https://doi.org/10.24036/jep/vol8-iss2/941

JEP (Jurnal Eksakta Pendidikan)
Volume 8, Issue 2, 99 - 114
ISSN: 2579-860X (Online), ISSN: 2514-1221 (Print)
https://jep.ppj.unp.ac.id/index.php/jep

Research Trends and Opportunities of Argumentation Based Learning for Solving Problems in Physics Learning: A Bibliometric Analysis

Hazrati Ashel[1], Ida Hamidah[2*], Sjaeful Anwar[3], Muslim[4]

[1] Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia.

[2] Mechanical Engineering Education, Faculty of Technology and Vocational Education, Universitas Pendidikan Indonesia, Bandung, Indonesia.

[3] Chemistry Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia.

[4] Physics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia.

Received: September 16th, 2024 ▪ Revised: October 31th, 2024 ▪ Accepted: November 25th, 2024

ABSTRACT

Research on argumentation has been widely conducted and continues to develop. Research trends and opportunities need to be known by researchers to conduct research. To find out this, a bibliometric analysis needs to be conducted. This analysis is conducted to determine the development of publications, trends, and research opportunities on the topic of argumentation in Physics learning. Article data was obtained from Scopus and analyzed using the VOSviewer application. The results obtained are that research in this topic tends to increase every year. Keywords that are trending in this topic include high school, physics and science education, e-learning and dialogic argumentation, and argumentation skills. Meanwhile, keywords that are opportunities are higher education, other fields that study Physics, the use of teaching materials and inquiry, assessment in argumentation-based learning, and understanding concepts. In addition, a relationship between argumentation and problem-solving skills was also obtained. There are still few articles that connected argumentation and problem-solving so that this topic can be an opportunity to conduct research, especially at the university level. We suggest exploring various methods in implementing argumentation in Physics learning. Argumentation can not only improve argumentation skills but also improve various 21st century skills such as problem-solving skills.

Keyword: Argumentation, Bibliometric analysis, Physics learning, Problem solving, Research trends

INTRODUCTION

Argumentation is a process of producing statements or arguments supported by evidence (Rahma et al., 2024). The statements produced are used to change views or influence others. Argumentation must always be oriented towards data, facts, or objective evidence so that its truth can be accepted. Someone needs to analyze the information obtained to produce

***Correspondence:**
Ida Hamidah, Pendidikan Teknik Mesin, Fakultas Pendidikan Teknologi dan Kejuruan, Universitas Pendidikan Indonesia, Bandung, Indonesia.
✉ email: idahamidah@upi.edu

a valid argument. Argumentation encourages students to make arguments and use them to explain natural phenomena based on reasoning (Juntunen & Aksela, 2014). For example, when learners try to find empirical evidence to confirm or refute claims made, argumentation can help them generate plausible explanations, models, and theories.

One of the argumentation models is the Toulmin argumentation pattern. Toulmin states that argumentation is the process of providing reasons to strengthen or reject a claim. Argumentation based on the Toulmin pattern has six main components, namely: 1) claims, consisting of conveying opinions or conclusions that will be accepted by others; (2) data, facts or a condition that can be objectively observed, trusted, and clearly accepted; (3) warrants, an explanation of the relationship between data and claims; (4) backing, namely basic assumptions that support warrants; (5) qualifiers, namely providing specific evidence stating that the claims stated are true; and (6) reservations, statements that refute or oppose arguments (Inch, 2006). Toulmin recommends that these six parts must have a reciprocal relationship, at least three parts, namely claim, warrant, data.

Argumentation plays an important role in Physics learning. Physics is not just about finding and presenting facts, but also building arguments based on data and theories, considering them, and debating various explanations of Physics phenomena. Based on the definition and components of argumentation, it can also be concluded that argumentation encourages students to actively develop reasoning and logic. Argumentation encourages students to be able to reason and think logically like scientists. Students' understanding of Physics can be assessed through the arguments they provide. Students who have understood the material will produce arguments that are in accordance with scientific concepts and can be accepted as true by others. They are confident in the arguments given because they are supported by facts and concepts that have been learned. Argumentation can reduce the level of abstraction of the material that has so far been identical to Physics learning (Sabí'n, 2024). Students should have the opportunity to present arguments or express their own models based on the evidence obtained (Praisri & Faikhamta, 2020).

Argumentation can be a tool to improve 21st century competencies. Argumentation can improve critical thinking skills, communication, develop mental models, conceptual understanding, and scientifc argumentation skills (Antonio & Prudente, 2021; Inch, 2006; Peten, 2022; Praisri & Faikhamta, 2020). In addition, argumentation also contributes to science learning, including expressing students' opinions, making decisions, and solving problems in everyday life (Songsil, 2019). Argumentation skills must be developed in every generation at every level of education. However, argumentation activities are rarely included in the learning process so that many students still have difficulty in identifying complex arguments, testing the quality of arguments using evidence, and applying knowledge related to real life. (Wu & Liu, 2021).

One of the competencies that is of concern in this study is problem-solving skills. Argumentation can improve problem-solving skills. Argumentation is a rational way of solving problems (Sinensis et al., 2019b). Students' problem-solving skills are demonstrated effectively to find solutions based on data and facts, provide arguments to each other, and combine knowledge through group discussions (Murdani et al., 2023). So, it can be concluded that there is a relationship between argumentation and problem-solving skills.

Several studies on argumentation have been conducted previously to improve student competence. Argumentation-based learning has been developed by several researchers such as model-based learning and argumentation, Argument-Driven Inquiry (ADI) model,

Metacognitive Argument-Driven Inquiry (MADI) model, online argumentation model, and project argumentative learning model (Antonio & Prudente, 2021; Fan et al., 2020; Hasnunidah et al., 2023; Peten, 2022; Praisri & Faikhamta, 2020). First, the development of model-based learning and argumentation is applied to improve students' understanding and mental models. This learning involves students in the process of argumentation and discussion to build their understanding of certain concepts. Second, the application of the ADI model in improving teachers' understanding of the nature of scientific inquiry. Participants are expected to not only be able to design experiments, handle data, interpret results, or form explanations in scientific inquiry. However, they must also be able to distinguish data from evidence to support their arguments or claims. They must understand the reasons given. Third, the application of MADI in improving conceptual understanding and argumentation skills. This model aims to provide learning experiences to students that imitate actual practices in science through scientific argumentation and inquiry-based learning. Fourth, the development of an online argumentation model to improve students' argumentation skills. Finally, the development of a project argumentative learning model. The development of this model is carried out by integrating the project-based model with ADI so that students can produce projects and have structured arguments.

Research on argumentation continues to develop. There are still many ways that can be done in implementing argumentation activities in Physics learning. Various skills can also be improved through argumentation-based learning. Therefore, it is urgent to conduct bibliometric analysis to determine current research trends and opportunities. These results can be the basis for developing and innovating argumentation-based learning. Researchers can focus on research that is trending or focus on certain topics that have not received much attention. This article aims to explain the bibliometric analysis of the literature on the topic of argumentation in Physics learning. The results of the analysis are used to answer several research questions, namely: 1) How is the development of publications on the topic of argumentation in Physics learning?; 2) What are the current research trends on argumentation in Physics learning?; and 3) What are the research opportunities on the topic of argumentation in Physics learning that can be carried out by researchers?

METHOD

Research Design

This study uses a bibliometric analysis method, that is analysis using data from publication databases to build structured mapping of certain fields. Through this analysis, researchers can identify the influence and significance of scientific publications, research directions, and the names of researchers and institutions conducting the research. The steps for mapping are as follows (Zupic & Čater, 2015).

Figure 1. Steps of Bibliometric Analysis

The first step is research design. Design research is defining the research question and choosing the appropriate bibliometric method to answer it. Some types of methods that can be chosen are co-citation, bibliographic coupling, co-word or co-occurence, co-author, direct citation, and hybrid. The research question has been described in the introduction. To answer the question, the method chosen is co-occurence, which is mapping the keywords. The second step is compiling the bibliometric data. Data is obtained from the Scopus database. In this step, the scope of the research is limited and the articles that will be included in the research are determined. The limitation is done by determining the keywords in the title and abstract. The third step is analysis. At this stage, the selection of appropriate bibliometric applications is carried out to data analysis. The application used is VOSviewer. The fourth step is visualization. At this stage, the selection of the appropriate visualization method is carried out. In this study, three types of visualizations were produced, namely network, overlay, and density visualization. Network visualization produces a visualization of the relationship between keywords. The stronger the relationship between keywords, the closer their position. Overlay visualization produces a mapping of keywords by year. Density visualization produces a mapping based on how many times the keyword appears. The final step is interpretation. At this stage, researchers need to describe and interpret the findings. To strengthen the visualization results, a deeper analysis of the most cited documents and the most recent documents is also carried out. The documents that have been analyzed need to be tested to reach valid conclusions. The interpretation results must be adjusted to the research questions that have been formulated.

Instrument

The article database was obtained from Scopus with a range from 2014 to 2024. The keywords used in this study are argumentation and physics education or learning which are limited to the period 2014 to 2024. We want to identify the development of research on argumentation-based learning in Physics in one decade. Furthermore, we analyze the opportunities to conduct research on this topic. After limiting the year, restrictions are also made on the types of documents (articles, conference papers, conference reviews, book chapters, and reviews). After several restrictions, 121 articles were obtained that met the criteria. Data from these articles are stored in CSV and RIS formats.

Data Analysis

Data analysis was carried out using the VOSviewer application, Microsoft Excel and notepad. When creating bibliometric mapping, the frequency of keywords that appear is limited to a minimum of 2 so that 81 keywords are obtained that are related to argumentation in Physics learning. The data obtained needs to be cleaned and tidied up by selecting several keywords with the same meaning, but appear several times. If there are several keywords that have the same meaning, researchers can reduce the word to one word using notepad. After going through this stage, 71 keywords were obtained. In addition, Microsoft Excel was also used to process the data. The results obtained are mappings of keywords related to argumentation in Physics learning.

RESULTS AND DISCUSSION

Results

The Development of Argumentation Research in Physics Learning

The development of research on the argumentation in Physics learning can be seen from the number of articles published each year. To answer this research question, data was obtained from Scopus without limiting the year. The number of data obtained was 153 articles. Figure 2 shows the development of argumentation research in Physics learning.

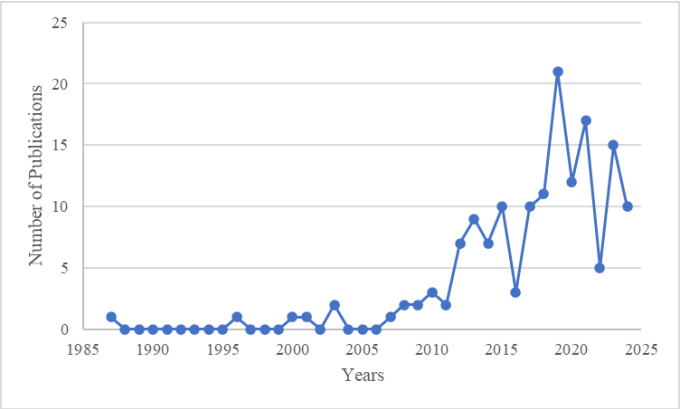

Figure 2. The Development of Argumentation Research in Physics Learning

The number of studies on this topic is fluctuating, but tends to increase. Argumentation research in Physics learning began to increase significantly in 2012. The most research on this topic was conducted in 2019 with 21 articles.

Trends and Opportunities for Argumentation Research in Physics Learning

Computational mapping of article metadata was performed using the VOSviewer application. This mapping was performed to determine the trends and opportunities of argumentation research in Physics learning in the last 10 years. The results obtained were in the form of visualization of the article database keywords. In this study, a visualization analysis of mapping was carried out in three forms, namely network, density, and overlay visualization. Figure 3 shows the network visualization on the topic of argumentation in Physics learning.

Network visualization mapping analysis shows the relationship between one item and another item both inside and outside the cluster. This relationship is shown through circles with different colors. Items that have the same color are in the same cluster (Nandiyanto et al., 2021; Nandiyanto & Al Husaeni, 2021). Based on the results of the analysis, several keywords related to argumentation in Physics learning were obtained. The most frequently occurring keywords are students, argumentation, and Physics. These keywords are classified into several discussion topics, namely: 1) argumentation in various levels of education; 2) argumentation in Physics learning in various fields of education; 3) implementation of argumentation learning; 4) assessment in argumentation-based learning; and 5) skills that can be trained in argumentation-based learning in Physics.

The first topic is argumentation in various levels of education. Research on argumentation in Physics learning can be conducted at the high school, higher education, and preservice teacher levels. The number of keyword occurrences is analyzed through the

percentage of occurrence as in Figure 4. Research on this topic is mostly conducted at the high school level, while at the university level it is still few. This is an opportunity for researchers to conduct research on argumentation for undergraduate students.

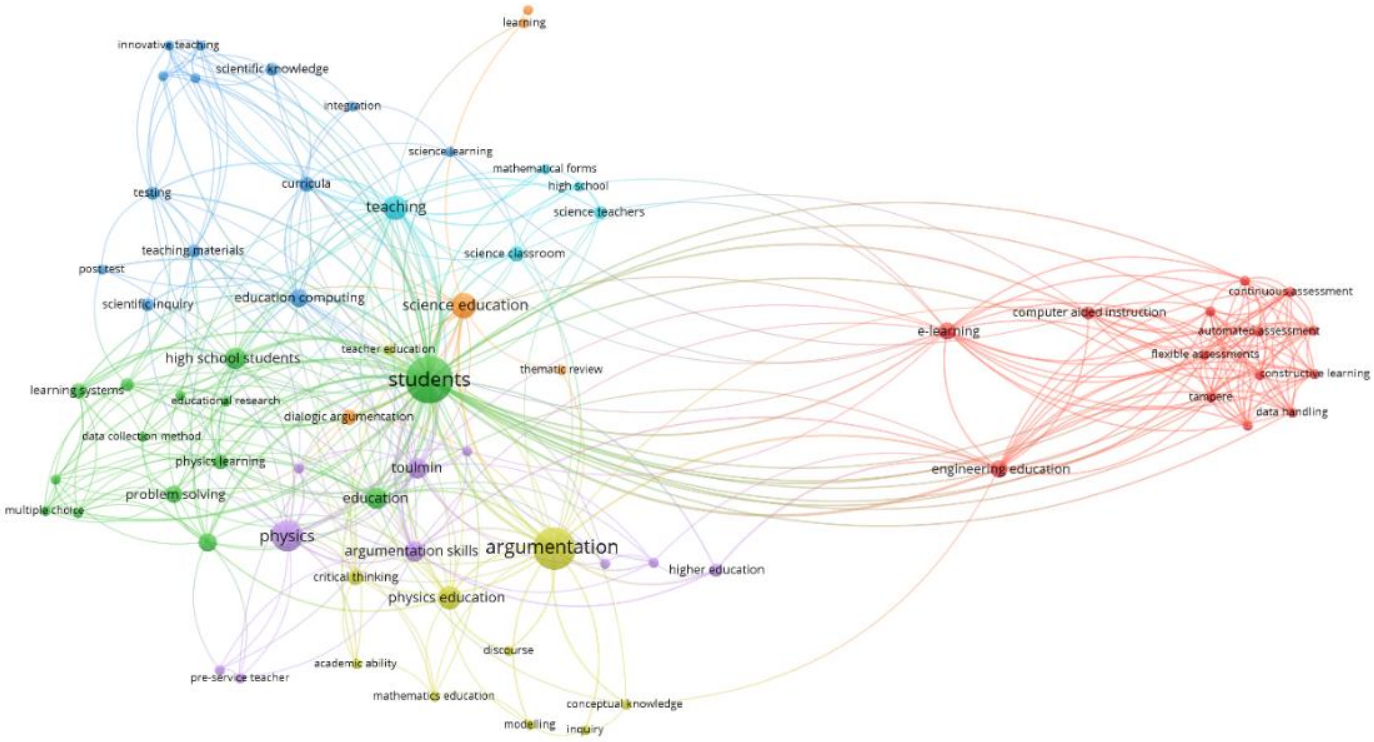

Figure 3. Network Visualization in Argumentation in Physics Learning

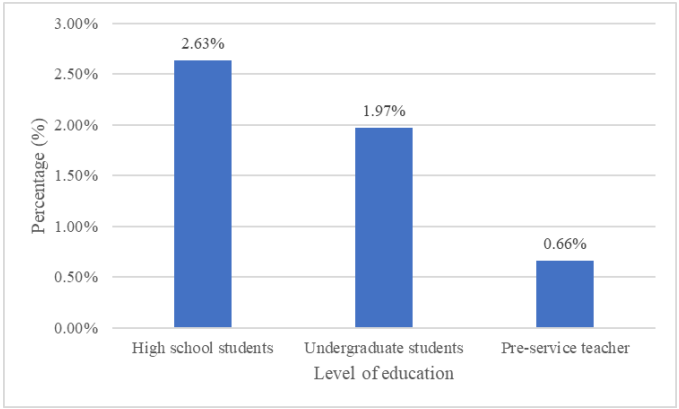

Figure 4. Argumentation Research in Physics Learning at Various Levels of Education

The second topic is argumentation in Physics learning in various fields of education. Physics is not only studied in the fields of Physics (2.96%) or science education (3.62%), but also studied in other fields that require the basics of Physics. These fields include computing education (1.97%), engineering education (1.64%), engineering physics (0.66%), information education (0.66%), and mathematics education (0.66). So, the opportunity to conduct research on argumentation in Physics learning is very large. This is because Physics material is needed in various fields of education.

The third topic is the implementation of argumentation learning. To apply argumentation in Physics learning, it can be done in various ways. Based on the percentage of

occurrences, there are 12 ways to apply argumentation in learning, namely through e-learning (1.64%), dialogic argumentation (1.32%), computer aided instruction (0.99%), use of teaching materials (0.99%), constructive learning (0.66%), discourse (0.66%), group work (0.66%), inquiry (0.66%), inquiry based science (0.66%), online environments (0.66%), social networking (0.66%), and thematic review (0.66%). Argumentation-based learning can be implemented online or offline. Arguments can be delivered directly or indirectly.

The fourth topic is assessment in argumentation-based learning. In argumentation-based learning, there are several forms of assessment that can be done. Assessment can be done online or offline. Online assessment is done through e-learning and consists of automated assessment, continuous assessment, flexible assessment, and online assessment. Meanwhile, offline assessment can be done through multiple-choice tests.

The last topic is the skills that can be trained in Physics learning argumentation. The results of the bibliometric analysis can identify skills that emerge from argumentation activities in Physics learning, namely scientific argumentation skills (Sabí'n, 2024), conceptual understanding (Rahma et al., 2024), critical thinking (Rahma et al., 2024), and problem solving (Iwuanyanwu, 2023). Problem-solving skills are one of the skills that students must have in facing the challenges of the 21st century. There are not many studies that connected argumentation with problem-solving skills. Therefore, this is an opportunity for researchers to conduct research on argumentation in Physics learning. Figure 5 shows the percentage of occurrences of skills related to argumentation in Physics learning.

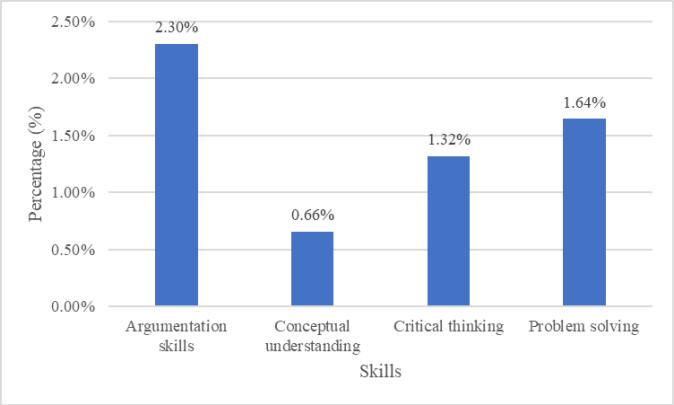

Figure 5. Skills That Can Be Trained

Another function of the VOSviewer application is to view the historical traces of research through overlay visualization mapping as shown in Figure 6. In this mapping, the novelty of the research being carried out can be seen (Nandiyanto et al., 2021; Nandiyanto & Al Husaeni, 2021). In 2021-2024, argumentation research in higher education began to be implemented. Researchers also conduct a lot of research on assessment through e-learning. Research on the topic of argumentation in Physics learning to improve problem-solving skills is in the range of 2018-2020. Meanwhile, research on the topic of argumentation related to critical thinking is in the range of 2019-2021. Based on the results of the overlay visualization, we can see the novelty of the research. For example, argumentation research in higher education is still rarely carried out (small occurrence value) and has only been carried out recently (yellow color). Therefore, argumentation research in higher education can be an opportunity to conduct research so that novelty can be obtained.

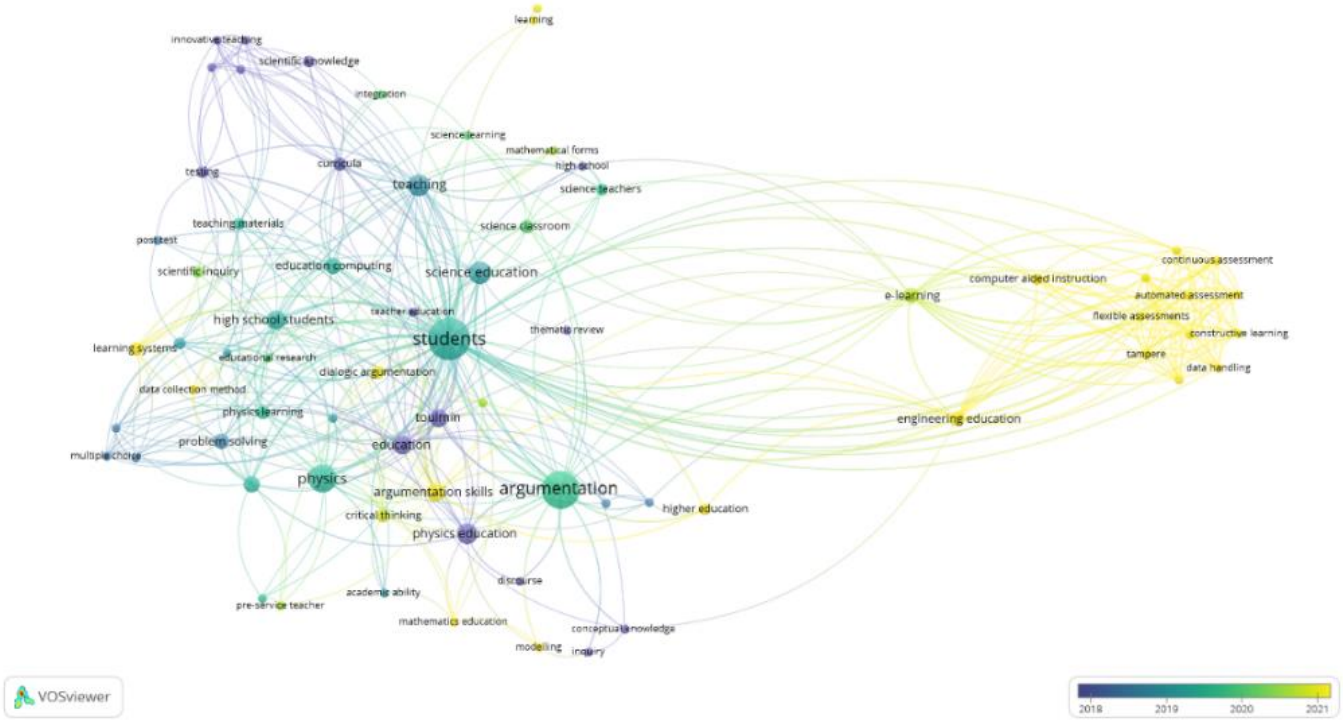

Figure 6. Overlay Visualization in Argumentation in Physics Learning

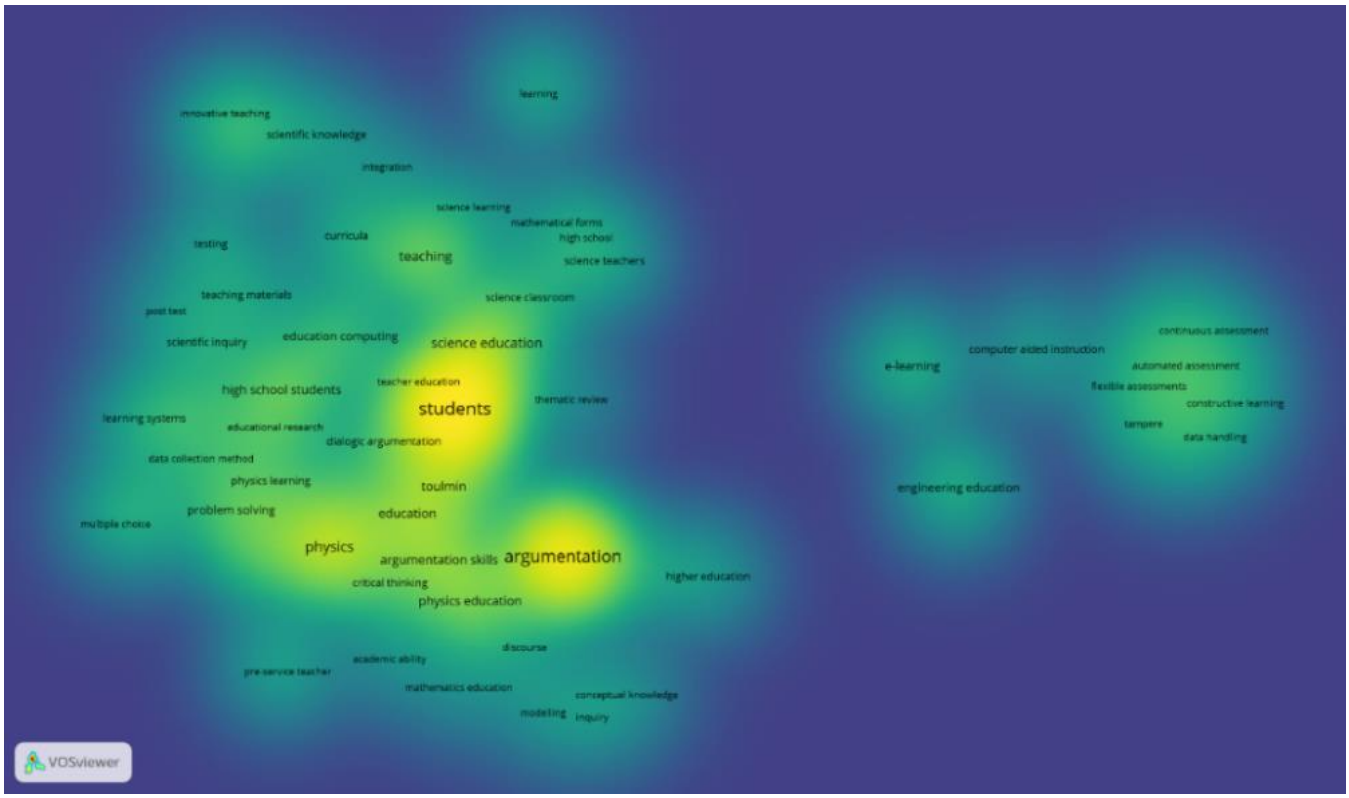

Figure 7. Density Visualization in Argumentation in Physics Learning

VOSviewer can also show the density or emphasis of the analyzed unit through density visualization. This analysis can be used to see parts of the research that are still rarely done (Nandiyanto et al., 2021; Nandiyanto & Al Husaeni, 2021). Bright yellow indicates that there is

a lot of research on the related item, while faded colors indicate that there is little research on the term. Based on Figure 7, it can be seen that the most research conducted is argumentation, students, and Physics. Meanwhile, other items such as problem solving, college, inquiry, and some assessments are still rarely implemented. This shows that there is still a great opportunity to conduct argumentation research in Physics learning and its novelty can be determined.

Figure 8 shows the distribution of publications based on document type. Research on the topic of argumentation in Physics learning is mostly published in article and conference paper formats, respectively, at 42.1% and 38.0%. This shows that there is a great opportunity to conduct research and publish articles, especially in Scopus-indexed international journals. In addition, researchers also have the opportunity to present their research results at international conferences.

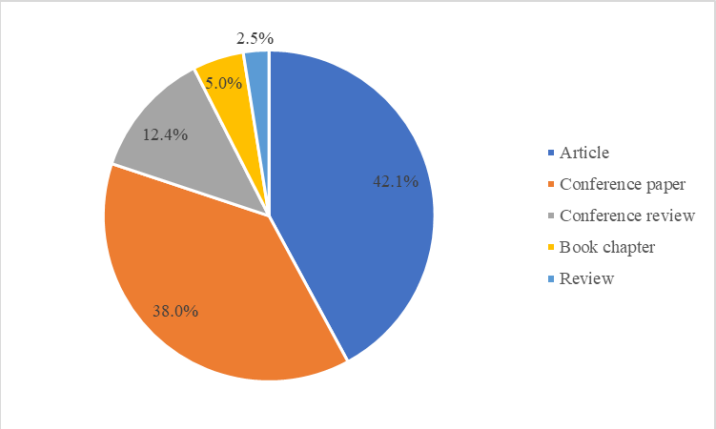

Figure 8. Distribution of Publications Based on Document Type

The distribution of argumentation publications in Physics learning based on research fields can be seen in Figure 9. Research on this topic is mostly related to the fields of social sciences (38.0%), physics and astronomy (37.4%), and computer science (6.7%). Based on this distribution, it can be seen that argumentation research in Physics learning is interdisciplinary research, namely a research process that combines knowledge and methods from two or more disciplines to solve complex problems. So, it can be concluded that there is an opportunity to conduct research on argumentation in Physics learning. Research is not only in the field of Physics, but can collaborate with other fields.

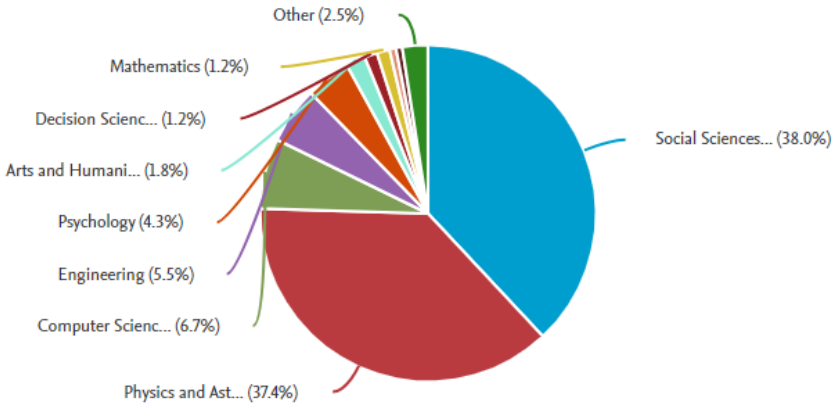

Figure 9. Distribution of Argumentation on Physics Learning Based on Research Fields

The results of this bibliometric analysis are supported by an analysis of the number of most cited articles. This analysis was conducted to determine what discussions are trending and in demand in argumentation research in Physics learning. Table 1 shows the most cited articles in the last 10 years.

Table 1. The Most cited articles

Citation	Document	Summary
42	Investigating the effect of argument-driven inquiry in laboratory instruction (Demircioglu & Ucar, 2015)	The argument-driven inquiry model is more effective in improving academic achievement and science process skills of prospective Physics teacher students. Meanwhile, the improvement of argumentation skills is not significantly different. Argumentation can be improved if the argumentation session is conducted longer and more laboratory activities are conducted.
32	Understanding a high school physics teacher's pedagogical content knowledge of argumentation (Wang & Buck, 2016)	Scientific argumentation is an important learning objective in science education. Argumentation is also an instructional approach for constructivist science learning. However, teachers' understanding of argumentation is still lacking, especially regarding the dialogic meaning of argumentation. Therefore, a case study was conducted to determine teachers' PCK on dialogic argumentation. This study examines the practice of argumentation from the perspective orientation, instructional strategies, students, curriculum, and assessment. Furthermore, challenges to implementing argumentation and solutions to address them are identified.
32	The evaluation of role-playing in the context of teaching climate change (Belova et al., 2015)	Role-playing as an imitation of social practices can support the development of argumentation and decision-making skills among students. Both skills are goals in science education and socioscientific issues. In role-playing, free argumentation is practiced in the context of climate change through several stages. The application of this activity in science learning can influence argumentation and decision-making.
31	A thematic review of argumentation studies at the K-8 level (Bag & Calik, 2017)	This article discusses thematically the study of argumentation at the K-8 level in the period 2006-2016. The results show that most of the argumentation studies have an effect on student achievement and science attitudes. Argumentation activities are mostly developed in Physics topics at the secondary school level. To improve argumentation skills from the elementary school level, it is recommended that educators use different methods, such as argumentation accompanied by gamification.
30	An exploration of social regulation of	Scientific argumentation and discourse are important aspects of science education and inquiry in the 21st

learning during scientific argumentation discourse (Lobczowski, 2020)	century. However, many students still struggle to apply these critical science skills, especially with challenging content or tasks. Therefore, an exploration of the social regulation of learning, scientific argumentation discourse, and socioemotional interactions in discussions of two groups of high school students in Physics learning was conducted. The differences between the two groups were when they implemented planning activities, the emphasis when challenging others' ideas or arguments, and how socioemotional interactions drove discourse.

Analysis of the latest articles was also conducted to find out the latest and up to date research. Through this analysis, researchers can find the latest topics in argumentation research in Physics learning. Table 2 shows some of the latest articles in 2024.

Table 2. Latest articles in 2024

Document	Summary
Use of historical scientific controversies in the context of physics teaching. A study of the scientific pragmadialectic argumentation at school (Álvarez-García & García-Martínez, 2024)	This article discusses the analysis of how the phenomenon of scientific argumentation in schools by combining the perspective of Physics teaching through the analysis of historical scientific controversies and using argumentative routes designed in three levels of dialogicity. The results of the study show relevant aspects related to the core categories related to the phenomenon of pragmatic-dialectical scientific argumentation in schools. In addition, there are several categories that define and characterize this activity.
Promoting abstract thinking and scientific argumentation in the teaching of physics (Sabí'n, 2024)	Abstract thinking and scientific argumentation are high-level cognitive skills that need to be developed by students in learning Physics. To train these skills, the POE strategy is used. The results obtained are that this strategy is effective for teaching abstract concepts, helping to identify students' prior knowledge, encouraging the use of scientific reasoning, and training students in activating their abstraction skills.
Student argumentation skill in physics learning: bibliometric analysis (Rahma et al., 2024)	Argumentation can develop several skills needed in the 21st century such as critical thinking, communication, collaboration, and creativity. Argumentation skills are important for students to understand scientific concepts. Based on bibliometric analysis, it was found that argumentation research continues to develop. Argumentation can be the center of attention especially in Physics learning.
Storytelling as a skeleton to design a learning unit: A model for teaching and	In this study, storytelling is used as a framework to construct a durable teaching unit, maintain coherence, and give meaning to its various elements. The

learning optics (Boscolo et al., 2024)	Storytelling Learning Unit (SLU) model is applied to the material of light to encourage modeling and argumentation skills in mathematics and physics learning. This unit is designed for ninth grade students in Italy. This development focuses on the design process.
Evidence of effectiveness for AJA strategy to argumentative skills development in engineering students (Flores-Amado et al., 2024)	The development of argumentative skills is fundamental for engineering students. They can identify assumptions and draw conclusions about observed phenomena. In this study, the Affirmation-Justification-Application of Laws and Principles (AJA) strategy was used to build arguments about engineering systems. The results obtained were that this strategy could significantly improve two of the three components of argumentative skills, namely justification and application of laws and principles, while the affirmation component did not increase significantly.

Discussion

Bibliometric analysis can provide insight into a research topic. Researchers can find out how the number of articles has developed from year to year. The development of research on the topic of argumentation in Physics learning has increased. The largest number of articles was in 2019. The first research on argumentation in Physics learning was conducted in 1987 with the title "A non-believer looks at physics" by Bondi H. This article discusses how he saw sharp differences in physics argumentation methods based on the views of several religions (Bondi, 1987). In 2024, there were 10 articles and it is likely to continue to increase. So, it can be concluded that argumentation research in Physics learning is still developing, in great demand, and is being conducted to this day.

Researchers can also find out trends and research opportunities on a particular topic. Research trends can be seen from the topics that most often appear or are discussed, while research opportunities can be seen from topics that are still rarely done. Argumentation research in Physics learning can be conducted at the high school level (Lobczowski, 2020), higher education (Demircioglu & Ucar, 2015), and preservice teacher (Wang & Buck, 2016). Argumentation research trends are mostly conducted for high school students, while for college level it is still limited. One example of the application of argument-based learning in college is the application of the Argument-Driven Inquiry (ADI) model. The ADI model has an effect on academic achievement, science process skills, and scientific argumentation of prospective Physics teacher students. In addition, argumentation research trends are also widely conducted in the field of Physics and science education through e-learning and dialogic argumentation. Several methods of implementing argumentation are still rarely used, including the use of teaching materials, group work, and inquiry. This method can be an opportunity to conduct research on the topic of argumentation.

Argumentation can be carried out offline or online. Online argumentation can be carried out through online discussions, computer-based argumentation, and using online worksheets based on the Toulmin argumentation pattern (Admoko et al., 2023; Murdani et al., 2023; Sulisworo & Safitri, 2022). Meanwhile, offline argumentation can be implemented through the

Argument-Driven Inquiry (ADI) model, role playing, POE strategy, Storytelling Learning Unit (SLU) model, and Affirmation-Justification-Application of Laws and Principles (AJA) strategy (Belova et al., 2015; Boscolo et al., 2024; Demircioglu & Ucar, 2015; Flores-Amado et al., 2024; Sabí'n, 2024). Based on the above description, it can be concluded that research on the topic of argumentation will continue to develop because its implementation is not limited to face-to-face meetings only.

Based on the results of the bibliometric analysis, it was found that scientific argumentation skills are a trend of skills that can be trained in argumentation activities. For example, the use of POE strategies can improve students' scientific argumentation in Physics learning (Sabí'n, 2024). Meanwhile, other skills related to argumentation are problem-solving skills. However, there are still few articles that discuss the relationship between argumentation and problem-solving skills, especially for Physics students in college. Problem-solving skills are important in learning Physics because problems in Physics are complex and related to everyday life (Rahmawati et al., 2017; Safitri et al., 2021). However, not all educators facilitate students in the problem-solving process (Sinensis et al., 2019b). Based on the results of the analysis, it was found that argumentation can be applied in the learning process to train students in solving Physics problems. Argumentation instructions can be used to help students improve their scientific reasoning, thinking way, and argumentation needed to solve problems involving scientific phenomena (Iwuanyanwu, 2023). Argumentation helps students solve problems through group discussions and building arguments based on data (Murdani et al., 2023). Argumentation is also related to problem solving skills where argumentation is a rational way of solving questions and problems (Sinensis et al., 2019a). The students' ability to solve problems is demonstrated effectively to provide arguments to each other, combine knowledge, and find solutions. Therefore, argumentation is related to problem solving in Physics learning and this becomes an opportunity to find novelty in research on the topic of argumentation.

Based on the results of bibliometric analysis, it can be seen that the keyword argumentation in Physics education or learning has been done a lot, but we still find gaps that have not been explored. This study has several limitations, namely: 1) it only discusses problem-solving skills as one of the competencies that can be improved through argumentation activities; 2) it has not discussed the distribution of countries and authors who are active in researching this topic; and 3) the data obtained is limited only from Scopus. In the future, we suggest exploring various methods in implementing argumentation in Physics learning and the resulting skills. Researchers can use this result to find and conduct a newer and more up to date research.

CONCLUSION

Bibliometric analysis can be used to determine the development of research, trends, and opportunities on the topic of argumentation in Physics learning. The development of research on this topic tends to increase. Keywords that are trending in research on this topic are high school, physics and science education, e-learning and dialogic argumentation, and argumentation skills. Keywords that are opportunities are higher education, other fields that study Physics, use of teaching materials and inquiry, assessment in argumentation-based learning, and understanding concepts. Based on this analysis, it can also be seen that argumentation can be used in training Physics problem-solving skills. The number of articles connecting argumentation and problem-solving skills is still small so that this topic can be an

opportunity in conducting research, especially at the university level. In the future, we suggest exploring various methods in implementing argumentation in Physics learning and the resulting skills. These results can be the basis for developing and innovating argumentation-based learning.

REFERENCES

Admoko, S., Sari, E. P. D. N., Hariyono, E., & Madlazim. (2023). Online discussion in improving argumentation skills during last decade: A review. *International Journal of Evaluation and Research in Education*, *12*(4), 1880–1892. https://doi.org/10.11591/ijere.v12i4.25445

Álvarez-García, L. M., & García-Martínez, A. (2024). Use of historical scientific controversies in the context of physics teaching. A study of the scientific pragmadialectic argumentation at school. *Investigacoes Em Ensino de Ciencias*, *29*(2), 57–83. https://doi.org/10.22600/1518-8795.ienci2024v29n2p57

Antonio, R. P., & Prudente, M. S. (2021). Metacognitive argument-driven inquiry in teaching antimicrobial resistance: Effects on students' conceptual understanding and argumentation skills. *Journal of Turkish Science Education*, *18*(2), 192–217. https://doi.org/10.36681/tused.2021.60

Bag, H., & Calik, M. (2017). A thematic review of argumentation studies at the K-8 level. *Egitim Ve Bilim-Education And Science*, *42*(190), 281–303. https://doi.org/http://dx.doi.org/10.15390/EB.2017.6845

Belova, N., Eilks, I., & Feierabend, T. (2015). The evaluation of role-playing in the context of teaching climate change. *International Journal of Science and Mathematics Education*, *13*(1), 165–190. https://doi.org/10.1007/s10763-013-9477-x

Bondi, H. (1987). A non-believer looks at physics. *Physics Education*, *22*(5), 280–283. https://doi.org/10.1088/0031-9120/22/5/316

Boscolo, A., Lippiello, S., & Pierri, A. (2024). Storytelling as a skeleton to design a learning unit: A model for teaching and learning optics. *Education Sciences*, *14*(3), 1–15. https://doi.org/10.3390/educsci14030218

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction. *Kuram ve Uygulamada Egitim Bilimleri*, *15*(1), 267–283. https://doi.org/10.12738/estp.2015.1.2324

Fan, Y. C., Wang, T. H., & Wang, K. H. (2020). Studying the effectiveness of an online argumentation model for improving undergraduate students' argumentation ability. *Journal of Computer Assisted Learning*, *36*(4), 1–14. https://doi.org/10.1111/jcal.12420

Flores-Amado, A., Sayeg-Sanchez, G., Amozurrutia-Elizalde, A., De-Oca, S. M., Hernández-Mena, C., Amado-Moranchel, N., Hidalgo-Reyes, J. I., & Zamora-Hernandez, I. (2024). Evidence of effectiveness for AJA strategy to argumentative skills development in engineering students. *IEEE Global Engineering Education Conference*, 1–6. https://doi.org/10.1109/EDUCON60312.2024.10578601

Hasnunidah, N., Maulina, D., & Rakhmawati, I. (2023). Developing a project-argumentative learning model with blended learning approach for junior high school students. *ULICoSS*, 990–1000. https://doi.org/10.2991/978-2-38476-046-6_96

Inch, E. (2006). *Critical Thinking and Communication*. Pearson.

Iwuanyanwu, P. N. (2023). When science is taught this way, students become critical friends: Setting the stage for student teachers. *Research in Science Education*, *53*(6), 1063–1079. https://doi.org/10.1007/s11165-023-10122-9

Juntunen, M. K., & Aksela, M. K. (2014). Education for sustainable development in chemistry-challenges, possibilities and pedagogical models in Finland and elsewhere. *Chemistry Education Research and Practice*, *15*(4), 488–500. https://doi.org/10.1039/c4rp00128a

Lobczowski, N. G. (2020). An exploration of social regulation of learning during scientific argumentation discourse. *Contemporary Educational Psychology*, *63*(1), 1–17. https://doi.org/10.1016/j.cedpsych.2020.101925

Murdani, E., Suhandi, A., Muslim, M., Setiawan, A., Samsudin, A., & Costu, B. (2023). Physics argumentation-based computer-supported collaborative hybrid learning to increase concept mastery and argumentation skills. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 232–240. https://doi.org/10.15294/jpii.v12i2.42457

Nandiyanto, A. B. D., & Al Husaeni, D. F. (2021). A bibliometric analysis of materials research in Indonesian journal using VOSviewer. *Journal of Engineering Research (Kuwait)*, *9*, 1–16. https://doi.org/10.36909/jer.ASSEEE.16037

Nandiyanto, A. B. D., Al Husaeni, D. N., & Al Husaeni, D. F. (2021). A bibliometric analysis of chemical engineering research using vosviewer and its correlation with Covid-19 pandemic condition. *Journal of Engineering Science and Technology*, *16*(6), 4414–4422. https://jestec.taylors.edu.my/Vol%2016%20Issue%206%20December%20%202021/16_6_4.pdf

Peten, D. M. (2022). Influence of the argument-driven inquiry with explicit-reflective nature of scientific inquiry intervention on pre-service science teachers' understandings about the nature of scientific inquiry. *International Journal of Science and Mathematics Education*, *20*(5), 921–941. https://doi.org/10.1007/s10763-021-10197-8

Praisri, A., & Faikhamta, C. (2020). Enhancing students' mental models of chemical equilibrium through argumentation within model-based learning. *International Journal of Learning, Teaching and Educational Research*, *19*(7), 121–142. https://doi.org/https://doi.org/10.26803/ijlter.19.7.7

Rahma, A., Wibowo, F. C., & Budi, E. (2024). Student argumentation skill in physics learning: bibliometric analysis. *AIP Conference Proceedings*, *3116*(1), 1–8. https://doi.org/10.1063/5.0215718

Rahmawati, Rustaman, N. Y., Hamidah, I., & Rusdiana, D. (2017). The use of classroom assessment to explore problem solving skills based on pre-service teachers' cognitive style dimension in basic physics course. *Journal of Physics: Conference Series*, *812*(1), 1–7. https://doi.org/10.1088/1742-6596/812/1/012047

Sabí'n, J. (2024). Promoting abstract thinking and scientific argumentation in the teaching of physicsle. *Physics Education*, *59*(4). https://doi.org/10.1088/1361-6552/ad4f3e

Safitri, H., Hamidah, I., Setiawan, W., & Kaniawati, I. (2021). Problem solving ability of distance education student on electrostatic topic. *Journal of Physics: Conference Series*, *2019*(1), 1–7. https://doi.org/10.1088/1742-6596/2019/1/012048

Sinensis, A. R., Firman, H., Hamidah, I., & Muslim, M. (2019a). Pengembangan instrument tes termodinamikan untuk mengukur kemampuan pemecahan masalah (PsACAr) pada mahasiswa calon Guru Fisika [Development of a thermodynamic test instrument to measure problem solving abilities (PsACAr) in prospective Physics Teacher students]. *Jurnal Inovasi Dan Pembelajaran Fisika*, *6*(2), 122–129. https://jipf.ejournal.unsri.ac.id/index.php/jipf/article/view/60

Sinensis, A. R., Firman, H., Hamidah, I., & Muslim, M. (2019b). Reconstruction of collaborative problem solving based learning in thermodynamics with the aid of interactive simulation

and derivative games. *Journal of Physics: Conference Series*, *1157*(3), 1–6. https://doi.org/10.1088/1742-6596/1157/3/032042

Songsil, W. (2019). Developing scientific argumentation strategies using revised argument-driven inquiry (rADI) in science classrooms in Thailand. *Asia-Pacific Science Education*, *5*(1), 1–22. https://doi.org/10.1186/s41029-019-0035-x

Sulisworo, D., & Safitri, I. (2022). Online Student-worksheet Based on Toulmin Argumentation Pattern in Physics Learning. *Journal of Physics: Conference Series*, *2394*(1), 1–7. https://doi.org/10.1088/1742-6596/2394/1/012033

Wang, J., & Buck, G. A. (2016). Understanding a high school physics teacher's pedagogical content knowledge of argumentation. *Journal of Science Teacher Education*, *27*(5), 577–604. https://doi.org/10.1007/s10972-016-9476-1

Wu, C. J., & Liu, C. Y. (2021). Eye-movement study of high- and low-prior-knowledge students' scientific argumentations with multiple representations. *Physical Review Physics Education Research*, *17*(1), 1–16. https://doi.org/10.1103/PhysRevPhysEducRes.17.010125

Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629