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Review

Bibliometric analysis on argumentation research in chemistry education

Kimya Eğitiminde Yapılan Argümantasyon Araştırmalarının Bibliyometrik Analizi

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ABSTRACT

This study is a pioneer bibliometric study about investigating the argumentation studies related to chemistry topics. While bibliometric analysis exists to some extent for analyzing argumentation in education, further research focusing on argumentation in chemistry topics is needed to close the gap in an educational context. The Scopus database was selected to trace the articles published in journals between the years 2006 to 2024. Following the eligibility process, the study was conducted with 94 articles. To reveal the publications and citation trends, performance analysis was conducted. Bibliographic mapping was utilized to understand the conceptual, intellectual, and social structures of the data. In addition to demonstrating the most prolific articles, journals, authors, and countries, the reasons behind their success were investigated. Thus, the current study could help the researchers to determine the research trends. They will also gain valuable insight into which journals should be chosen to publish or which countries are more appropriate to apply for collaborations for projects like Erasmus+. Finally, the results reveal that argumentation studies have great potential in chemistry education.

Keywords: Argumentation, chemistry education, bibliometric analysis.

ÖZ

Bu çalışma, kimya eğitiminde yapılan argümantasyon çalışmalarını inceleyen öncü bir çalışmadır. Alan yazında farklı eğitim alanlarında yapılan argümantasyon çalışmalarına yönelik bibliyometrik analizler bulunmaktadır. Buna rağmen, alan yazında hem argümantasyon çalışmaları hem de kimya eğitimi üzerine odaklanan bir bibliyometrik analize rastlanmamıştır. Bu sebep ile, bu çalışmanın yapılması literatürdeki bu boşluğun doldurması açısından önemlidir. Çalışmanın verileri, 2006-2024 yılları arasındaki zaman dilimini kapsamaktadır ve Scopus veri tabanından elde edilmiştir. Çalışmada kullanılacak veriler için, seçim ve uygunluk sürecinin tamamlanmasından sonra, 266 makaleden sadece 94 tanesi çalışma için uygun bulunmuş ve veri analizine dahil edilmiştir. Yayınlama ve atıf trendlerini açığa çıkarmak adına, performans analizi uygulanmıştır. Çalışmaya dahil edilen verileri; kavramsal yapı, entelektüel yapı ve sosyal yapıları üzerinden değerlendirebilmek için, Bibliyometrik haritalama kullanılmıştır. Veriler içinde öne çıkan makale, dergi, yazar ve ülkelerin belirlenmesinin yanı sıra, bu öğelerin başarılı olma sebepleri de çalışmada detaylı olarak incelenmiştir. Bu sayede çalışmanın güncel trendleri ve literatürdeki boşlukları saptama aşamasında araştırmacılara yararlı bir kaynak olacağı düşünülmektedir. Ayrıca bu çalışmanın makalelerini

yayınlamak için dergi seçiminde veya uluslararası projelerde iş birliği yapacakları ortakları (yazar, ülke) bulma gibi konularda da araştırmacılar için yararlı olacağı düşünülmektedir. Son olarak araştırmanın sonuçları, kimya konularına yönelik argümantasyon çalışmalarının yayınlanma açısından önemli bir potansiyele sahip olduğunu ortaya çıkarmıştır.

Anahtar Kelimeler: Argümantasyon, kimya eğitimi, bibliyometrik analiz.

INTRODUCTION

Currently, there has been a steady increase in the number of research publications focusing on argumentation in chemistry education (Erduran, 2019). For instance, Hosbein et al. (2021) examined student argumentation using argument-driven inquiry (ADI) in General Chemistry classrooms. Kodani and Koga (2021) developed an argumentation-based chemistry course on exothermic phenomena. Deng and Flynn (2021) designed argumentation-based organic chemistry tasks. Additionally, the book edited by Erduran (2019) presents 12 different argumentation studies focused on chemistry education (e.g., Msimanga & Mudadigwa, 2019; Towns et al., 2019). In the chapter written by Hofstein et al. (2019), the researchers examined the factors that support the teaching and learning of arguments regarding the laboratory context. Crujeiras-Perez & Jimenez-Aleixandre (2019) discussed the importance of considering chemistry in an interdisciplinary context and they provided examples of chemistry activities to leverage argumentative discourse. Moreover, some authors in that book focused on promoting argumentation in various branches of chemistry, such as physical chemistry, organic chemistry, etc. (Towns et al., 2019). Furthermore, another researcher investigated the impact of COVID-19 on four areas of chemistry education research. These areas were "Nature of Chemistry", "Argumentation", "Technology" and "STEM", respectively (Erduran & Pabuçcu-Akış, 2023). In this study, the researchers used a rapid review and collected data from the ERIC database between the year 2012 up to 2021. Moreover, subfields of chemistry, such as biochemistry and food chemistry were included in the study as far as they related to educational context. The results demonstrated that the most pronounced increase in the number of research articles within the pandemic has been in relation to Virtual Chemistry Laboratory and Virtual Tools. Also, they stated that more studies need to be done to integrate the nature of chemistry & argumentation into online learning environments. Besides, many reviews of chemistry education research have been produced to examine the argumentation studies conducted in chemistry classes. For instance, Aydeniz (2019) provided a summary, and a critique of argumentation studies designed for chemistry education and examined the implications for practice and future argumentation studies in chemistry education.

Some researchers have run bibliometric analysis for the argumentation (Atabey & Yapıcıoğlu-Evren, 2021) and the chemistry (Evdokimenkova & Soboleva, 2020; Hassan et.al., 2022) in educational context, which are carried out as separate studies. For instance, Hassan et al. (2022) conducted a bibliometric analysis to present the organic chemistry education's trends in the 2011–Jun 2020 time frame. For this analysis, they investigated 1056 papers from the Scopus database. Their study identified the growing popularity of organic chemistry studies in the literature. The United States was found as the most important contributor to organic chemistry education research. To provide another instance, Kartimi et al. (2022) conducted the bibliometric analysis on virtual laboratories in chemistry education. They retrieved the data from Google Scholar database from 2011 to 2021. Their query yielded 117 publications. The authors believed that their study could help the researchers design and utilize Virtual Lab applications for chemistry learning. Moreover, a few researchers conducted bibliometric analyses focused on argumentation studies. For instance, Atabey and Yapıcıoğlu- Evren (2021) present a bibliometric analysis to examine the features of the argumentation papers in the 1976–2020-time frame. For this analysis, they investigated 2176 papers from the Web of Science database. They used Vosviewer software for the analysis. The analysis focused on the distributions of the number of articles and citations across the years, pioneer institutions and countries, collaborations between

the countries, the most frequent co-occurrences of the keywords. They employed descriptive and bibliometric analyses in their study. The results showed that the argumentation studies made the most progress in science education.

Although research papers on argumentation have highlighted the importance of students' engagement in discursive practices of chemistry, as far as we know, there are no bibliometric studies that solely investigate the use of argumentation in the context of chemistry education. In this way, we believed that this study offers a unique contribution to the literature.

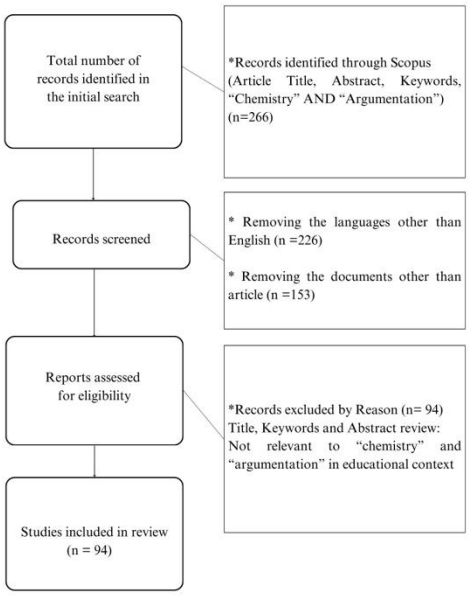
METHOD

2.1. Database Selection

The data was obtained from the Scopus database because Scopus is appropriate to be used by the primary bibliometric analysis tools (i.e., Vosviewer, Biblioshiny) and many researchers have preferred to use it in their research studies (e.g., Gao et al. 2022). The data was analyzed according to three phases of PRISMA (2020), namely, identification, screening, and inclusion.

Figure 1

The diagram for the data selection [adapted from PRISMA (2020)]



Identification. In this phase, the data was derived from the following strategy: TITLE-ABS-KEY (Argumentation) AND TITLE-ABS-KEY (Chemistry) and produced a total of 266 publications (see Figure 1).

Screening. This phase consists of selection in terms of the inclusion/exclusion criteria and the eligibility process (see Table 1). Selecting the languages other than English left 226 publications (see Figure 1). Additionally, having selected the article as the only type in terms of the document type, 153 articles remained. Then, these 153 articles were explored regarding the abstract and the titles by two researchers to ensure that they fit the criteria for the study. Upon this stage, if the research article is not related to argumentation studies and does not include at least

one chemistry topic, it was eliminated from the database. For instance, the following articles, titled “How accurate is the CASPT2 method?”, “The ontological autonomy of the chemical world” and “What is chemistry, for Kant?” were omitted from the dataset because they do not focus on argumentation as in chemistry education, but use the word “argumentation” in its general sense. Moreover, when the research article on argumentation does not focus on at least one chemistry topic, it was also dismissed from the database. For instance, the following article, titled “Effectiveness of epistemic beliefs and scientific argument to improve learning process quality " was removed from the database. Indeed, this study includes the keyword “chemistry” only because the students from Biology, Chemistry, Physics, and Mathematics study programs participated in the study. Finally, the studies that gathered the data from textbooks, blogs etc. were removed from the database.

Inclusion. After screening process, 94 of the articles were selected.

Table 1

Inclusion and Exclusion Criteria

Inclusion	Exclusion	Criteria
English	Removing the languages other than English	Language
Peer Reviewed Journal Articles	Reports, proceeding papers, book chapters, meeting abstracts	Type
The study is accessible	No access	Accessibility
2006-2024	Before 2006, after June 2024	Time
The articles focus on both argumentation & chemistry in the educational context	Focusing only on one of the keywords (Argumentation or Chemistry)	Subject

2.2. Data Analysis

Performance analysis and Bibliometric mapping were conducted to discover the research trends of argumentation research studies in chemistry education. While performance analysis is accepted as a method for examining academic output for productivity, quality, and scientific impact (Dede & Ozdemir, 2022), the bibliometric mapping states the structural and dynamic structure of the data (Börner et al., 2003). We used Vosviewer and Biblioshiny in data visualization and in discovering the relations in citations, co-authorship, and bibliographic coupling.

FINDINGS AND DISCUSSION

3.1. The Data Set

Table 2 presents the information on 94 articles published in the period between January 2006 and 2024. As it seen in Table 2, all of them were published by 187 authors who used 213 distinct keywords. Average number of co-authors per each document was found as 2.77. Even though the average number of co-authors per document is low, the relatively high international co-authorships percentage (19.15) would show the importance of interdisciplinary collaboration in this field. Average citations per document (23.22) implies that “the research related to argumentation in chemistry education” is a topic that attracts academic interest.

Table 2

Descriptive Statistics of the Articles in the Dataset

Description	Results
Timespan	2006-2024
Journals	33
Articles	94
Document Average Age	6.36
Average citations per doc	23.22
Author's Keywords	213
Authors	187
Co-Authors per Doc	2.77
International co-authorships %	19.15

3.2. The Most Influential Articles

Top 10 most cited articles of the database were presented in Table 3. Only publications with at least 51 citations were included in Table 3. The article with the highest total citation (176 recorded) was written by two authors, Sampson, V. and Clark, D. It was published in Science Education in 2009. The researchers of the article randomly assigned high school chemistry students into the individual or group argumentation conditions in the chemistry classes. During the intervention, the teachers finished the units, focused on various introductory chemistry topics such as the molecular–kinetic theory of matter. (Sampson & Clark, 2009). With 131 citations, the article by Mcneill was the second on the database and it was also published in Science Education in 2019. In the study, the researcher focused on how teachers used a chemistry curriculum where the students are expected to justify the claims by showing proper evidence and reasoning rather than solely focusing on mere comprehension of the science content. The results demonstrate the positive impact of the curriculum materials as a means of supporting scientific argumentation in the classroom (Mcneill, 2009). The authors of the third most influential article (Walker & Sampson, 2013) examined whether students enhanced the ability to involve in scientific argumentation in a General Chemistry-I Laboratory course. The laboratory activities were designed utilizing the Argument-Driven Inquiry (ADI) as an instructional model during the course.

Table 3

Top 10 Most Cited Articles in The Database

No	Articles	Sources	TC*
1	Sampson & Clark (2009)	Science Education	176
2	Mcneill (2009)	Science Education	131
3	Walker & Sampson (2013)	Journal of Research in Science Teaching	123
4	McDonald (2010)	Journal of Research in Science Teaching	119
5	Walker et al. (2011)	Journal of Chemical Education	89
6	Katchevich et al. (2013)	Research in Science Education	80
7	Sampson & Clark (2011)	Research in Science Education	77
8	Becker et al. (2013)	Chemistry Education Research and Practice	56
9	Aydeniz et al. (2012)	International Journal of Science & Mathematics Education	52
10	Cetin (2014)	Research in Science and Technological Education	51

*TC: The total citations

3.3. Research Productivity in terms of publications and citations

In terms of the annual research productivity (see Figure 2), we found that the first article of the dataset was published in 2006. The name of the first article was “Argumentative Discourse in a High School Chemistry Classroom” and cited 23 times. The researchers of this article studied

with 10th grade students in a chemistry classroom to determine the types of arguments promoted in different settings which include several chemistry topics such as atomic structure, the periodic table, electron configuration, and chemical reactions. Findings revealed that the quality and the number of student arguments were low, with mostly incomplete structures. Additionally, the authors of this study stated that traditional classroom setting is not compatible with argumentative discourse in science classrooms. However, researchers suggested that in classrooms students' questions and ideas should not go unacknowledged, rather their ideas should be used to leverage argumentative discourse (Abi-El-Mona & Abd-El-Khalick, 2006).

As seen in Figure 2, the highest numbers of publications (n= 12) and citations (n =359) were received in 2021 and 2013, respectively. Moreover, the number of articles produced between 2021 and 2023 constituted 33% of total publications within the 19-year period. Indeed, as the year 2024 is not finished yet, the decline in Figure 2 for this year can be accepted as normal. Additionally, a quick glance at Figure 2 exhibits a wide fluctuation in the number of publications and citations per year for the period of 2006 and 2024. This seemingly difficult-to-interpret trend could be owing to various reasons such as rapid advancements in technology, COVID-19 impact and so on.

Therefore, to present the data more clearly, we have opted to show the publications and citations trends between 2006 and June 2024 as five-year periods instead of yearly figures (see Figure 3). There was a drastic increment between the years 2006 and 2015. In the following years, although the pace of the rise slowed down, it continued its increase. The reason behind the deceleration during 2016-2020 could be the impact of COVID-19. Furthermore, the slowed down increase during 2021- June 2024 could have resulted from the fact that the period only includes 3.5 years. The upward trend in publications despite this shorter period can anticipate a further growth of such studies in the coming years. Also, Figure 3 shows that the 2011-2015 period got the highest citations. Following this peak in 2015, the decreasing citation numbers in the periods 2016-2020 and 2021-2024 are also due to the factors explained above.

Figure 2

Number of Publications and Citations per Year

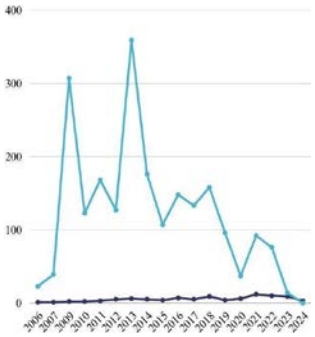
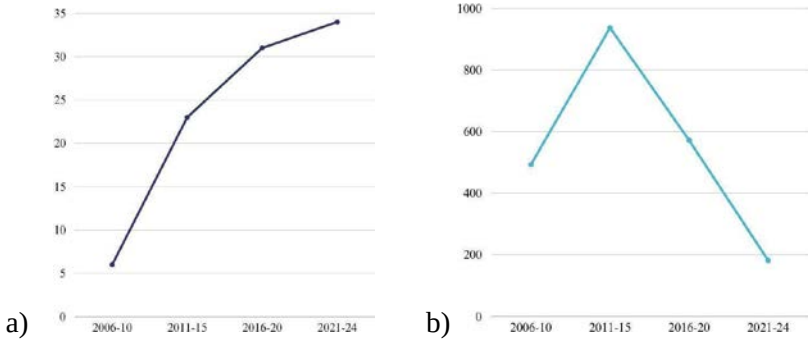


Figure 3

Number of a) Publications and b) Citations for Five-Year Periods



3.4. Leading Countries

Twenty-three countries contributed to the articles in our dataset. The most productive countries were USA (n = 37), Turkey (n = 19), Germany (n = 7), and Indonesia (n = 7) respectively. Following them, Australia, Brazil, Canada, and Malaysia each have 4 articles. Then, China and Israel each have 3 articles. The rest of the countries had two or fewer publications. Figure 4 also shows that the USA (n = 1244), Turkey (n = 387), Australia (n = 134), Canada (n=97) and Israel (n = 92) have the highest citations in the related field. As can be seen in Figure 4, the top two countries are the same for both publications and citations, yet the ranking after these two is different. This lack of consistency between two graphs can be observed in several studies and reasons behind are not easy to pinpoint. The countries (Germany and Indonesia) ranking third and fourth position on publication graph in Figure 4 and those (Australia and Canada) in the same ranks for the citations graph were subjected to descriptive statistical analysis.

Figure 4

Trends of a) Publications and B) Citations of the Leading Countries

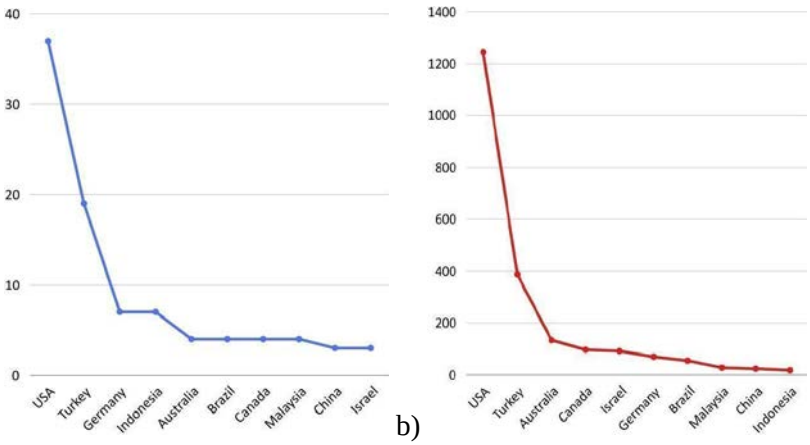


Table 4

Descriptive Statistics of the Selected Countries

Description	Australia	Canada	Germany	Indonesia
Timespan	2010-22	2010-21	2015-23	2018-24
Journals	3	3	6	6
Articles	4	4	7	7
Document Average Age	8.25	7.5	2.86	2
Average citations per doc	33.5	24.25	10	2.57
Author's Keywords	17	10	22	24
Authors	6	8	15	27
Co-Authors per Doc	2.5	2.5	3.14	3.86
International co-authorships %	50	50	42.86	14.29

As seen in Table 4, although Germany and Indonesia had two times more publications than Australia and Canada, the latter ones get more citations. The result may be because of a difference between the "Document average age" of these two groups of countries. "Document Average Age" for these four countries ranges from 2 (Indonesia) to 8.25 (Australia). In other words, Indonesia and Germany started to publish on this topic in 2018 and 2015, relatively much later than Australia and Canada. Looking at the descriptive statistics of Germany and Indonesia, the "Document average age" for these countries is quite similar to each other. However, "International co-authorships" percentage for Germany (42.86) was higher than that of Indonesia (14.29). The result may be contributing to the differences between the percentages of "Average citations per document" for Germany (10) and Indonesia (2.57).

3.5. Collaborative Networks between Countries

Figures 5 and 6 visualized the analysis of cooperation relations between countries. These figures were created by Vosviewer software. Each country is presented by a circle. The USA is the most collaborative country in the dataset of this study (see Figure 5). The curve linking the two circles shows the cooperation between the two countries (see Figure 6). The 16 clusters developed from 26 countries. The first and second clusters, the most crowded ones, contained four countries (Ireland-Taiwan-Turkey-United Kingdom and China-South Korea-United States-Zimbabwe). Cluster 3 had three countries (Australia-Canada-Malaysia). Clusters 4 and 5 each had two countries (Germany-Indonesia and Brazil-Portugal) inside. The remaining 11 clusters consist of only one country.

Figure 5

The co-authorship Across 26 Countries

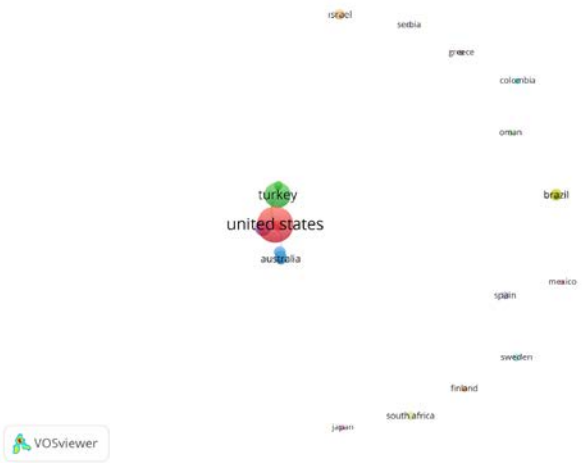
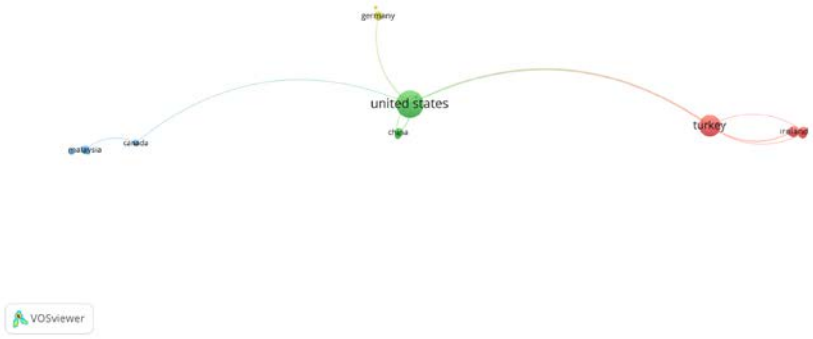


Figure 6

The Co-authorship Across the 13 Countries

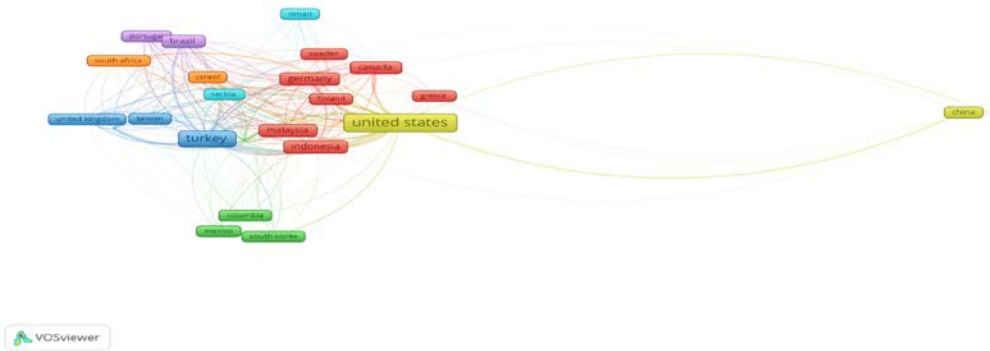


3.6. Bibliographic Coupling of Countries

Bibliographic coupling of countries develops when articles from two countries reference articles from a third country (see Figure 7). All countries in the dataset were included in the study and classified into seven clusters. The cluster 1 (red cluster) is the most crowded one containing 8 countries (Canada-Finland-Germany-Greece-Indonesia-Malaysia-Spain-Sweden). South Korea, Mexico, Colombia and Australia are placed in cluster 2 (green one). Turkey is placed along with the United Kingdom, Taiwan, and Ireland in cluster 3 (blue cluster). The United States is in cluster 4 with China, and Zimbabwe (yellow one). Brazil and Portugal are in Cluster 5. Oman, and Serbia are placed in cluster 6. Finally, Cluster 7 contains Israel and South Africa. Countries with the top bibliographic coupling action included the USA; Turkey; Australia; and Brazil.

Figure 7

Bibliographic Coupling of Countries

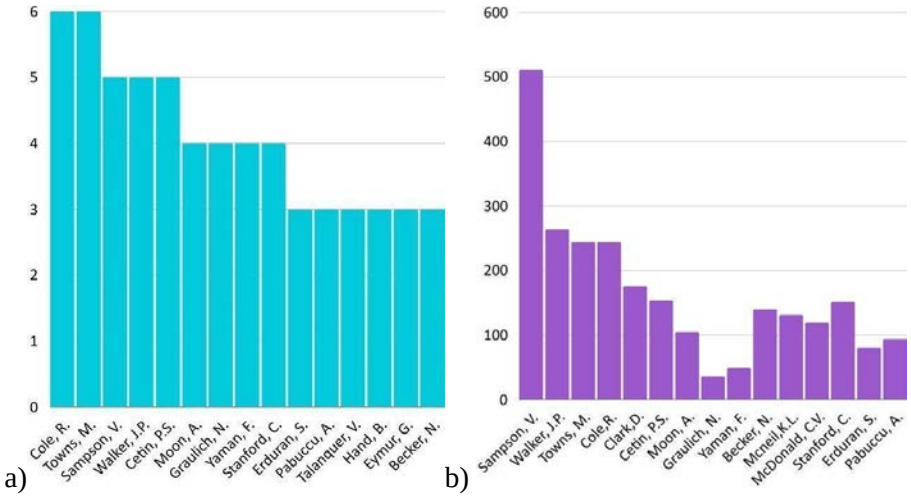


3.7. Most Productive Authors

Figure 8 shows the most productive authors with the total number of publications and the total citations. As shown in Figure 8, only two authors published six papers on the topic; who are Cole, R. and Towns, M. Additionally, three authors published five papers on the topic; Walker, J.P., Cetin, P.S., and Sampson, V. In terms of Scopus, Cetin, P.S (4 articles) and Seda Cetin, P. (1 article) are assigned as different authors. For instance, Scopus documented 4 articles for Cetin, P.S., but Cetin, P.S also contributed another article to the database of this study. The author had two names (Pınar Seda) and one last name (Cetin). Unfortunately, in one article her name was added into the author's last name. We have made the necessary adjustments to calculate the number of articles and citations for the author's publications. On a similar note, we made adjustments for the author, Sampson, V., with increasing the total number of his articles and citations. Consequently, Sampson, V. has had the highest citations in argumentation and chemistry related studies in the database.

Figure 8

Top 15 Most A) Productive and B) Cited Authors in the Dataset

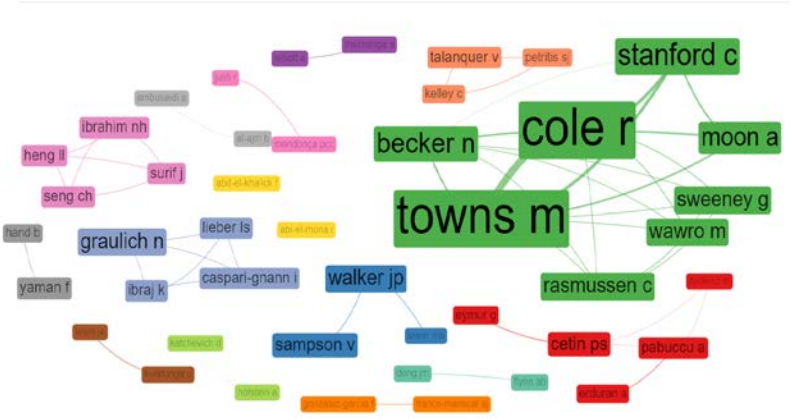


3.8. Co-Authorship Network Map

We used biblioshiny software to visualize the authors' collaboration network (see Figure 9). Figure 9 presents the Towns, M. and Cole, R. have the strongest collaboration relationship.

Figure 9

Co-authorship Network Map



3.9. Most Influential Journals

Table 5 presents the most influential journals with the total number of articles and the total citations associated with these articles. Also, Table 5 presents the indexes of the journals. The most published and cited journals are: Chemistry Education Research and Practice, Journal of Chemical Education and Journal of Research in Science Teaching.

Table 5

Top Contributing Journals

Sources	n	TC	Index
Chemistry Education Research and Practice (CERP)	18	382	SSCI
Journal of Chemical Education (J. Chem. Educ.)	15	328	SCIE
Journal of Research in Science Teaching (JRST)	9	425	SSCI
International Journal of Science Education	6	110	SSCI
International Journal of Science and Mathematics Education	5	158	SSCI
Research in Science Education	4	176	SSCI
Chemistry Teacher International (CTI)	3	2	ESCI
Eurasia Journal of Mathematics, Science and Technology Education	3	12	ESCI
Science & Education	3	29	SSCI
Science Education	3	311	SSCI

SSCI: Social Sciences Citation Index, SCIE: Science Citation Index Expanded, ESCI: Emerging Sources Citation Index

As seen in Table 5, although Science Education has published three articles on this topic, the fourth place belongs to it in terms of the number of citations. It is an unexpected result because three articles published in Science Education had almost the same number of citations as the Journal of Chemical Education, which had five times more articles published than Science Education. To evaluate the distribution of publications/citations among the journals, we investigated the descriptive statistics for five journals (see Table 6).

In addition to Science Education, we selected two other journals (Chemistry Teacher International and Science & Education), having the same number of publications with Science Education, but with fewer citations for the same number of articles. As it is seen in Table 6, the number of citations for Science & Education (n=29) and Chemistry Teacher International (n=2) were drastically lower than for Science Education (n=311) with each having three articles. Looking at Average citations per document, the document average age for Science & Education

(n= 5.33) and Chemistry Teacher International (n=1) were also much lower than Science Education (n=10.7). Indeed, the extreme difference in the average document age between Science Education and Chemistry Teacher International could be accepted as a major contributing factor to the difference in the average citations per document ratios of Science Education, Science & Education, and Chemistry Teacher International, which are 103.7, 9.66 and 0.66, respectively. Moreover, the percentage of international co-authorship for Science Education is 33.33, while the other journals stand at zero. This also could have contributed to the higher number of citations of Science Education.

In addition to these three journals, we added the top two productive journals' descriptive statistics to Table 6 to further investigate the distributions of the number of articles and citations ratios. Looking at Chemistry Education Research and Practice (CERP) and Journal of Chemical Education, we found that they had similar Document Average Age (5.61 and 5.07) and Average citations per document (21.22 and 21.87). The reason CERP got more citations could result from; (1) having more articles published, (2) having a higher percentage of international co-authorships or (3) having more authors in total. Apart from these, of course, there could be more of these affecting factors behind these results.

Table 6

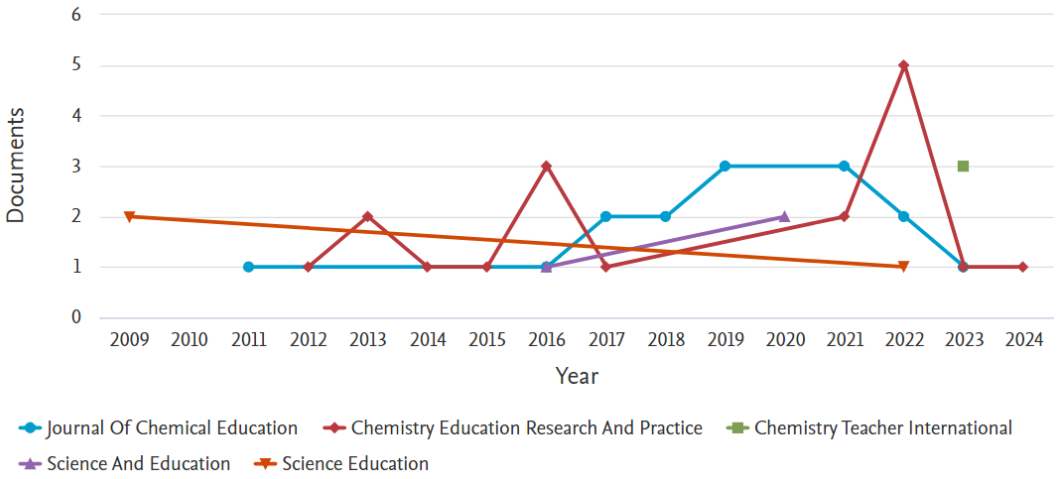
Descriptive Statistics of The Selected Journals

Description	CTI	Sci. Educ.	Sci. & Educ.	CERP	J. Chem. Educ.
Timespan	2023-23	2009-22	2016-22	2012-24	2011-23
Articles	3	3	3	18	15
Doc. Average Age	1	10.7	5.33	5.61	5.07
Average citations per doc	0.66	103.7	9.66	21.22	21.87
Authors	11	5	8	43	36
Co-Authors per doc	3.67	1.67	2.67	3	2.87
International co-authorships %	0	33.33	0	22.22	6.66

Figure 10 developed by Scopus to present the distributions of the documents by year per these five journals placed in Table 6. In Figure 10, each journal is shown with an different color in the graph: Journal of Chemical Education (blue), Chemistry Education Research and Practice (red), Chemistry Teacher International (green), Science &Education (purple), and Science Education (orange). As seen in Figure 10, the number of articles in Chemistry Education Research and Practice publications seems to have increased impressively with a peak in 2022. Additionally, Journal of Chemical Education, reached peaks in 2019 and 2021.

Figure 10

Documents by Year per Journals (from Scopus)



3.10. Most Frequently Used Words in the Dataset

Figure 11 shows the top 15 words that appeared most frequently in the database. The most used keywords were “argumentation” (f=27), “inquiry-based/discovery learning” (f=8), “chemistry education” (f=8), “chemistry” (f=7), “problem solving/decision making” (f=7), “chemical education research” (f=6), and “organic chemistry” (f=6).

Figure 11

The Word Cloud of The Author's Keywords

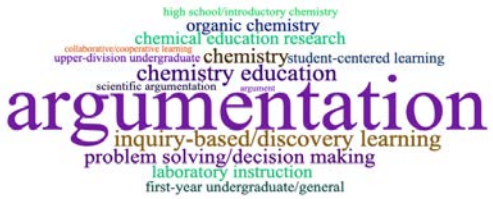
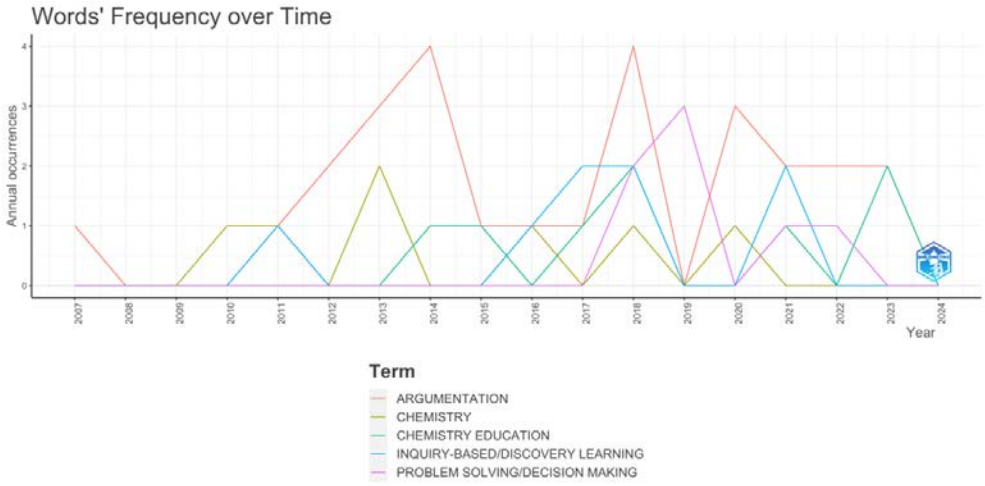


Figure 12 presents the top 5 keywords’ frequency over time. Each keyword is denoted with an individual color to distinguish in the graph: Argumentation (red), Chemistry (dark green), Chemistry Education (light green), Inquiry-based/discovery learning (blue), and Problem solving/decision making (fuchsia). As seen in Figure 12, the use of argumentation as the author’s keywords in publications seems to have increased noticeably with a peak in 2014 and 2018. Problem solving/decision making, however, reached a peak in 2019.

Figure 12

The Word Growth of The Top 5 Keywords

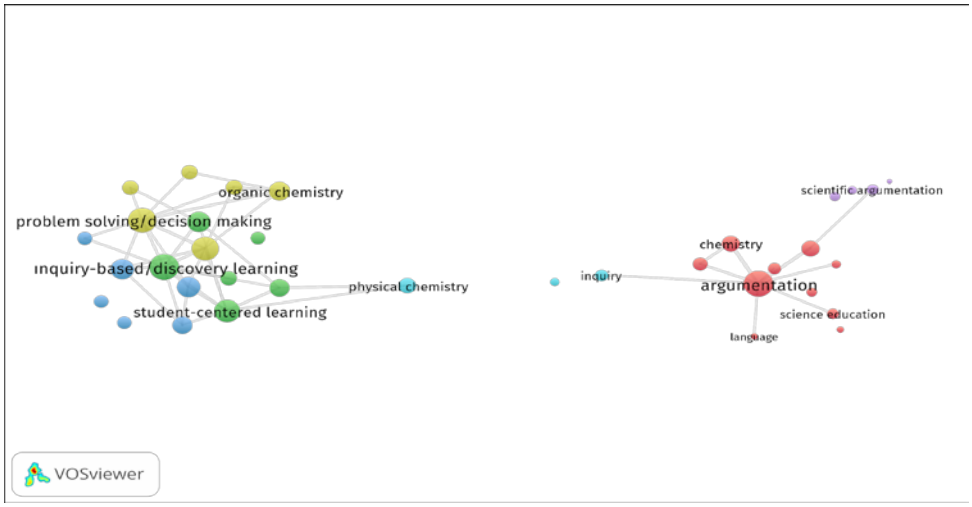


3.11. Co-Occurrence Network Mapping

With the minimum repetition count was chosen as two, 37 keywords met this threshold in the Vosviewer program (see Figure 13). The size of a circle indicates the frequency of the keyword. Six clusters with different colors were obtained after the analysis. These clusters were composed of 3 to 10 keywords. The largest circle of each cluster indicates the dominant keyword. “argumentation” for the red cluster, “inquiry-based/discovery learning” for the green one, “first-year undergraduate/general” for the blue cluster, “problem solving/decision making” for the yellow one, “scientific argumentation” for the purple cluster, and “physical chemistry” for the light blue cluster were the dominant keywords. The total link strengths for these keywords were as follows; 30, 30, 19, 28, 5, 11 respectively.

Figure 13

The Co-occurrence of the Authors’ Keywords



CONCLUSION, RECOMMENDATIONS AND LIMITATIONS

The growing popularity of argumentation studies has led to more authors advocating argumentation in chemistry education. Within this scope, this study investigated the argumentation studies related to chemistry topics. Although there are research studies conducting bibliometric analysis for the investigation of argumentation and chemistry in educational context individually, there is more need for research focused on argumentation and chemistry topics in educational context. The findings of the study indicated that the first article on that purpose appeared in 2006. There was a broad fluctuation in the number of publications and citations per year for the period of 2006 and 2024. This apparently difficult-to-interpret trend could be due to various reasons such as rapid advancements in technology, COVID-19 impact and so on. When we investigated the publications and citations trends in 19 years as five-year periods instead of yearly. We observed a drastic increment in the first decade. However, the pace of the rise slowed down for the number of publications while declined for the citations in the following years. The reason behind that could be various, such as the impact of COVID-19. During the 2020-2021 period, the lockdown forced schools to switch to online education where technologies such as virtual tools saw a spike in chemistry education, also creating learning environments to promote students' argumentation in chemistry classrooms was challenging. Thus, future research on argumentation could aim to foster understanding of how evidence-based reasoning can be integrated in an online learning environment (Erduran & Pabuçcu-Akış, 2023). Furthermore, the slowed down increase during 2021- June 2024 could have resulted from the fact that the period only includes 3.5 years. The upward trend in publications despite this shorter period can anticipate a further growth of such studies in the coming years.

The findings of the study revealed that the most cited article in the dataset appeared in 2009 and was written by Sampson, V. and Clark, D. from the USA. In our database, Sampson, V. was detected as the most cited author. He is also one of the top 5 productive authors with contributing 5 articles and getting 511 citations associated with these publications. On the other hand, his co-author' (Clark, D.) contribution to our database was limited to only one article. That article was also published in Science Education. We observed that the fourth place belongs to this journal in means of citations even though it published only three articles in the database. However, when we listed the journals of the database in terms of the citations they get, we observed that average document age of the articles and percentage of international collaboration are very decisive factors regarding their rankings. For instance, the document average age for Chemistry Teacher International and Science Education were 1 and 10.7, respectively. It means Chemistry Teacher International has started its publications much sooner than Science Education. Thus, it is anticipated the number of citations per document for Chemistry Teacher International will increase further soon. However, the percentage of international co-authorship for Science Education is stunningly high (33.33), while the other journals stand at zero. This also could have contributed to the higher number of citations of Science Education. Furthermore, when we documented the top 10 most cited articles in the database, we observed that all of these articles focused on creating a learning environment to promote participants' argumentation related to chemistry topics. Thus, reading these top 10 journals could also be helpful to the chemistry teachers who need help to integrate argumentation in their classes. Additionally, the authors of this most cited article were from the USA. Indeed, the most prolific authors contribute to making their countries reach the leading position as observed in other studies in the literature (Pabuçcu-Akış, 2024). The fact that the most productive and cited authors were from the USA has led the USA to emerge as the leading country in the related field. Also, the USA was the most internationally collaborative country in the database. The following countries are likely to increase their figures by promoting international collaboration between authors. Currently, not enough cooperation was found within the dataset regarding the collaboration between universities.

Regarding the recommendations, we believe that it is imperative for researchers interested in argumentation studies focusing on chemistry topics to follow the publications of the most prominent authors and journals. Acknowledging the most eminent articles, journals, authors, and countries could prove to be a useful reference for researchers working on this topic. Finally, among the 213 keywords reported, five of them stood out in terms of frequency. Knowing and including these five keywords would provide benefits to the researchers to become more prominent in their fields. In addition to those, since the eligibility process is one of the crucial parts of the bibliometric analysis, we suggest the researchers carefully review the titles, keywords and abstracts to have the general picture and idea of the articles. Moreover, some studies in the literature also recommend examining the conclusion to ensure that the articles fit the criteria for the study (e.g., Mohd Ghazali et al., 2023). For instance, one bibliometric study that examines the use of Arduino in STEM education reported that the Scopus database identified the word "system" as "stem" in the abstract and included this irrelevant article in the database of the study (Pabuçcu-Akış, 2024). The researchers also observed that the word "STEM" had different usages foreign to STEM education, such as "stem cell." Indeed, in our study, we also found out that Scopus mistakenly recorded the same person as two different authors. Then, we adjusted to calculate the number of articles and citations for the author's publications. We can detect the database error because we were familiar with the most prolific authors in the field of the study. Thus, we suggest that the researchers should conduct a bibliometric study related to their main research topic.

This study obtained its data only from one database and it was limited until June 2024. Other data sources besides the Scopus might yield different perspectives and findings in future studies. Argumentation studies on chemistry and another subject could be subject to analysis. Furthermore, the inclusion-exclusion criteria chosen for the study at hand may have impacted the results. Altering these criteria may bring forth a different outcome of the research area. Future research may be extended to encompass other document types, such as book chapters or conference papers.

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GENİŞLETİLMİŞ ÖZ

Giriş

Son zamanlarda, özellikle kimya eğitiminde argümantasyon araştırmalarına yer veren çalışmaların sayısı önemli bir artış göstermiştir (Towns, Cole, Moon & Stanford, 2019). Örneğin, Hosbein vd. (2021) Argümantasyon Tabanlı Sorgulayıcı Araştırma Yöntemini, Genel Kimya derslerinde kullanarak öğrencilerin yaptıkları argümantasyonları değerlendirmiştir. Ayrıca, farklı kimya konularına (genel kimya, organik kimya, fizikokimya gibi) yönelik argümantasyona uygulamaları geliştiren pek çok araştırmacı bulunmaktadır (Deng & Flynn, 2021; Kodani & Koga, 2021; Towns vd., 2019). Bunun yanında, alan yazında eğitim alanında yapılan argümantasyon çalışmalarına yönelik bibliyometrik analiz çalışmalarına az da olsa rastlanmaktadır. Örneğin, Atabey ve Yapıcıoğlu-Evren (2021) fen eğitiminde kullanılan argümantasyon çalışmalarına yönelik bir bibliyometrik analiz çalışması yapmıştır. Ayrıca, alan yazında organik kimya eğitimine yönelik bibliyometrik analiz çalışmaları da bulunmaktadır (Evdokimenkova & Soboleva, 2020; Hassan vd., 2022 gibi). Örneğin, Hassan vd. (2022), 2011-2020 yılları arasındaki organik kimya eğitimindeki popüler akımları tespit etmek için bir bibliyometrik analiz yapmıştır. Bütün bu çalışmalardan farklı olarak hem argümantasyon hem de kimya eğitimi araştırmalarına odaklanan bir bibliyometrik analiz çalışmasına alan yazında rastlanmamıştır. Bu anlamda, bu çalışmanın ilgili literatüre anlamlı ve özgün katkıları olacağı düşünülmektedir. Ayrıca, bu çalışma ile ilgili alandaki akımların belirlenmesi ve gelecekte yapılacak olan araştırmacılara öneriler verilmesi de amaçlanmaktadır.

Yöntem

Çalışma için "kimya" ve "argümantasyon" anahtar kelimeleri Scopus veri tabanının "Başlık-Özet-Anahtar Kelimeler" kısmında aratılarak 2006-2024 yılları arasındaki süreçte, bu doğrultuda üretilen 266 makaleye ulaşılmıştır. Çalışmada kullanılacak verileri için seçim ve uygunluk sürecinin tamamlanmasından sonra, 266 makaleden 94 tanesi veri analizine dahil edilmiştir. Çalışmanın verileri bibliyometrik yöntem ile analiz etmiştir. Bibliyometrik yöntemde, yayınlama ve atıf trendlerinin değerlendirilmesi performans analizi ile yapılmıştır. Bunun yanında, verilerin kavramsal, entelektüel ve sosyal yapılarını anlaşması için bibliyometrik haritalamadan yararlanılmıştır. Bibliyometrik analizde verilerin görselleştirilmesi için Vosviewer ve Biblioshiny programları tercih edilmiştir. Yapılan analizler, araştırma kategorilerinin yayın sayısına göre dağılımı, yayınların yıllık atıfları, yayınların ve atıfların ülke, dergi ve yazarlara göre dağılımı ve trend olan anahtar kelimelerin analizine odaklanmaktadır. Bunların yanında, VOSviewer ve Biblioshiny programları kullanılarak, ortak yazarlık (co-authorship analysis), bibliyografik eşleştirme (bibliographic coupling) ve birlikte bulunma analizleri (co-occurrence analysis) oluşturulup verilerin görselleştirilmesi sağlanmıştır.

Bulgular

Araştırma verileri hakkında istatistikler incelendiğinde, 94 makalenin 33 farklı dergide yayınlandığı ve toplamda 187 yazarın katkısı ile oluşturulduğu görülmüştür. Makale başına düşen ortak yazar sayısı ise 2.77 olarak bulunmuştur. Bu sayı literatürdeki diğer çalışmalara göre biraz daha az olsa da "Uluslararası ortak yazarlık" yüzdesinin (19.15) yüksek olduğu gözlemlenmiştir. "Makale başına ortalama alıntı sayısı" ise 23.33 olarak bulunmuştur. Bu değer ileride argümantasyon çalışmalarında kimya konularına daha çok yer verileceğini düşündürmektedir.

94 makaleye ait bilgilerin yıllara göre dağılımına bakıldığında 2006-2015 arasındaki ilk on yıllık zaman aralığında, bu konuda yayınlanan makale sayısı ile bu makalelerin aldıkları atıf sayılarında hızlı ve düzenli bir artışın olduğu görülmüştür. Fakat, 2016-2020 arasında yayınlanan makale sayısındaki artış sürse de ivmesinin biraz azaldığı kaydedilmiştir. Atıf sayısında ise azalma olduğu kaydedilmiştir. Bunun sebebi olarak, COVID-19 salgını ile uzaktan eğitime geçilmesi ve kimya eğitiminde yapılan araştırmalarda teknoloji ve sanal araç (arttırılmış gerçeklik, sanal gerçeklik araçları gibi) kullanımının hızla artması gösterilebilir (Erduran & Pabuçcu-Akış, 2023). 2021-Haziran 2024 arasında kalan zaman diliminde ise makale yayınlama hızı azalsa da makale sayısında artış olması olumlu bir sonuçtur çünkü bu aralık sadece 3,5 yıllık bir zaman dilimini kapsamaktadır. Alınan atıf sayısındaki azalma ise çok doğaldır. Sürenin kısalığının yanında bu yıl yayınlanan makalelerin atıf sayısının genelde sıfır olması bu düşüşe sebep olmuş olabilir.

Çalışmada, ABD'nin en fazla makale üreten, en çok atıf alan ve en fazla iş birliği kuran ülke olduğu görülmüştür; makalelerde en sık kullanılan kelimelerin ise "argümantasyon", "araştırma/keşfetme temelli öğrenme", "kimya eğitimi", "kimya", "problem çözme/karar verme", "kimya eğitim araştırmaları" ve "organik kimya" olduğu görülmüştür. Araştırma sonucunda Cole, R. ve Towns, M.'un ilgili alana en fazla katkıyı sağlayan yazarlar olduğu görülmüştür. Ayrıca yazarlara dayalı olarak iş birliği ağı analiz edildiğinde, en çok iş birliği yapan ilk iki yazarın Cole, R. ve Towns, M olduğu tespit edilmiştir. Bu çalışmada, makalelerine en çok atıf alan yazar ise Sampson, V. olarak bulunmuştur. Ayrıca, Science Education dergisinin araştırma alanına katkı yapan ilk dergi olduğu tespit edilmiştir. Bunun yanına en çok yayın yapan ve atıf alan dergilerin; Chemistry Education Research and Practice, Journal of Chemical Education and Journal of Research in Science Teaching olduğu görülmüştür.

Anahtar kelime ağı haritasına bakıldığında 6 farklı kümenin olduğu anlaşılmaktadır. Bu kümelerin 3 ile 10 anahtar kelime içerdiği bulunmuştur. Ek olarak çalışmada ülke bazında bibliyografik eşleştirme analizi yapılmış ve oluşturulan ağ haritasında 7 kümenin olduğu görülmüştür. Bu kümelerden en kalabalığı 8 ülke içermektedir (Kanada-Finlandiya-Almanya-Yunanistan-Endonezya-Malezya-İspanyapain-İsveç). Bunların yanında çalışmanın en çok atıf alan 10 makalesi incelenmiş ve bunlar ile ilgili bu alanda yayın yapan araştırmacılara ve derslerinde argümantasyon uygulamalarına yer vermek isteyen kimya öğretmenlerine yararlı olabilecek öneriler çalışmaya eklenmiştir.

Tartışma, Sonuç ve Öneriler

Bu çalışmada öne çıkan makale, dergi, yazar ve ülkelerin yanı sıra, aynı zamanda bunların popüler olmalarının sebepleri de incelenmiştir. Bu sebeple, bu çalışmanın, araştırma yaparken güncel trendleri ve literatürdeki boşlukları saptamada araştırmacılara yararlı bir kaynak olacağı düşünülmektedir. Aynı zamanda bu çalışma, araştırmacıların çalışmalarını yayınlamak için hangi dergileri seçmeleri gerektiği veya uluslararası projelerinde hangi ülkelerle/yazarlarla iş birliği yapabilecekleri konusunda öneriler sunmaktadır. Ayrıca bu çalışmada, bibliyometrik analiz yapacak araştırmacılar için öneriler de bulunmaktadır. Bu yönde ilk önerimiz, çalışmaya dahil edilecek yayınların değerlendirilmesinde; başlıkların ve özetlerin dikkatlice okunmasıdır. Dikkatli özet okunmasının öneminden bahseden başka bir bibliyometrik analiz çalışması da, STEM eğitiminde Arduino kullanımına yöneliktir. Bahsedilen çalışmada Pabuçcu-Akış (2024),

özetinde “stem” anahtar kelimesini içeren pek çok makalenin aslında STEM eğitimi ile alakalı olmadığını tespit etmiştir. Örneğin, Scopus veri tabanı tarafından “system” kelimesini içeren bir makalenin “STEM” makalelerine dahil edildiğini gözlemlemiştir. Bunun yanında, “STEM” anahtar kelimesinin eğitim dışında “stem cell” gibi çok farklı alanlarda kullanımı olduğunu da tespit etmiştir. Araştırmacı, dikkatli özet okuması sayesinde STEM eğitimi ile ilgili olmayan makaleleri çalışmasının veri setinden çıkartabilmiştir. Bibliyometrik analiz yapacak araştırmacılara bir diğer önerimiz ise, literatürüne hâkim oldukları alanlarda inceleme yapmalarıdır. Örneğin, bizim kimya eğitiminde argümantasyon çalışmaları ile ilgili önde gelen araştırmacıları ve onların çalışmalarını bilmemiz, Scopus tarafından yapılan yanlış sınıflandırmaları tespit etmemize olanak sağlamıştır. Son olarak, bu araştırmanın sonuçlarının, kimya eğitiminde argümantasyon çalışmalarının sayısının artış göstereceğini desteklediği söylenebilir.