020, doi: 10.1186/s40594-020-00207-6.
[30] B. K. Prahani, K. Nisa, M. A. Nurdiana, E. Krisnaningsih, M. Z. Bin Amiruddin, and I. Sya'roni, "Analyze of steam education research for three decades," *Journal of Technology and Science Education*, vol. 13, no. 3, pp. 837–856, 2023, doi: 10.3926/JOTSE.1670.
[31] J. Ali, A. Jusoh, A. F. Abbas, and K. M. Nor, "Global trends of service quality in healthcare: a bibliometric analysis of Scopus database," *Journal of Contemporary Issues in Business and Government*, vol. 27, no. 1, pp. 2917–2930, 2021.
[32] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: an overview and guidelines," *Journal of Business Research*, vol. 133, no. 1, pp. 285–296, 2021, doi: 10.1016/j.jbusres.2021.04.070.
[33] L. C. Ampese, W. G. Sganzerla, H. Di Domenico Ziero, A. Mudhoo, G. Martins, and T. Forster-Carneiro, "Research progress, trends, and updates on anaerobic digestion technology: a bibliometric analysis," *Journal of Cleaner Production*, vol. 331, p. 130004, 2022, doi: 10.1016/j.jclepro.2021.130004.
[34] L. Xie, Z. Chen, H. Wang, C. Zheng, and J. Jiang, "Bibliometric and visualized analysis of scientific publications on atlantoaxial spine surgery based on Web of Science and VOSviewer," *World Neurosurgery*, vol. 137, pp. 435-442.e4, 2020, doi: 10.1016/j.wneu.2020.01.171.
[35] I. Hamidah, Sriyono, and M. N. Hudha, "A bibliometric analysis of COVID-19 research using VOSviewer," *Indonesian Journal of Science and Technology*, vol. 5, no. 2, pp. 209–216, 2020, doi: 10.17509/ijost.v5i2.24522.
[36] B. K. Prahani, M. Z. Bin Amiruddin, B. Jatmiko, N. Suprapto, and T. Amelia, "Top 100 cited publications for the last thirty years in digital learning and mobile learning," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 8, pp. 18–33, 2022, doi: 10.3991/ijim.v16i08.29803.
[37] M. Barak and Y. J. Dori, "Enhancing higher order thinking skills among in service science teachers via embedded assessment," *Journal of Science Teacher Education*, vol. 20, no. 5, pp. 459–474, 2009, doi: 10.1007/s10972-009-9141-z.

[38] D. Clark *et al.*, "Scaffolding scientific argumentation between multiple students in online learning environments to support the development of 21st century skills," *National Research Council Workshop Exploring the Intersection of Science Education and the Development of 21st Century Skills*, 2009.
[39] B. S. Haug and S. M. Mork, "Taking 21st century skills from vision to classroom: what teachers highlight as supportive professional development in the light of new demands from educational reforms," *Teaching and Teacher Education*, vol. 100, p. 103286, 2021, doi: 10.1016/j.tate.2021.103286.
[40] N. Gultepe and Z. Kilic, "Effect of scientific argumentation on the development of scientific process skills in the context of teaching chemistry," *International Journal of Environmental and Science Education*, vol. 10, no. 1. pp. 111–132, 2015. doi: 10.12973/ijese.2015.234a.
[41] B. K. Prahani, M. Z. Bin Amiruddin, N. Suprapto, U. A. Deta, and T. H. Cheng, "The trend of physics education research during COVID-19 pandemic," *International Journal of Educational Methodology*, vol. 8, no. 3, pp. 517–533, 2022, doi: 10.12973/ijem.8.3.517.
[42] D. J. Hess and B. K. Sovacool, "Sociotechnical matters: reviewing and integrating science and technology studies with energy social science," *Energy Research and Social Science*, vol. 65, p. 101462, 2020, doi: 10.1016/j.erss.2020.101462.
[43] J. Rose and C. W. Johnson, "Contextualizing reliability and validity in qualitative research: toward more rigorous and trustworthy qualitative social science in leisure research," *Journal of Leisure Research*, vol. 51, no. 4, pp. 432–451, 2020, doi: 10.1080/00222216.2020.1722042.
[44] D. W. Aksnes, F. N. Piro, and L. W. Fossum, "Citation metrics covary with researchers' assessments of the quality of their works," *Quantitative Science Studies*, vol. 4, no. 1, pp. 105–126, 2023, doi: 10.1162/qss_a_00241.
[45] D. S. J. Costa, R. Mercieca-Bebber, C. Rutherford, M. A. Tait, and M. T. King, "How is quality of life defined and assessed in published research?" *Quality of Life Research*, vol. 30, no. 8, pp. 2109–2121, 2021, doi: 10.1007/s11136-021-02826-0.
[46] M. U. Genisa, B. Subali, Djukri, A. Agussalim, and H. Habibi, "Socio-scientific issues implementation as science learning material," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 9, no. 2, pp. 311–317, 2020, doi: 10.11591/ijere.v9i2.20530.
[47] J. F. Osborne *et al.*, "Impacts of a practice-based professional development program on elementary teachers' facilitation of and student engagement with scientific argumentation," *American Educational Research Journal*, vol. 56, no. 4, pp. 1067–1112, 2019, doi: 10.3102/0002831218812059.
[48] I. H. El-adaway, G. Ali, R. Assaad, A. Elsayegh, and I. S. Abotaleb, "Analytic overview of citation metrics in the civil engineering domain with focus on construction engineering and management specialty area and its subdisciplines," *Journal of Construction Engineering and Management*, vol. 145, no. 10, 2019, doi: 10.1061/(asce)co.1943-7862.0001705.
[49] F. A. Faize, W. Husain, and F. Nisar, "A critical review of scientific argumentation in science education," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 14, no. 1, pp. 475–483, 2018, doi: 10.12973/ejmste/80353.
[50] J. B. Henderson, K. L. McNeill, M. González-Howard, K. Close, and M. Evans, "Key challenges and future directions for educational research on scientific argumentation," *Journal of Research in Science Teaching*, vol. 55, no. 1, pp. 5–18, 2018, doi: 10.1002/tea.21412.
[51] E. Sumeyye and C. P. Seda, "Utilizing argument-driven-inquiry to develop pre-service teachers' metacognitive awareness and writing skills," *International Journal of Research in Education and Science*, vol. 5, no. 2, pp. 628–638, 2019.
[52] A. Caputo, G. Marzi, J. Maley, and M. Silic, "Ten years of conflict management research 2007-2017: An update on themes, concepts and relationships," *International Journal of Conflict Management*, vol. 30, no. 1, pp. 87–110, 2019, doi: 10.1108/IJCMA-06-2018-0078.
[53] L. E. Bleem *et al.*, "The SPTpol extended cluster survey," *The Astrophysical Journal Supplement Series*, vol. 247, no. 1, p. 25, 2020, doi: 10.3847/1538-4365/ab6993.
[54] C. Chen and M. Song, "Visualizing a field of research: a methodology of systematic scientometric reviews," *PLoS ONE*, vol. 14, no. 10, pp. e0223994–e0223994, Oct. 2019, doi: 10.1371/journal.pone.0223994.
[55] S. Huang, Z. Kang, I. W. Tsang, and Z. Xu, "Auto-weighted multi-view clustering via kernelized graph learning," *Pattern Recognition*, vol. 88, pp. 174–184, 2019, doi: 10.1016/j.patcog.2018.11.007.
[56] J. T. McAllister, L. Lennertz, and Z. Atencio Mojica, "Mapping a discipline: a guide to using VOSviewer for bibliometric and visual analysis," *Science and Technology Libraries*, vol. 41, no. 3, pp. 319–348, 2022, doi: 10.1080/0194262X.2021.1991547.
[57] S. Hrastinski, "Digital tools to support teacher professional development in lesson studies: a systematic literature review," *International Journal for Lesson and Learning Studies*, vol. 10, no. 2, pp. 138–149, 2021, doi: 10.1108/IJLLS-09-2020-0062.
[58] A. Kuzior and M. Sira, "A bibliometric analysis of blockchain technology research using VOSviewer," *Sustainability (Switzerland)*, vol. 14, no. 13, p. 8206, 2022, doi: 10.3390/su14138206.
[59] M. Bathgate, A. Crowell, C. Schunn, M. Cannady, and R. Dorph, "The learning benefits of being willing and able to engage in scientific argumentation," *International Journal of Science Education*, vol. 37, no. 10, pp. 1590–1612, 2015, doi: 10.1080/09500693.2015.1045958.
[60] M. Bondi, "Perspectives on keywords and keyness," in *Keyness in Texts*. John Benjamins Publishing Company, 2010, pp. 1–18. doi: 10.1075/scl.41.01bon.
[61] C. Von Aufschnaiter, S. Erduran, J. Osborne, and S. Simon, "Arguing to learn and learning to argue: case studies of how students' argumentation relates to their scientific knowledge," *Journal of Research in Science Teaching*, vol. 45, no. 1, pp. 101–131, 2008, doi: 10.1002/tea.20213.
[62] F. H. van Eemeren, R. Grootendorst, R. H. Johnson, C. Plantin, and C. A. Willard, *Fundamentals of Argumentation Theory*. Routledge, 2013. doi: 10.4324/9780203811306.
[63] N. J. van Eck and L. Waltman, "Citation-based clustering of publications using CitNetExplorer and VOSviewer," *Scientometrics*, vol. 111, no. 2, pp. 1053–1070, 2017, doi: 10.1007/s11192-017-2300-7.
[64] J. Cook, P. Ellerton, and D. Kinkead, "Deconstructing climate misinformation to identify reasoning errors," *Environmental Research Letters*, vol. 13, no. 2, p. 24018, 2018, doi: 10.1088/1748-9326/aaa49f.
[65] S. Cottrell, *Critical thinking skills: Effective Analysis, Argument and Reflection*. Bloomsbury Publishing. 2017. doi: 10.1057/978-1-137-55052-1.
[66] R. D. Rieke, M. O. Sillars, and T. R. Peterson, *Argumentation and critical decision making*. New York, NY: Pearson, 2012.
[67] L. K. Berland and D. Hammer, "Framing for scientific argumentation," *Journal of Research in Science Teaching*, vol. 49, no. 1, pp. 68–94, 2012, doi: 10.1002/tea.20446.
[68] F. Fischer *et al.*, "Scientific reasoning and argumentation: advancing an interdisciplinary research agenda in education," *Frontline Learning Research*, vol. 2, no. 3, pp. 28–45, 2014, doi: 10.14786/flr.v2i3.96.
[69] V. Sampson and M. R. Blanchard, "Science teachers and scientific argumentation: trends in views and practice," *Journal of Research in Science Teaching*, vol. 49, no. 9, pp. 1122–1148, 2012, doi: 10.1002/tea.21037.

[70] E. Manz, "Representing student argumentation as functionally emergent from scientific activity," *Review of Educational Research*, vol. 85, no. 4, pp. 553–590, 2015, doi: 10.3102/0034654314558490.
[71] K. L. McNeill and A. M. Knight, "Teachers' pedagogical content knowledge of scientific argumentation: the impact of professional development on K-12 teachers," *Science Education*, vol. 97, no. 6, pp. 936–972, 2013, doi: 10.1002/sce.21081.

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