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Bibliometric analysis of formative assessment research in science education

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Abstract

Purpose: The purpose of this study is to study a bibliometric analysis of articles within the scope of "formative assessment in science education"

Design and Methodology: This study was conducted according to bibliometric analysis which uses different qualitative and quantitative literature review methods to explore and analyze large volumes of scientific data obtained from previous studies. In this study, articles published in the "Web of Science", one of the most popular bibliographic databases containing 22,000 peer-reviewed journals worldwide, were examined. In this study, VOSviewer software and Biblioshiny developed in R language developed for bibliometric analysis were used.

Results: In the Web of Science, studies on formative assessment in science education have been published since 2001, while Turkey-based publications have been published since 2014. The most frequently published articles and citations on the subject appear to be in science education, teacher-focused, and technology-focused journals.

Implications & Suggestions: It can be argued that studies on formative assessment in science education have become increasingly widespread in recent years. Furthermore, considering the journals in which the articles are most frequently published, it can be argued that teachers and educational technologies are important factors in the formative assessment process in science education, and that teacher-focused, technology-supported studies will contribute to literature.

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1. INTRODUCTION

Measurement is the representation of the degree to which living or non-living beings have a certain quality or characteristic with numbers or symbols within the framework of certain rules. Evaluation is the comparison of measurement results with criteria and reaching a decision about the measured characteristic. Measurement and evaluation studies in the field of education generally examine the cognitive, affective and motor behaviors of individuals (Atılgan et al., 2009). According to their functionality, evaluation activities that have an important place in the teaching process are diagnostic evaluation, formative evaluation, summative evaluation (Lawton et all, 2012; Menezes & De Bortolli, 2016; Bell & Cowie 2001). Diagnostic assessment is used at the beginning of the teaching process to determine the student's readiness level (Lawton et al., 2012; Menezes & De Bortolli, 2016; Bell & Cowie 2001), weaknesses and strengths (Terwase & Oluwatoyin, 2018).

With diagnostic assessment, areas where students need to learn can be determined. Organizing the teaching process according to these needs is very effective in developing students' knowledge and skills. (Terwase & Oluwatoyin, 2018). Formative evaluation, which aims to establish an effective learning-teaching process by determining the degree to which the student has reached the expected goals during the teaching period; and summative evaluation, which is carried out with the aim of determining the level reached at the end of the teaching (Lawton et et al., 2012; Menezes & De Bortolli, 2016; Bell & Cowie 2001). Summative evaluations, which provide general information about progress in education, are important for educators and politicians in terms of generally giving an idea about what kind of educational reforms should be made and how much budget should be allocated for education; formative evaluations carried out during the teaching process allow the student to have an idea about his/her own learning and the effectiveness of the learning activities provided by teachers. In this way, the teacher and the student can make arrangements in a more efficient way.

Formative evaluation in science education; Determining the extent to which the concepts that students construct in their minds overlap with scientifically accepted concepts is very important in terms of determining the student's ability to transfer/use the information they have learned to different situations and developing the teaching process accordingly (Bell & Cowie 2001; Shavelson et al., 2008). Scriven (1967) discussed formative assessment with the aim of improving the curriculum, and Bloom (1969) discussed it with the aim of providing continuous feedback and correction to students during the teaching process (Bennet, 2011). Grob et al (2017) drew attention to the importance of formative assessment in developing students' self-regulated learning ability.

Formative assessment: It aims to help students' conceptual understanding, attitude, motivation, effort for learning, explanation in the context of the learned subject and production of arguments about the subject (Dini et al., 2020) and to make the curriculum more effective (Cowie & Beverley, 1999). It can be said that the teaching process of teachers who use formative assessment practices effectively is more efficient (Dini et al., 2020). In a planned formative assessment, teachers should firstly reveal students' ideas about concepts (elicit), secondly reveal to what extent the essence of the targeted concept has been learned by the student (noticing substance / interpreting) and thirdly support the student's learning in order to direct his/her learning (Cowie et al., 2015; Levin et al., 2009). Support can also be obtained from experienced and successful teachers in the field in planning formative assessment activities and preparing questions (Adams & Wieman, 2010).

In order for conceptual understanding to occur in science classes, it is important to have qualitative questions in the formative assessment process in a classroom environment where students can express their opinions comfortably, reason, comment and transfer their knowledge to daily life events (Bulunuz & Bulunuz, 2013). Studies have shown that most science teachers use innovative, constructivist teaching methods effectively (İnaltun & Ateş, 2018), but they cannot use formative assessment practices effectively (Atasoy & Kaya, 2022; Bennet, 2011; İnaltun & Ateş, 2018). Some of the difficulties that teachers encounter in formative assessment practices are i- placing formative assessment practices in the teaching process, ii- content and structure of feedback, iii- students' interaction with feedback (Grob et al., 2017), crowded classes, and the difficulty of providing personalized feedback for each student (Buchanan, 2000; Hatziapostolou & Paraskakis, 2010; Hsu et al., 2011). Although developments in information and communication technologies contribute to the renewal and development of learning-teaching and assessment and evaluation activities inside and outside the school,

it is difficult to say that teachers who are accustomed to traditional and face-to-face teaching environments use technology effectively (Kamble et al., 2021). Sadi-Yılmaz & Yaşar, (2023) stated that the use of technology-supported formative assessment activities in science education has many advantages, but it also has some limitations and emphasized the importance of supporting teachers and teacher candidates in overcoming these limitations.

The purpose of this study is to conduct a bibliometric analysis of articles published within the scope of "formative assessment in science education" in Web of Science, one of the most popular bibliographic databases containing articles from 22,000 peer-reviewed journals worldwide (European University Institute, 2025), using the free and uncoded software VosViewer, R Studio, and bibliometrix/biblioshiny. This aims to present the research conducted in the field of "formative assessment in science education" to readers in a holistic manner.

Over time, scholars have resorted to various quantitative and qualitative methods to understand and organize the research done in previous years on a certain topic. Among these, bibliometrics is based on systematic, transparent, and repeatable measurements based on the measurement of scientific activities. However, bibliometric analyses are seen as a difficult process for some researchers because they require the use of a large number and variety of analysis and mapping software (Aria & Cuccurullo, 2017). The Vosviewer software used in the bibliometric analysis in this study can reveal co-authorship networks, citation-based networks, and concurrency networks based on data downloaded from Web of Science, Scopus, Dimensions, and Lens (Vosviewer, 2025). Additionally, with VOSviewer Online, visualizations of bibliometric networks can be examined interactively in a web browser (LeidenMatrics, 2025). Another software tool used in this study; Biblioshiny, developed in the R language, imports data from databases such as SCOPUS, Web of Science, and PubMed, enabling co-citation, scientific collaboration analysis, and co-word analysis, as well as bibliometric analysis (Bibliometrix, 2025). The reason for using two different software programs in this study is that each software creates unique visuals using existing data. This study aimed to provide a richer mapping analysis of the data.

2. METHOD

2.1. Research Model

This study was conducted according to bibliometric analysis (Aria &, Cuccurullo, 2017), which uses different qualitative and quantitative literature review methods to explore and analyze large volumes of scientific data obtained from previous studies. Bibliometric analysis is used to reveal the general trends and components of a topic in articles, journals, etc. Bibliometric analysis can be done in the form of i- performance analysis, which addresses the contributions of research components, and ii- mapping, which focuses on the relationships between research components (Donthu et al., 2021).

2.2. Study Group

This research was conducted in the “Web of Science” database in the “Web of Science Core Collection” area. The search was conducted by analysing 213 articles that were accessed as a result of the search using the document type “article”, “Web of Science Categories”, “Refine by Citation Topic Meso” and “Refine by Citation Topics Micro” options.

2.3. Data Collection and Analysis Process

Within the scope of this study, 146 documents were reached in the search conducted on 23.09.2024 in the Web of Science database with the keywords "formative assessment" and "science education" in the "Web of Science Core Collection" field on formative assessment in science education (Appendix, Figure 4). In order to increase the validity of the study, the opinions of two experts in the field were taken and the keyword group "formative assessment" and ("science education" or "science learning" or "science teaching" or "science teacher" or "science student" or "biology education" or "biology learning" or "biology teaching" or "biology teacher" or "chemistry education" or "chemistry learning" or "chemistry teaching" or "chemistry teacher" or "physics education" or "physics learning" or "physics teaching" or "physics teacher" or "science curriculum" or "biology

curriculum" or "chemistry curriculum" or "physics curriculum" or "physics curriculum" was created. As a result of the search made with the keyword group, 304 documents were reached (Appendix, Figure 6). In determining the documents to be analysed, 213 articles (Appendix, Figure 14) were included in the analysis because of the inclusion of some criteria and the exclusion of some criteria. The data collection process is given in Table 1.

Table 1. *Data Collection Process*

Obtaining data from the database	As a result of the search conducted with the relevant keyword group from the "Topic" option of the WoS Core Collection database, 304 studies were reached (Appendix, Figure 6).
Refining the data	When the "article" option was selected from the "Documant types" section, 233 articles were reached on the subject. With the options selected from "Web of Science Categories", "Refine by Citation Topic Meso" and "Refine by Citation Topics Micro", 213 articles were reached at the end of the scan (Appendix, Figure 14), and these 213 articles were included in the analysis.

In line with the purpose of the study, the research titles and the applications used in the analysis of the data obtained from WosCC are listed in Table 2.

Table 2. *Research Titles and Applications to be Used in the Analysis of Related Titles*

	Research Titlles	Applications used in data analysis	Table, Figure, Graph No.
1	Number of articles published and number of citations by year	*	Graph 1
2	The most published and cited journals	***	Graph 2, Graph 3
3	Most cited articles	*	Table 3
4	Authors with the most articles	*	Graph 4
5	Articles published from Turkey on the subject	*	Table 4
6	Co-authorship of authors	**	Figure 1
7	Citation of authors	**	Figure 2
8	Co-occurance of all keywords	**	Figure 3
	Distribution of frequently used keywords by authors by year	***	Graph 5
9	Keywords- authors- references	***	Figure 4
10	Distribution of articles according to corresponding author countries	***	Table 5

* Analysis of data obtained from WosCC was done with Microsoft Excel program.
** Analysis of data was done with VosViewer 1.6.20 software.
*** Analysis of data was done with R 4.4.1 version, R studio, bibliometrix/ biblioshiny.

2.3.1. *Ensuring validity and reliability*

In scientific research, the factors that support validity are that the research serves its purpose, the findings reflect the truth, and the accuracy of the research results (Creswell & Clark, 2007). To increase the validity of this study, a search was conducted in WoSCC by creating a keyword group that would cover the subject of the study after receiving the opinions of three field experts. In addition, while searching in WoSCC, preferences (inclusion-exclusion) were made in accordance with the purpose of the study. When the keywords "science education" and "formative assessment" were used in WoSCC, 146 documents were accessed, when the keyword group related to physics, chemistry, biology and science education was used, 304 documents were accessed, and when the search was made within the article, 213 articles were accessed. To ensure/increase the reliability of the study, which is related to the reproducibility of the research results, the data collection process was explained in detail, and a screenshot of the search results made in WoSCC is included in Appendix.

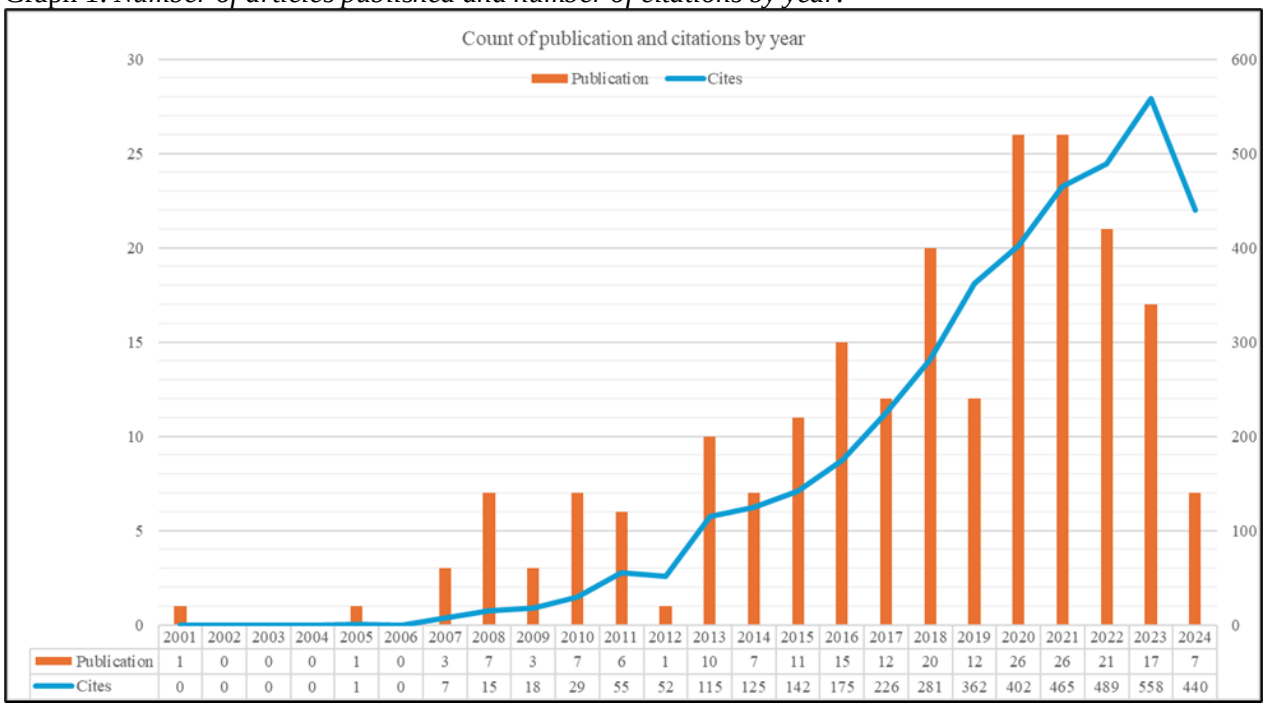
3. RESULTS / FINDINGS

In this section, the results of the data analysis are presented in the form of graphs, figures and tables to address the research topics.

3.1. Distribution of Published Articles by Year and Number of Citations

When a search is made in the Web of Science Core Collection under this title without limiting the publications by year, it is seen that the articles related to the subject started to be published since 2001. It is seen that the number of publications decreased after 2020-2021. It is seen that the number of citations of the articles decreased in 2023-2024 (Graph 1).

Graph 1. *Number of articles published and number of citations by year.*

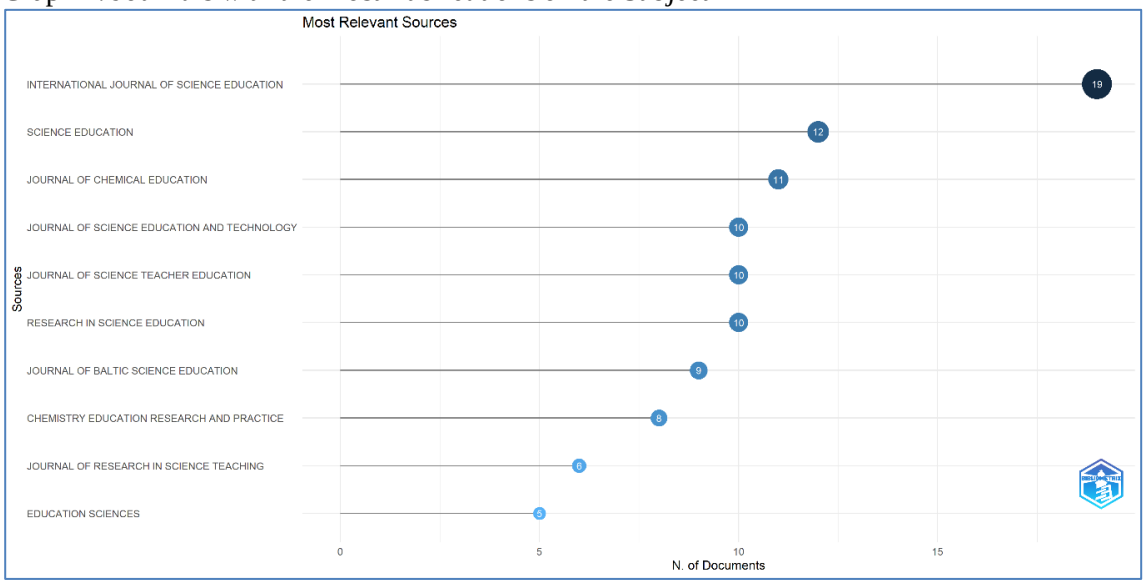


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Publication	1	0	0	0	1	0	3	7	3	7	6	1	10	7	11	15	12	20	12	26	26	21	17	7
Cites	0	0	0	0	1	0	7	15	18	29	55	52	115	125	142	175	226	281	362	402	465	489	558	440

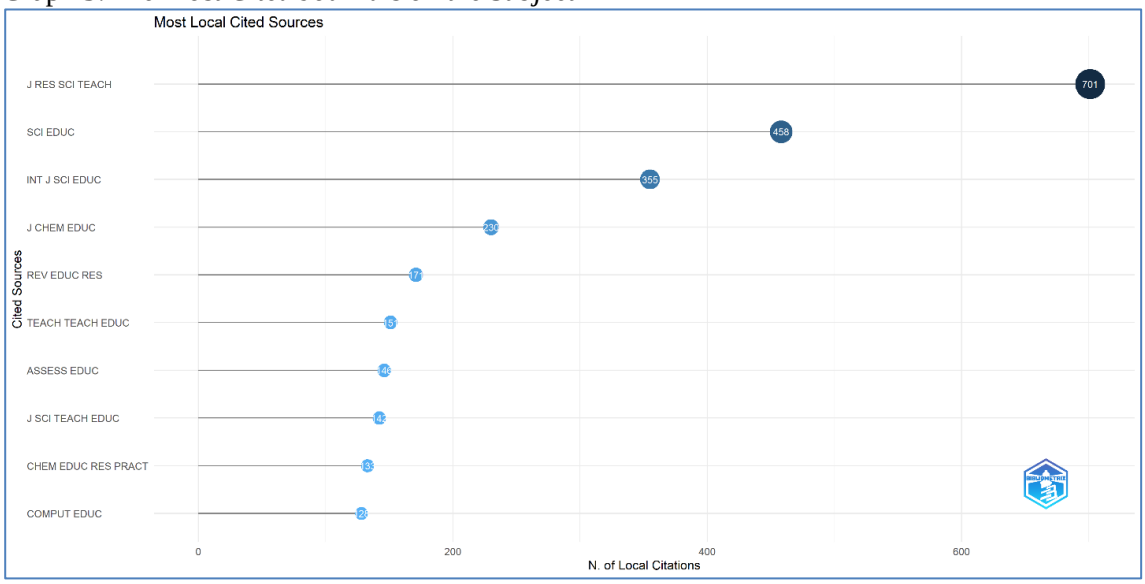
3.2. Journals with the Most Publications and Citations on the Subject

The ten journals that published the most articles on the subject (Graph 2) and the ten journals that received the most citations (Graph 3) are listed under this heading. It is seen that the journal that published the most articles (19) is “International Journal of Science Education”. It is seen that the journal with the most citations (701) is Journal of Research in Science Teaching

Graph 2. *Journals with the Most Publications on the Subject*



Graph 3. *The Most Cited Journals on the Subject*



In Graph 3, it was determined that the journal with the most citations (701) was "Journal of Research in Science Teaching", and the journals with the most publications (Graph 2) and the most citations (Graph 3) included "Science Education", "International Journal of Science Education", "Journal of Chemical Education", Journal of Research in Science Teaching", "Chemistry Education Research and Practice", and "Journal of Science Teacher Education".

3.3. Most Cited Articles

Information on the ten most cited articles on the subject is given in Table 3. When the most cited articles (Table 3) and the authors with the most articles (Graph 4) are examined together, it is seen that the authors of the most cited articles are not the authors who publish the most. However, it can be said that Furtak E.M. has made a great contribution to the literature in terms of both the number of articles and the number of citations to his articles. The contents of the most cited articles are briefly summarized below. Formative assessment activities should be prepared by experts in the field and the results obtained from the activities should be evaluated by experts in the field. These activities should enable students to use the information they learn in new situations they encounter (Wendy & Carl, 2010). The science concepts that the student has formed in his mind should be determined with formative assessment activities, the degree to which these concepts overlap with scientifically accepted concepts should be determined, and the teacher should provide feedback to the student accordingly.

Teacher-student dialogue is very important in this process (Bell & Cowie, 2001). The missing and incorrect information that the student has formed in his mind should be determined with formative assessment activities, and the reason for the student's missing or incorrect construction of the information should be examined. Teachers should be very sensitive in this process because students can sometimes express what they know correctly by using incomplete or incorrect words. Here, different question types can be used to determine the information that students' structure in their minds more clearly and as it is (Coffey et al., 2011). Laboratory practices in science education are effective learning environments that support students to internalize and structure information in their minds. Students working like scientists in laboratories, comparing their self-assessment rubrics with experimental results in the process of obtaining information, and exchanging ideas with course instructors about the experimental results can contribute to the student's learning environment (Etkina et al., 2010). In science education, it is especially important to integrate instant and interactive formative assessment activities into the curriculum through the joint work of program developers and formative assessment developers (Shavelson et al., 2008). In science education, in formative assessment activities, it is especially important for the teacher to encourage students to think and create a classroom discussion environment in the learning process of information and communication technologies as a catalyst (Webb, 2005).

Table 3. *Information on the Ten Most Cited Articles*

Number	Years	Article title	Authors	Journal Name	Total number of citations	Annual citation average
1	2010	Development and Validation of Instruments to Measure Learning of Expert-Like Thinking	Adams, Wendy K.; Wieman, Carl E.	International Journal of Scıence Educatıon	232	16,57
2	2001	The characteristics of formative assessment in science education	Bell, B; Cowie, B	Science Education	210	8,75
3	2011	The Missing Disciplinary Substance of Formative Assessment	Coffey, Janet E.; Hammer, David; Levin, Daniel M.; Grant, Terrance	Journal of Research in Science Teaching	197	14,07
4	2010	Design and Reflection Help Students Develop Scientific Abilities: Learning in Introductory Physics Laboratories	Etkina, Eugenia; Karelina, Anna; Ruibal-Villasenor, Maria; Rosengrant, David; Jordan, Rebecca; Hmelo-Silver, Cindy E.	Journal of the Learning Sciences	147	9,8
5	2008	On the Impact of Curriculum-Embedded Formative Assessment on Learning: A Collaboration between Curriculum and Assessment Developers	Shavelson, Richard J.; Young, Donald B.; Ayala, Carlos C.; Brandon, Paul R.; Furtak, Erin Marie; Ruiz-Primo, Maria Araceli; Tomita, Miki K.; Yin, Yue	Applied Measurement in Education	121	7,12
6	2005	Affordances of ICT in science learning: implications for an integrated pedagogy	Webb, ME	International Journal of Science Educatıon	107	5,35
7	2016	Effects of a computer-assisted formative assessment intervention based on multiple-tier diagnostic items and different feedback types	Maier, Uwe; Wolf, Nicole; Randler, Christoph	Computers & Education	89	9,89

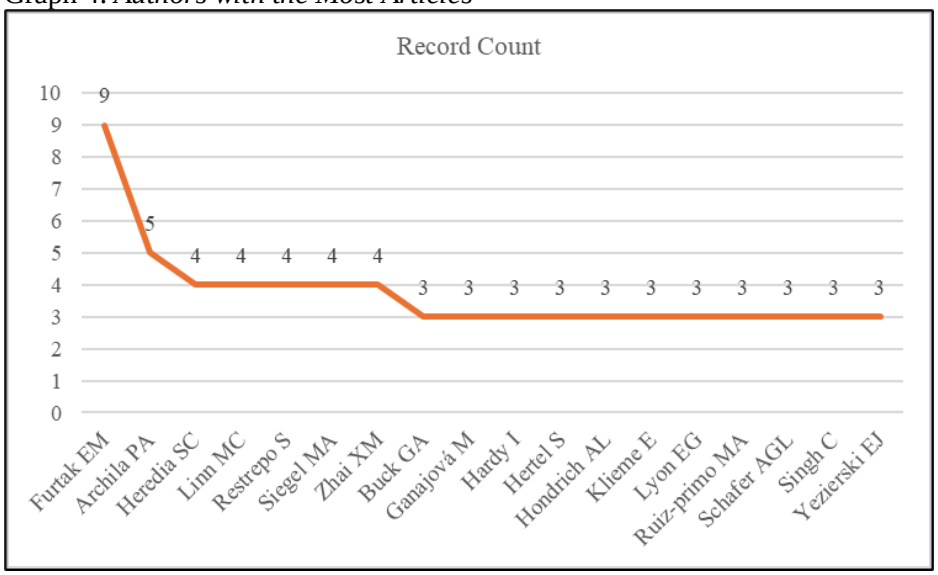
8	2016	Teachers' formative assessment abilities and their relationship to student learning: findings from a four-year intervention study	Furtak, Erin Marie; Kiemer, Katharina; Circi, Ruhan Kizil; Swanson, Rebecca; de Leon, Vanessa; Morrison, Deb; Heredia, Sara C.	Instructional Science	80	8,89
9	2020	The effect of automated feedback on revision behavior and learning gains in formative assessment of scientific argument writing	Zhu, Mengxiao; Liu, Ou Lydia; Lee, Hee-Sun	Computers & Education	76	15,2
10	2014	Epistemology and expectations survey about experimental physics: Development and initial results	Zwickl, Benjamin M.; Hirokawa, Takako; Finkelstein, Noah; Lewandowski, H. J.	Physical Review Special Topics-Physics Education Research	73	6,64

There are some limitations in the effective implementation of formative assessment activities, some of which are insufficient class hours, handling complex concepts (Maier et al., 2016), and inadequacy of science teachers in revealing the knowledge in students and providing appropriate feedback (Furtak et al., 2016). In determining the student's learning level in depth, computer-aided different types of feedback (descriptive, instant, simple, detailed, personalized) can contribute to the teaching process (Maier et al., 2016). In student success, it is very effective for teachers to design the formative assessment process well and to have the professional skills to reveal the thoughts of the students and provide feedback accordingly (Furtak, Kiemer, Circi, Swanson, Morrison & Heredia, 2016). Studies have shown that in formative assessment studies conducted with automatic feedback, multiple-choice exams are preferred more than exams with structured response items (Zhu et al., 2020). In addition to evaluating student learning in the teaching process, students who take laboratory courses can give educators an idea about what should be done to increase the efficiency of laboratory courses (Zwickl et al., 2014).

3.4. Authors with the Most Articles

This title includes researchers who have at least three articles on the subject (Graph 4).

Graph 4. *Authors with the Most Articles*



It is seen that Furtak EM is the author with the most articles on the subject (9 articles) (Graph 4).

3.5. Article Information Published from Turkey on the Subject

In this title, articles published from Turkey on the subject are included as a result of the search made in the WoSCC database (Table 4).

Table 4. *Information of Articles Published from Turkey*

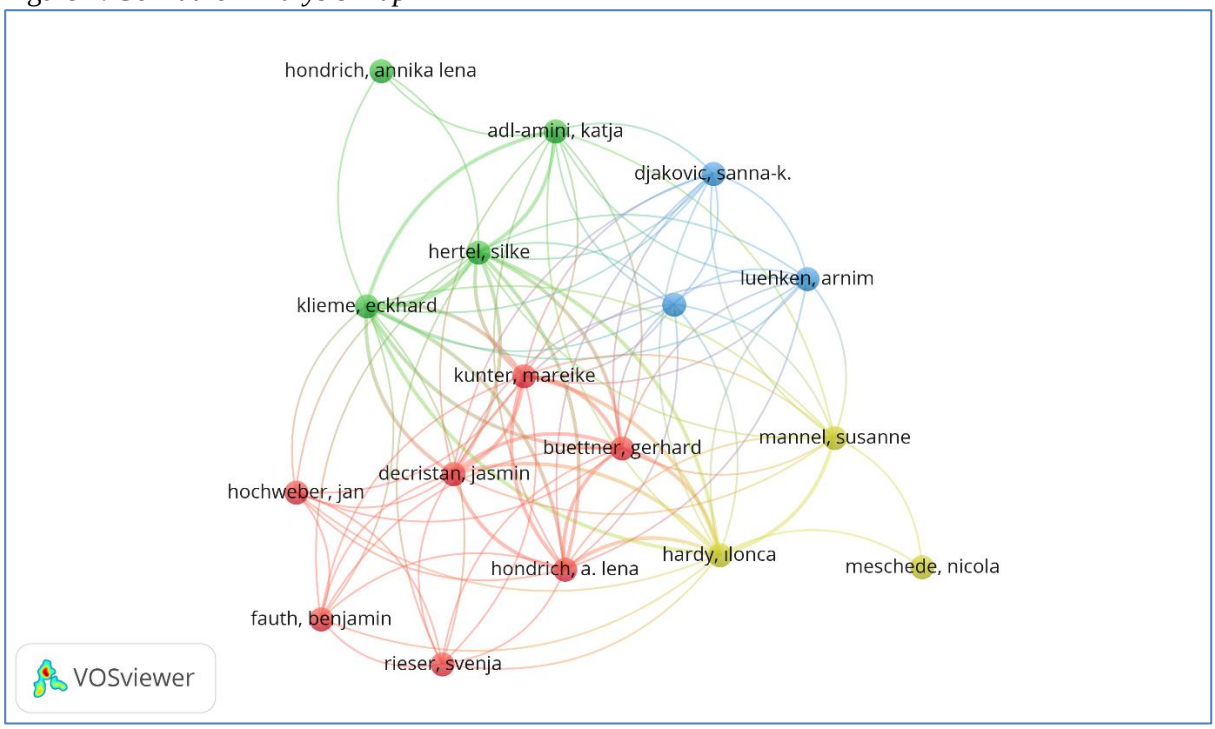
Year	Article title	Authors	Journal name	Institution	Total Number of Citations
2022	Formative assessment practices in science education: A meta-synthesis study	Atasoy, V; Kaya, G	Studies In Educational Evaluation	Kastamonu University	2
2019	Biology Teachers' Practices of Formative Assessment: A Case of the Identifying Learning Gap Element	Bayrak, N; Çalik, M; Dogan, S	Pamukkale University Journal of Education	Trabzon University; Erzincan Binali Yildirim University	2
2014	Effects of formative assessment probes integrated in extracurricular hands-on science: middle school students' understanding	Bulunuz, N; Bulunuz, M; Peker, H	Journal of Baltic Science Education	Uludag University; Ministry of National Education Turkey	7
2021	Does Teacher Education Matter? Comparison of Education and Science Major Teachers' Assessment Literacy	Demirdogen, B; Korkut, HM	Journal Of Qualitative Research in Education	Zonguldak Bulent Ecevit University; Marmara University	1
2022	The Effects of Formative Assessment Practices in Science Education on Students' Metacognitive Knowledge and Regulation Skills	Gedikli, H; Buldur, S	Hacettepe University Journal of Education	Cumhuriyet University	0
2021	The Role of Science Teachers' Awareness in their Classroom Practice of Formative Assessment	Kaya, G; Atasoy, V; Candan-Helvaci, S; Pektas, M	Egitim ve Bilim-Education and Science	Kastamonu University	3
2024	A Co-design Based Research Study: Developing Formative Assessment Practices with Preservice Science Teachers in a Chemistry Laboratory Setting	Kaya, ON; Kaya, Z	Research In Scıence Educatıon	Usak University	1
2023	Examining the type and quality of questions asked by a science teacher	Saka, T; Inaltekin, T	Journal Of Baltıc Scıence Educatıon	Kafkas University	2
2023	The Effect of Web-Based Biology Learning Environment on Academic Performance: A Meta-analysis Study	Vekli, GS; Çalik, M	Journal Of Scıence Educatıon and Technology	Bozok University; Trabzon University	3

The article titled “Effects of formative assessment probes integrated in extracurricular hands-on science: middle school students' understanding” published in 2014 appears to be the most cited article (Table 4).

3.6. Co-author analysis

To determine the co-authorship relationship of the authors, an analysis was conducted in the Vosviewer software with the criterion that an author has at least one publication. As a result of the analysis, 558 authors were included in the analysis (Figure 1).

Figure 1. *Co-Author Analysis Map*

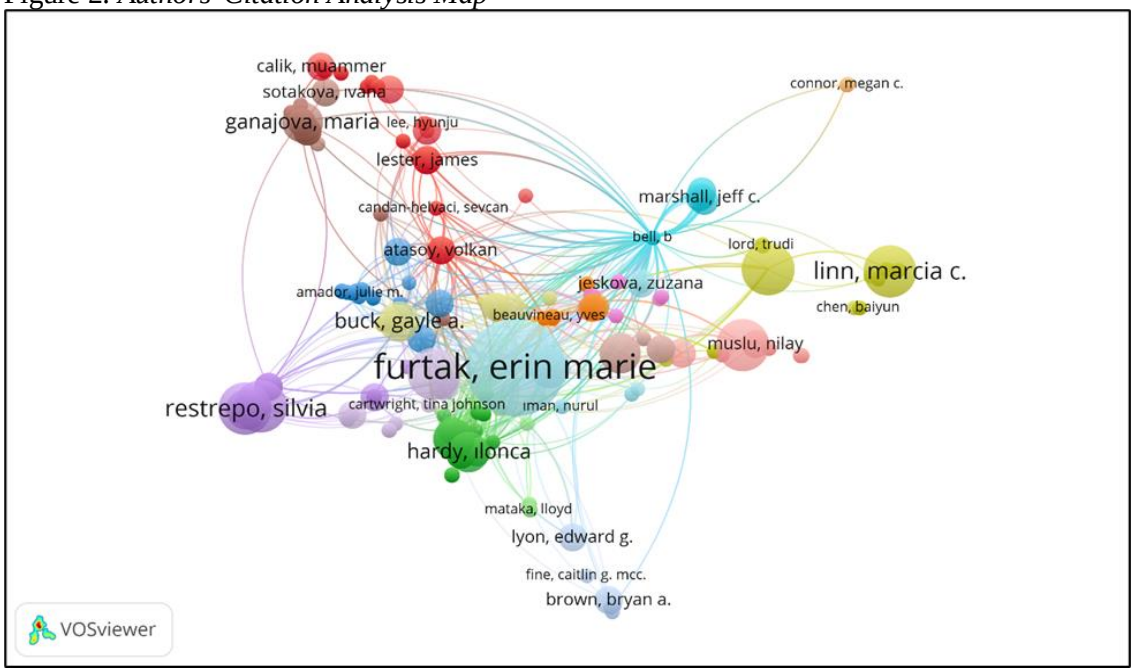


When Figure 1 is examined, it is seen that the 17 authors who are most connected to each other are in the main cluster. The main cluster is divided into four clusters (yellow, red, blue, green). In the analysis with 95 connections and a total connection power of 120, Hertel, S and Klieme, E are in the first place with 15 connections and a total connection power of 23. Hertel, S and Klieme, E are also seen to be among the researchers who have published the most with 3 articles. It was determined that Hardy, Ilonca is in second place with 15 connections and a total connection power of 22. Kunter, Mareike; Decristan, Jasmine; Hondrich, A. Lena; Buettner, Gerhard are in the third place with 14 connections and a total connection power of 20. It is seen that Hardy, I and Hondrich AL are also in the list of those who have published the most with 3 articles (Figure 1).

3.7. Authors' Citation Analysis

In the citation-author relationship analysis conducted with the Vosviewer program, it was determined that the number of authors was 558 and the number of authors receiving at least one citation was 515 (Figure 2). The analysis was conducted with the criteria of at least one publication and at least one citation for an author.

Figure 2. *Authors' Citation Analysis Map*

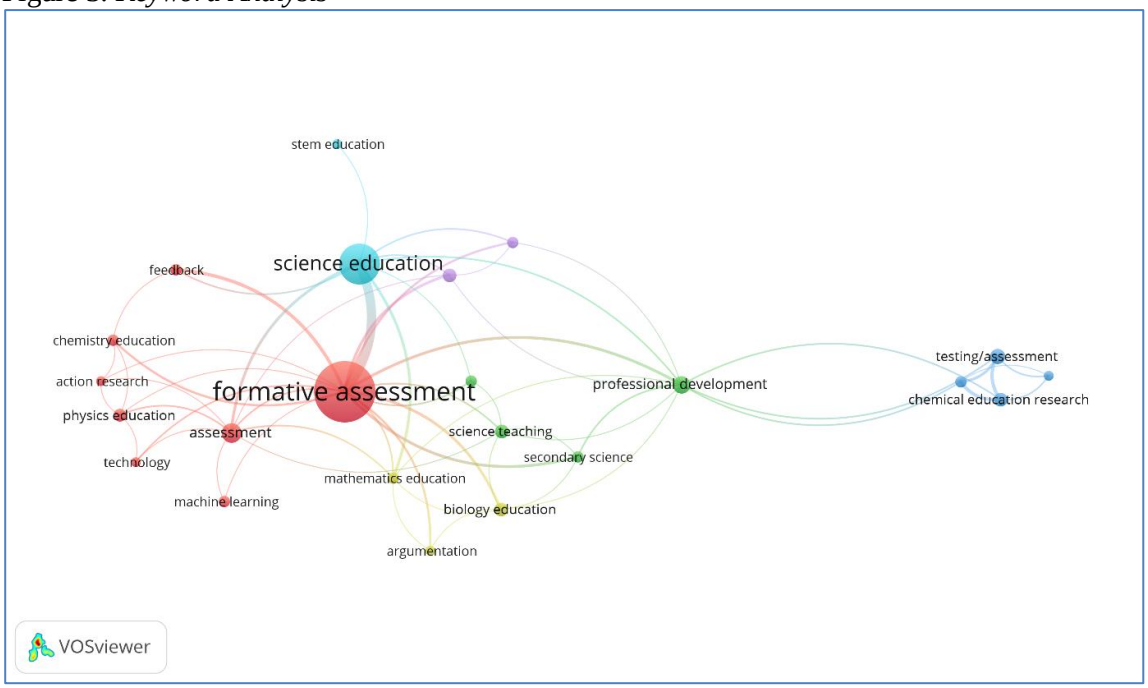


As a result of the citation analysis of the authors, the 338 authors with the most connections to each other were gathered in 17 clusters. It was determined that there were 2600 connections and a total connection strength of 3260. Furtak, who has 135 connections, and Erin Marie, who has a total connection strength of 257, are in first place. Bell, B, who has 132 connections and a total connection strength of 157, are in second place (Figure 2).

3.6. 8. Co-Occurence of All Keywords Analysis

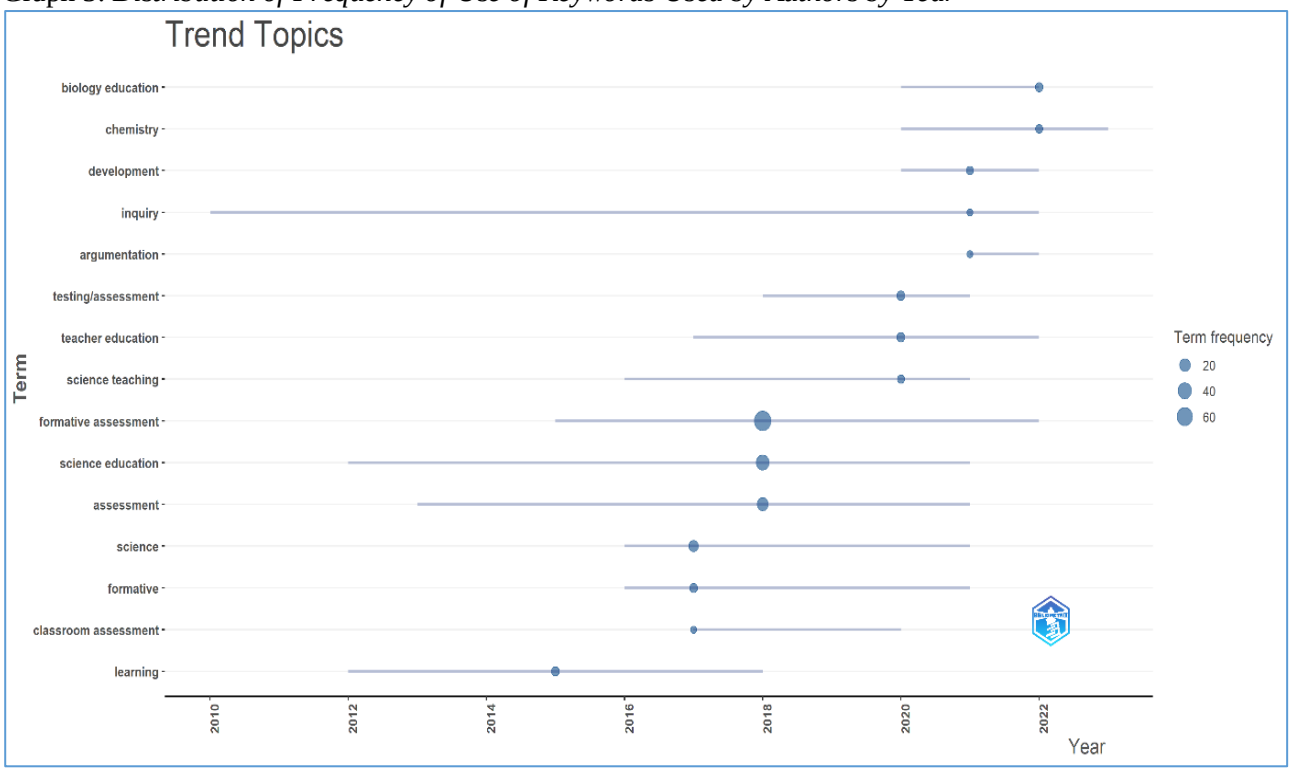
In the keyword analysis, when the analysis was made with the criterion that a keyword must be used at least four times, it was determined that 23 out of 551 keywords met this criterion (Figure 3). In addition, the result of the analysis made with Biblioshiny to see the distribution of keywords used by the authors by year is given in Figure 5.

Figure 3. *Keyword Analysis*



As a result of the analysis, it was determined that 23 keywords had 6 clusters, 60 connections and a total connection strength of 133. Among the 23 keywords, it was determined that "formative assessment" was repeated 79 times and had a total connection strength of 133. It was determined that "science education" was repeated 40 times and had a total connection strength of 36 and had 9 connections (Figure 3). It is seen that the authors frequently used the keywords "formative assessment" and "science education" in 2018, and the keywords "biology education" and "chemistry" were used in 2022 (Graph 5).

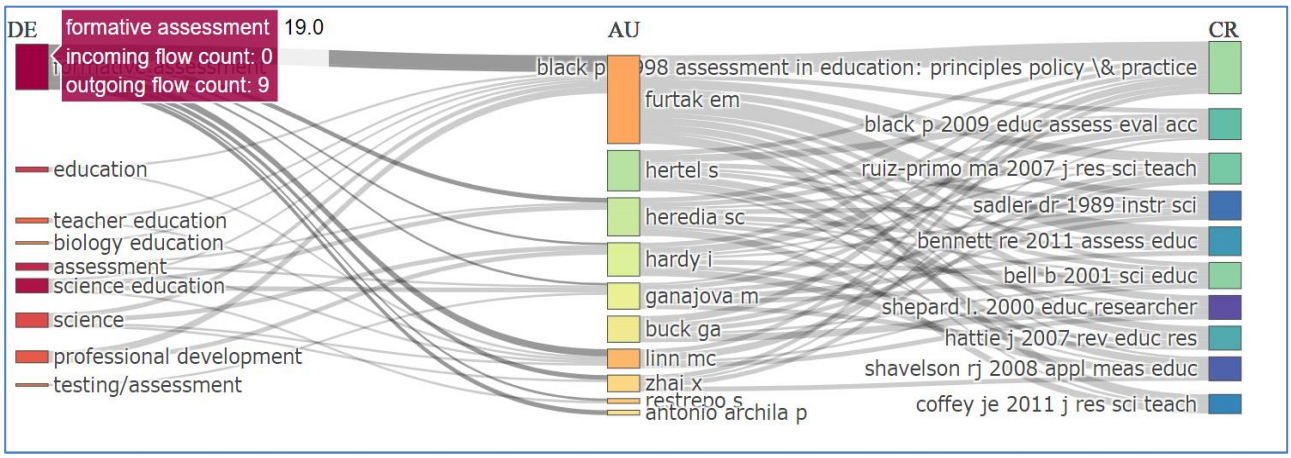
Graph 5. *Distribution of Frequency of Use of Keywords Used by Authors by Year*



3.6. 9. Keywords, Authors, References Analysis

The analysis of the three area graphs of keywords, authors and references in this title was created using the R program version 4.4.1, R studio, bibliometrix/ biblioshiny 4.1.2 package program. The analysis was conducted with a ten-keyword limitation in the right column, a ten-author limit in the middle column and a ten-reference limit in the left column (Figure 4).

Figure 4. *Three Area Plot Analysis of Relationships Between Keywords, Authors and References*



As seen in Figure 4, the most frequently used keyword at the end of the analysis is “formative assessment”, which is used by all authors except “Hertel S” and “Buck GA”. The keyword “science education” is used by “Furtak EM”, “Heredio SM”, “Ganajova M” and Restrepo S”. It is also seen that “Hertel S” and “Buck GA” authors do not use the keywords in the left column. In the right column, it is seen that the most frequently cited reference by the authors is “Black P. 1998 assessment in education: principles policy / & practice”.

3.6. 10. Distribution of Articles by Corresponding Author Country

In this title, the responsible authors are listed according to their countries. Here, the authors are analyzed according to whether they are from a single country or multiple countries (Table 5). The table was created with R studio.

Table 5. *Distribution of Articles by Corresponding Author Country*

Country	Number of articles	Article %	Single country articles	Multi country articles	Multi-country authors %
USA	103	48,4	97	6	5,8
CHINA	11	5,2	8	3	27,3
GERMANY	11	5,2	10	1	9,1
TURKEY	9	4,2	7	2	22,2
SPAIN	7	3,3	7	0	0
UNITED KINGDOM	7	3,3	7	0	0
SWEDEN	6	2,8	6	0	0
COLOMBIA	5	2,3	5	0	0
NETHERLANDS	5	2,3	4	1	20
AUSTRALIA	4	1,9	4	0	0

As seen in Table 5, most articles by single-country and multi-country authors are from the USA. It is also seen that Turkey ranks third on the list.

4. DISCUSSION and CONCLUSION

The search results from WoSCC, which are made within the framework of certain criteria, show that studies on the subject of formative assessment in science education have been published since 2001, and the number of publications increased in 2020-2021, which was the Covid 19 pandemic period. Content analysis of articles published between 2020-2021 can be performed, and it can be examined whether the articles published during these dates are related to “distance education” or “technology-supported education”. It can be seen that the most published and cited journals on the subject are journals in the field of science education such as International Journal of Science Education, Science Education, Journal of Research in Science Education, and; however, it can be seen that studies on the subject are also published and cited in the journals “Journal of science education and technology” and “computer education”, where technology-supported education studies are generally published. It can be said that as a result of the developments in information communication technology and the widespread use of these developments in the field of education, studies on formative assessment in science education will become widespread in technology-focused education journals.

It is seen that studies on the subject are published and cited in the teacher-focused journals “Teaching and Teacher Education” and “Journal of Science Teacher Education”. Also, It is seen that the most cited journal (Journal of Research in Science Teaching) is ranked ninth in the most published journals. It is seen that biology and physics education themed journals are not included in the list of journals related to chemistry education. It is seen that the most cited article on the subject is “Development and Validation of Instruments to Measure Learning of Expert-Like Thinking” published in 2011, and the second most cited article is “The characteristics of formative assessment in science education”. It is seen that the authors of the article ranked first in the citation

ranking Adams, Wendy. K & Wieman Carl. E and the authors of the article ranked second Bell, B & Cowie, B are not among the first 18 authors with the most publications on the subject. As can be seen from Graph 4, the authors who contributed to the literature with the most studies on the subject are Furtak EM (9 articles) and Archilla PA (5 articles). It is seen that the two articles that Furtak EM was among the authors of in 2008 and 2016 are among the ten most cited articles (Table 3).

The most cited articles can be summarized under ten headings according to their subject content. i- The importance of having formative assessment activities prepared by experts in the field and having the results evaluated by experts in the field, developing the student's ability to use the information he/she has learned, ii- Determining to what extent the concept that the student has formed in his/her mind matches the correct concept with formative assessment activities and providing appropriate feedback to the student, the importance of teacher-student communication in the feedback process, iii- Teachers need to be sensitive in determining whether the concepts that the student has constructed in his/her mind are correct, incorrect or incomplete with formative assessment activities. Students can sometimes express the concepts they have constructed correctly using the wrong words. Teacher-student communication is very important here. iv- In science laboratory applications, students can realize their deficiencies/mistakes and make arrangements as a result of their interviews with teachers using self-assessment rubrics while structuring their knowledge. v- It is very important to integrate formative assessment activities into the curriculum in science education, and for this, it is very important for program development experts and experts who prepare formative assessment activities in science education to cooperate. vi- Developments in information and communication technologies can act as a catalyst in formative assessment activities in science education, and here it is very important for the teacher to plan the classroom discussion environment. vii- Teacher competence is very important in carrying out formative assessment activities effectively in science education. viii- In depth determination of student level and provision of different types of feedback (descriptive, detailed etc.) to the student are very important in formative assessment activities in science education, and here again the teacher competence is very important. ix- Effective use of developments in information and communication technologies is very important. Especially in systems where automatic feedback is used, only multiple-choice question types should not be used. x- Students' evaluations of the course process can provide important clues about the arrangements that teachers should make in the teaching process. When these ten summarized topics are considered holistically, it is seen that there are teachers who are program implementers at the center.

With the advancements in information and communication technologies, access to technology has facilitated easier access to information, resulting in changes in the role of the teacher, which was traditionally viewed as a source of knowledge. Students now have easier access to information. However, in the field of science education, which some students perceive as an abstract accumulation of concepts, it can be said that the role of the teacher has become increasingly important in supporting students' ability to accurately structure their knowledge and to transform the knowledge they acquire into skills that can be applied in their daily lives. This is particularly significant in the formative assessment process, where the teacher provides feedback that enhances students' learning motivation.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJEDAI belongs to the author(s).

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APPENDIX

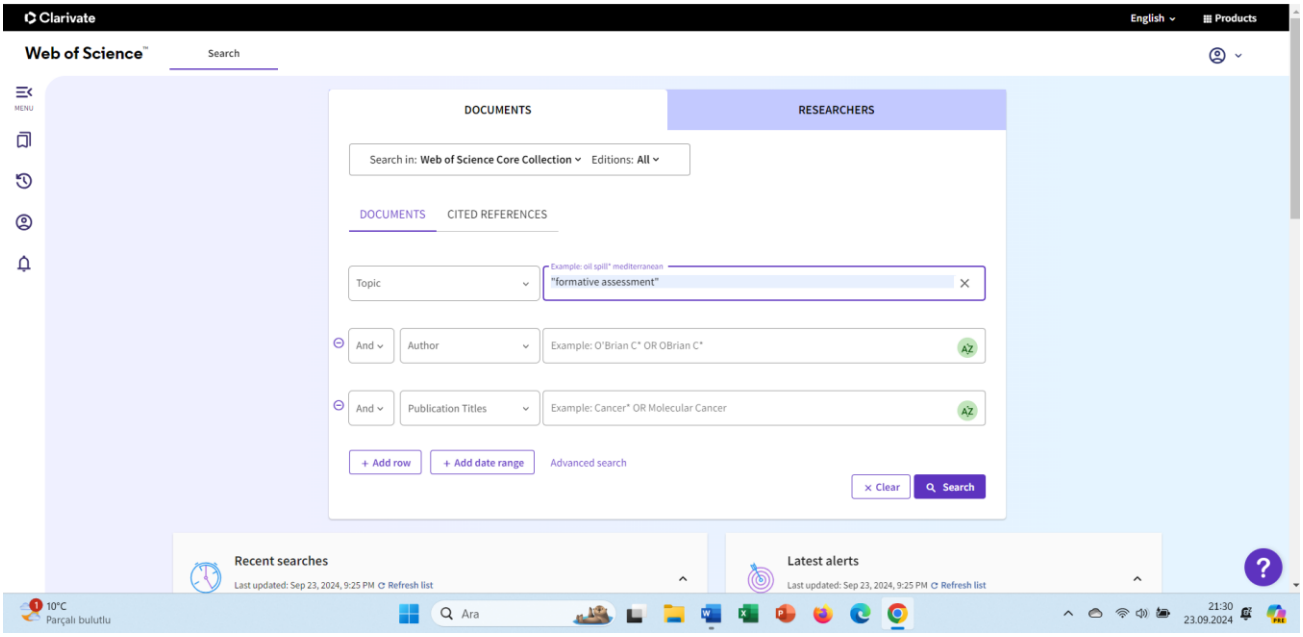

Figure1. *Web of Science Core Collection'dan "formative assessment" screenshot of the search with keywords*

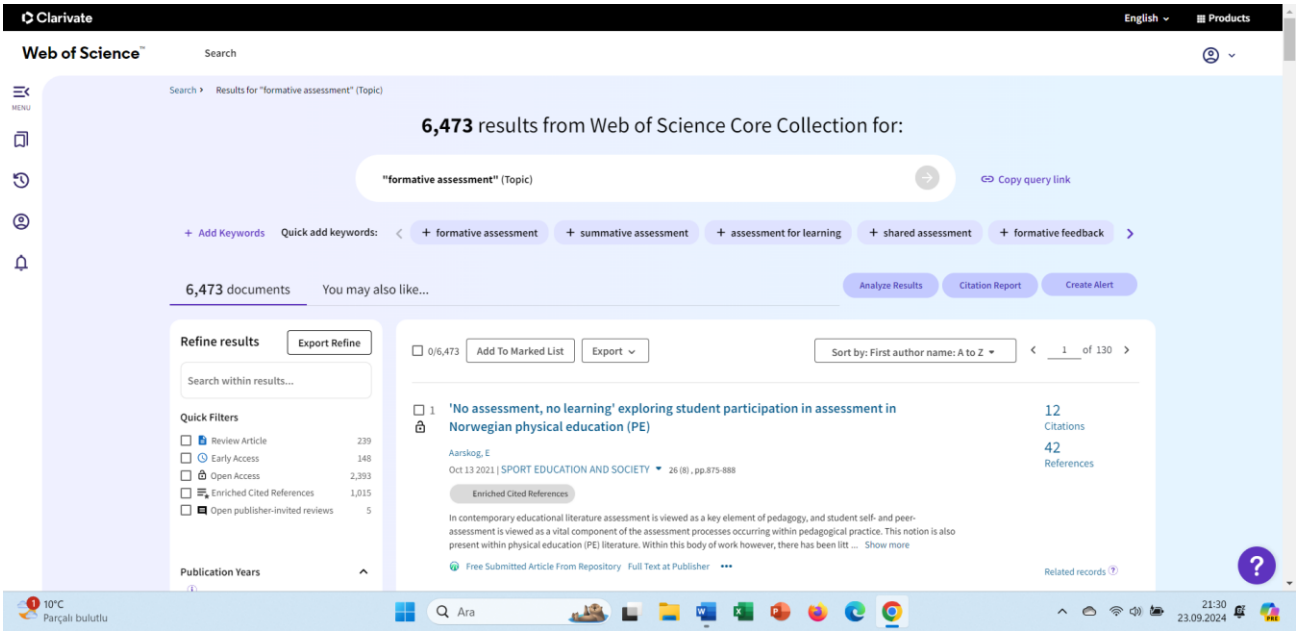

Figure 2. *Web of Science Core Collection'dan "formative assessment" screenshot of search results using keywords*

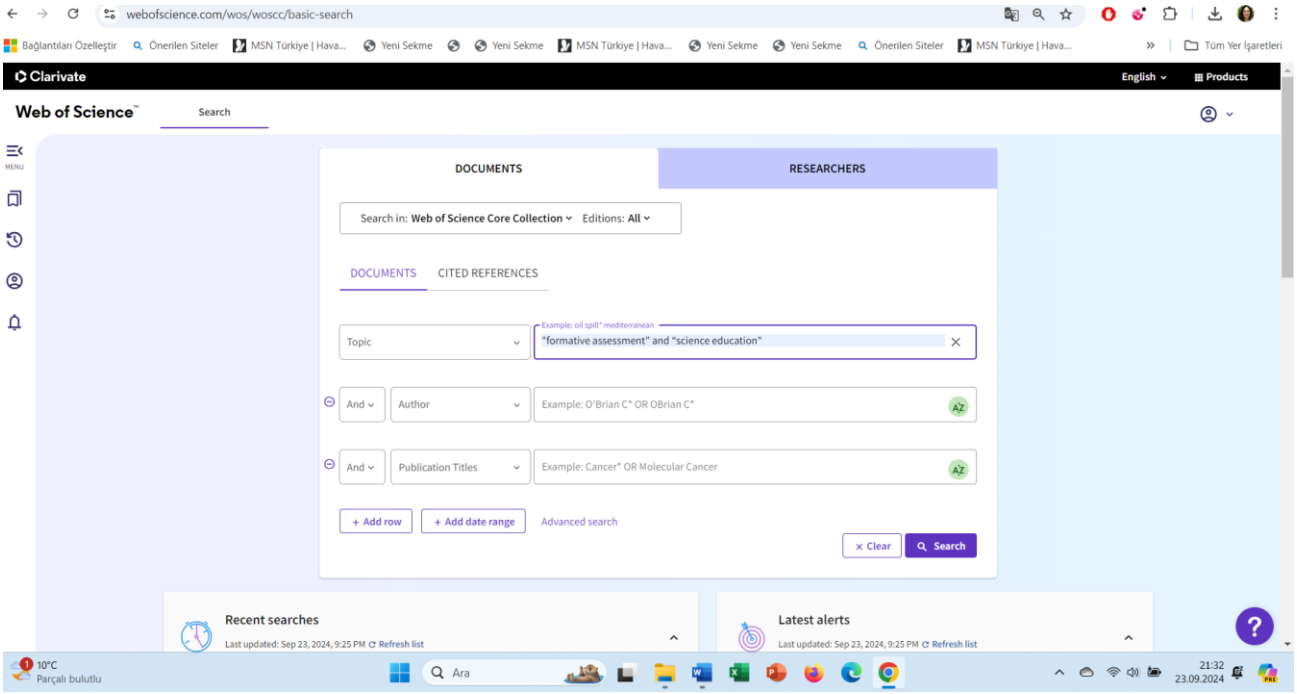

Figure 3. *Web of Science Core Collection'dan "formative assessment" and "science education" screenshot of search results using keywords*

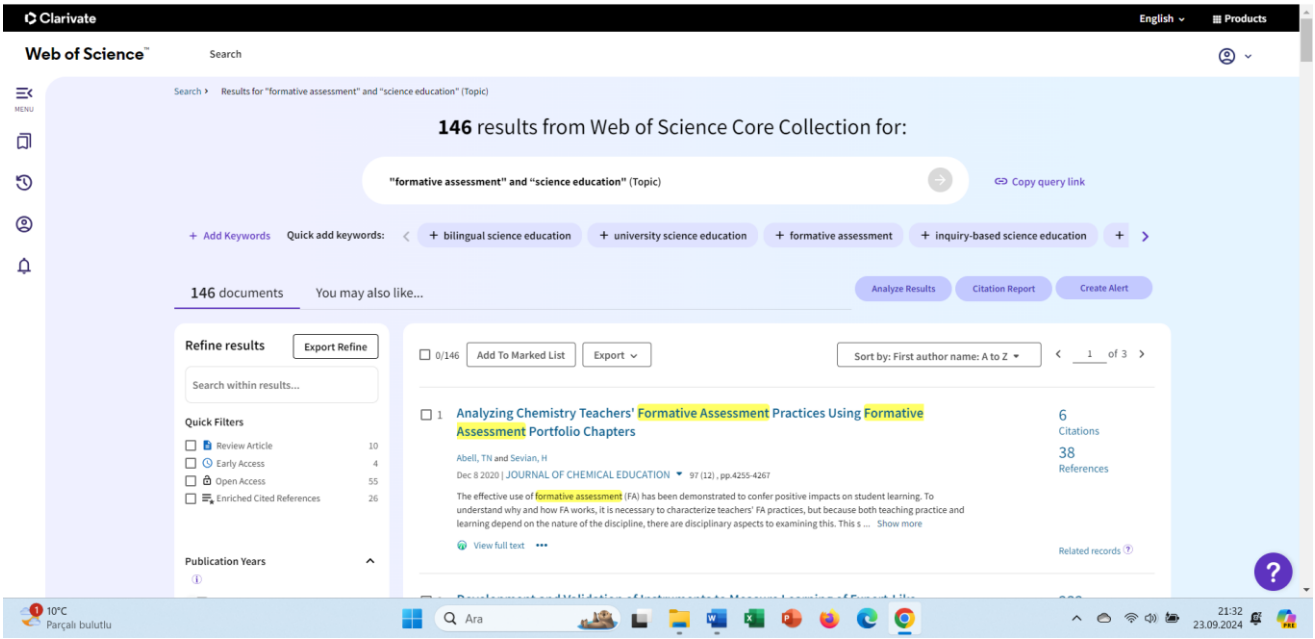

Figure 4. *Web of Science Core Collection'dan "formative assessment" and "science education" screenshot of search results using keywords*

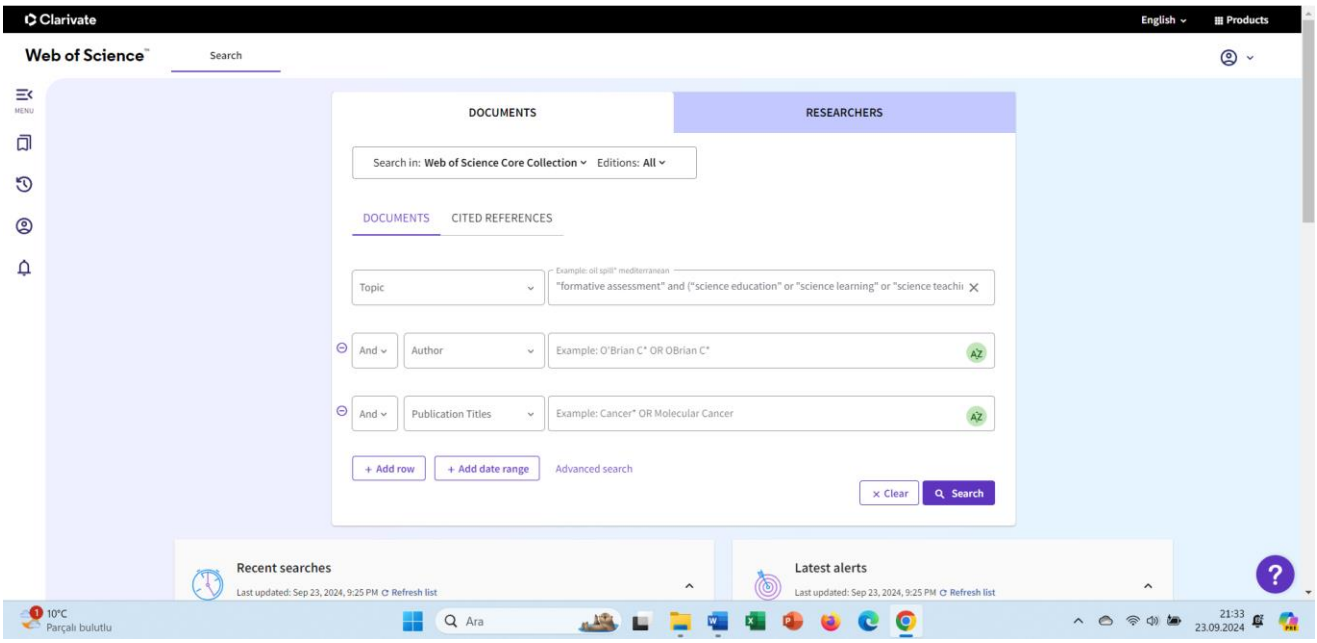

Figure 5. Web of Science Core Collection'dan *"formative assessment" and ("science education" or "science learning" or "science teaching" or "science teacher" or "science student" or "biology education" or "biology learning" or "biology teaching" or "biology teacher" or "chemistry education" or "chemistry learning" or "chemistry teaching" or "chemistry teacher" or "physics education" or "physics learning" or "physics teaching" or "physics teacher" or "science curriculum" or "biology curriculum" or " chemistry curriculum" or " physics curriculum"* screenshot of search results using keywords

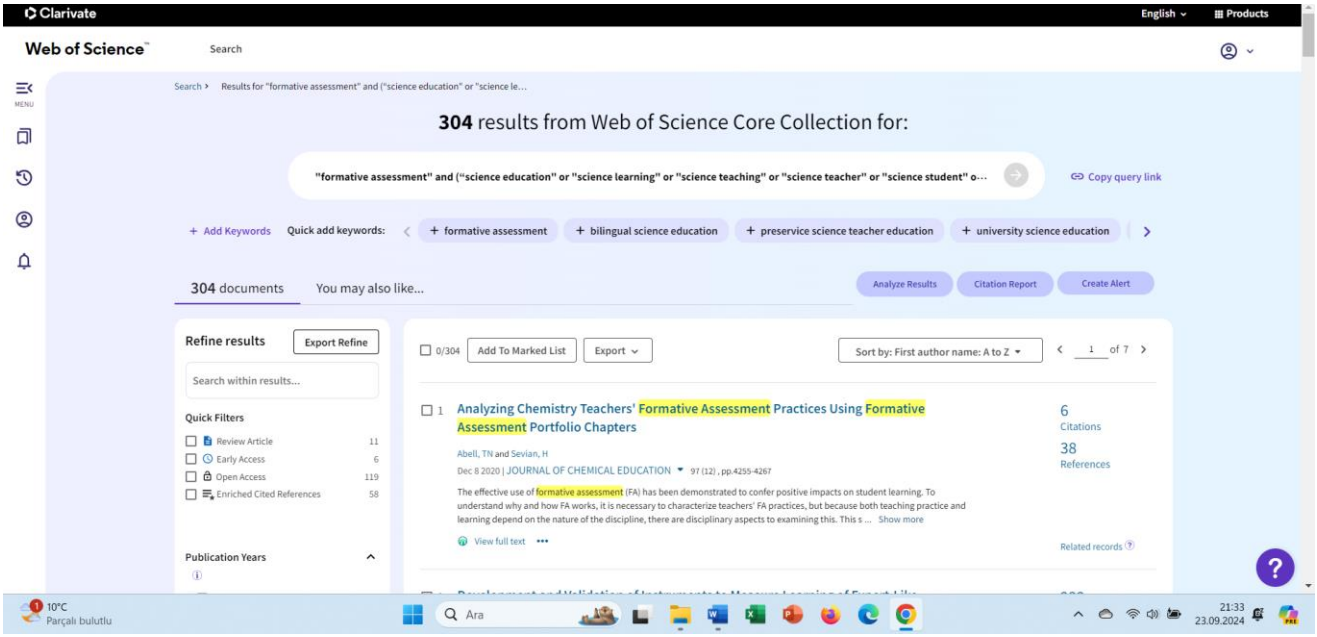

Figure 6. *Web of Science Core Collection'dan "formative assessment" and ("science education" or "science learning" or "science teaching" or "science teacher" or "science student" or "biology education" or "biology learning" or "biology teaching" or "biology teacher" or "chemistry education" or "chemistry learning" or "chemistry teaching" or "chemistry teacher" or "physics education" or "physics learning" or "physics teaching" or "physics teacher" or "science curriculum" or "biology curriculum" or " chemistry curriculum" or " physics curriculum" screenshot of search results using keywords*

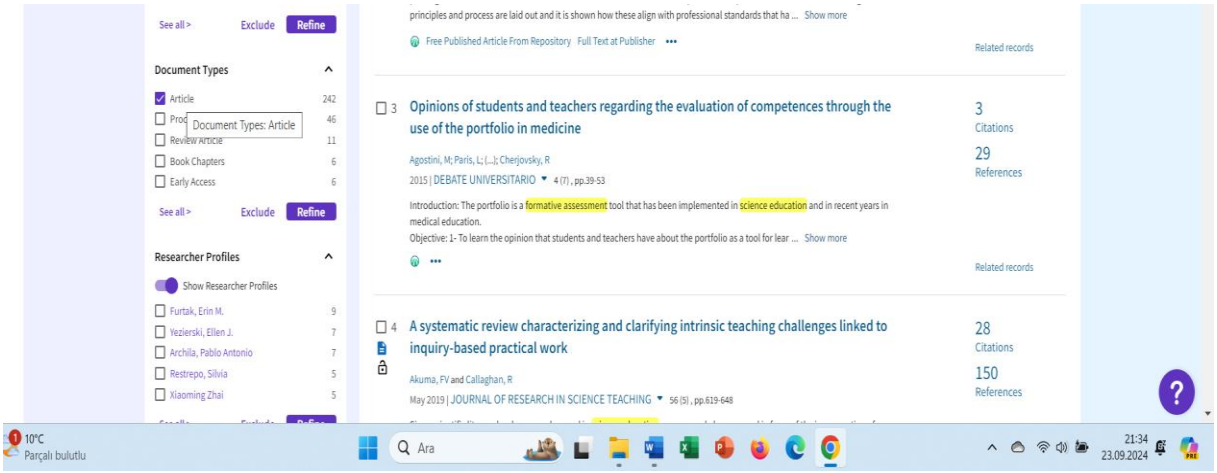

Figure 7. *Screenshot of the search where Document type is selected as article in the search*

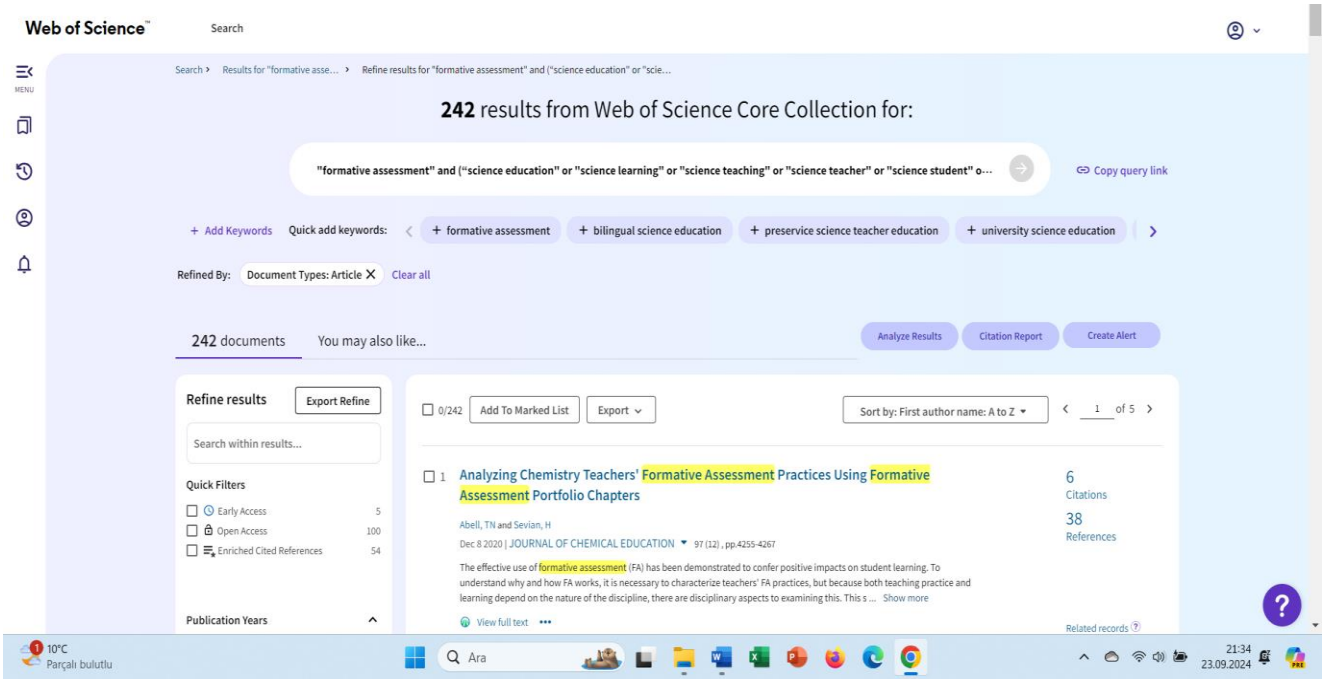

Figure 8. *Screenshot of the search result where the Document type is selected as article in the search*

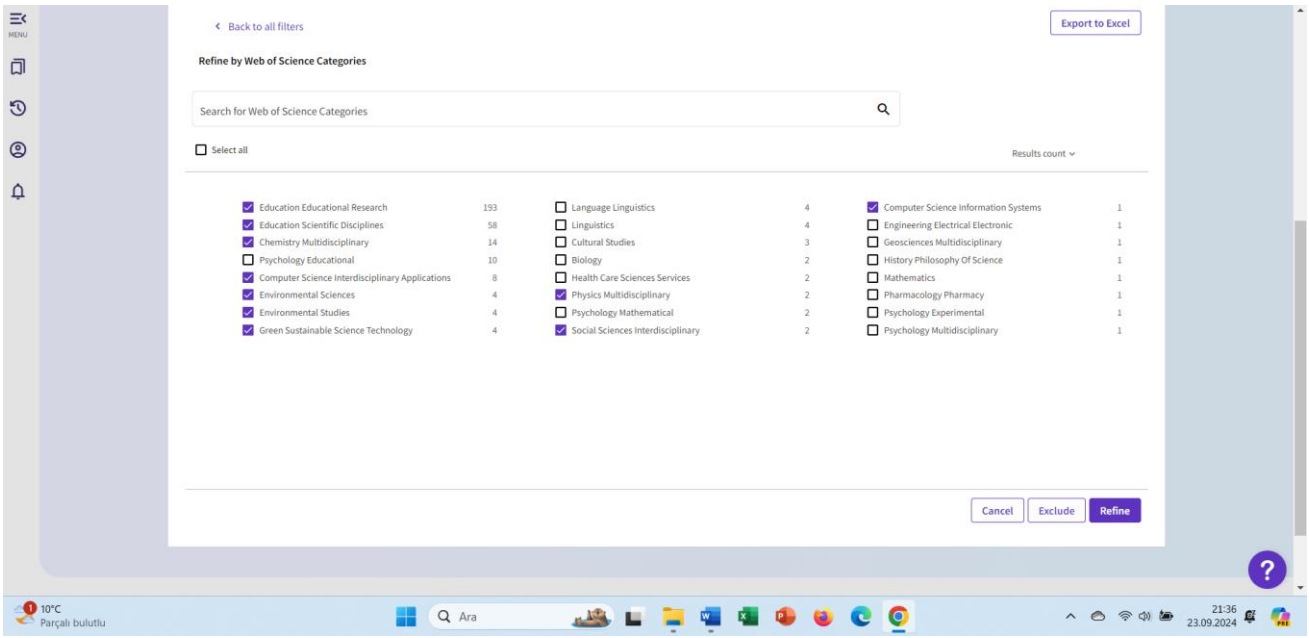

Figure 9. *"Web of Science Categories" preferred search options screenshot*

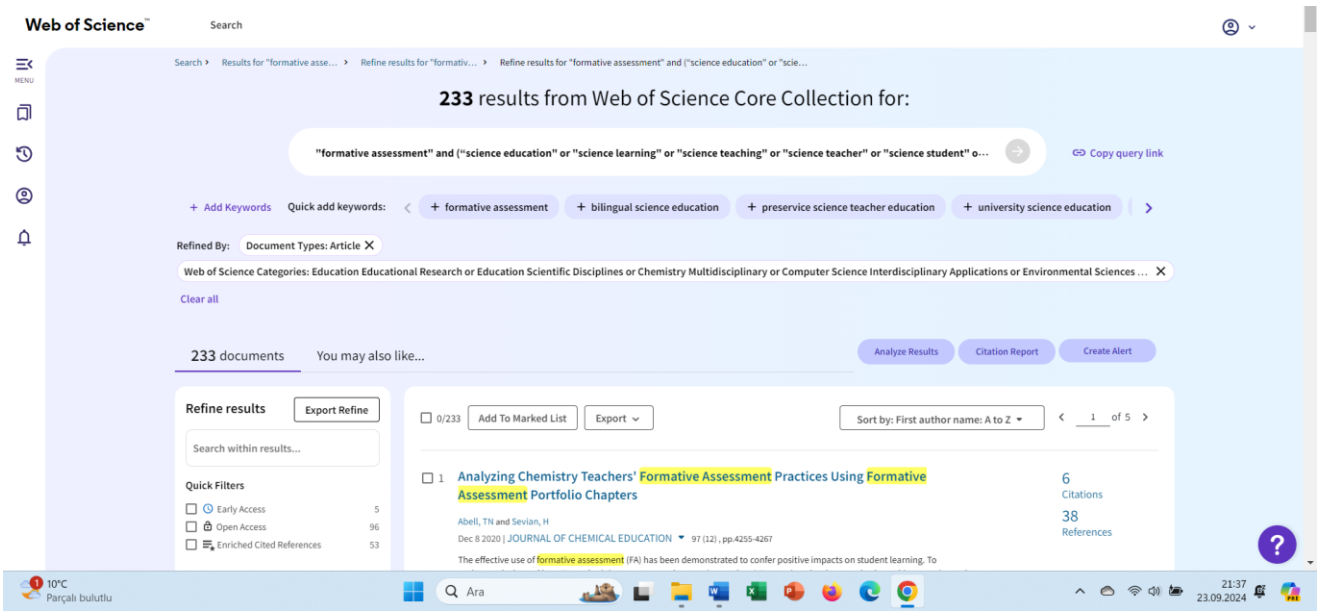

Figure 10. *"Web of Science Categories" screenshot showing the result of the chosen options*

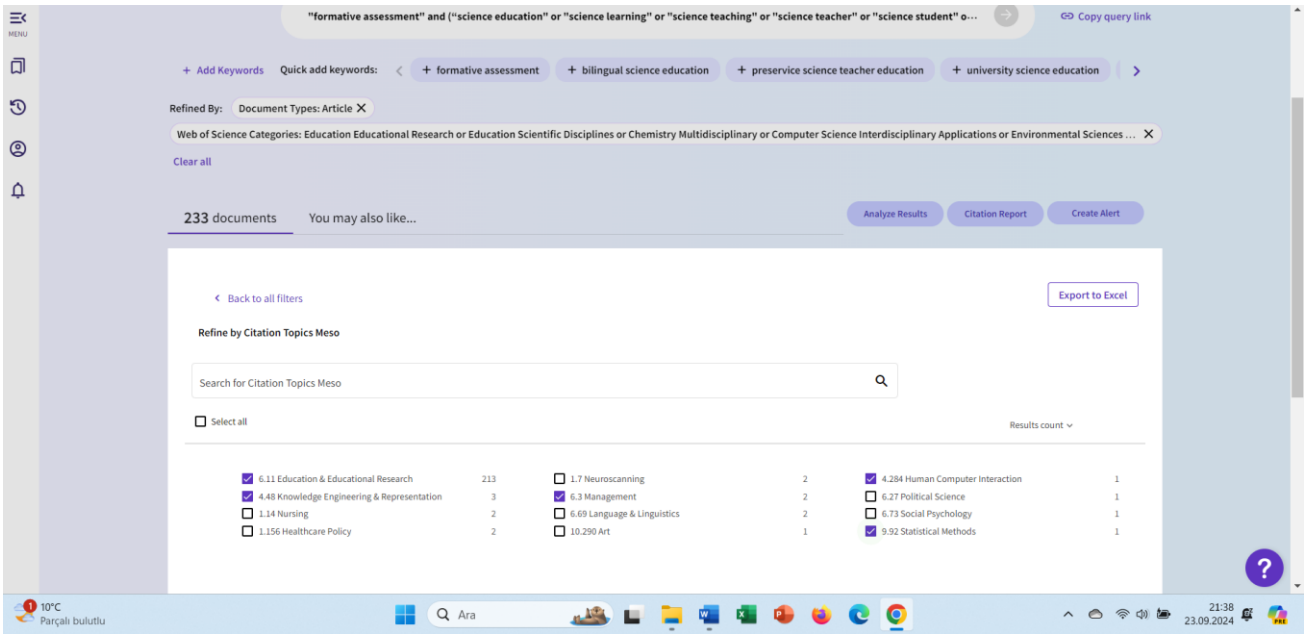

Figure 11. *"Refine by Citation Topics Meso" screenshot showing preferred search options result*

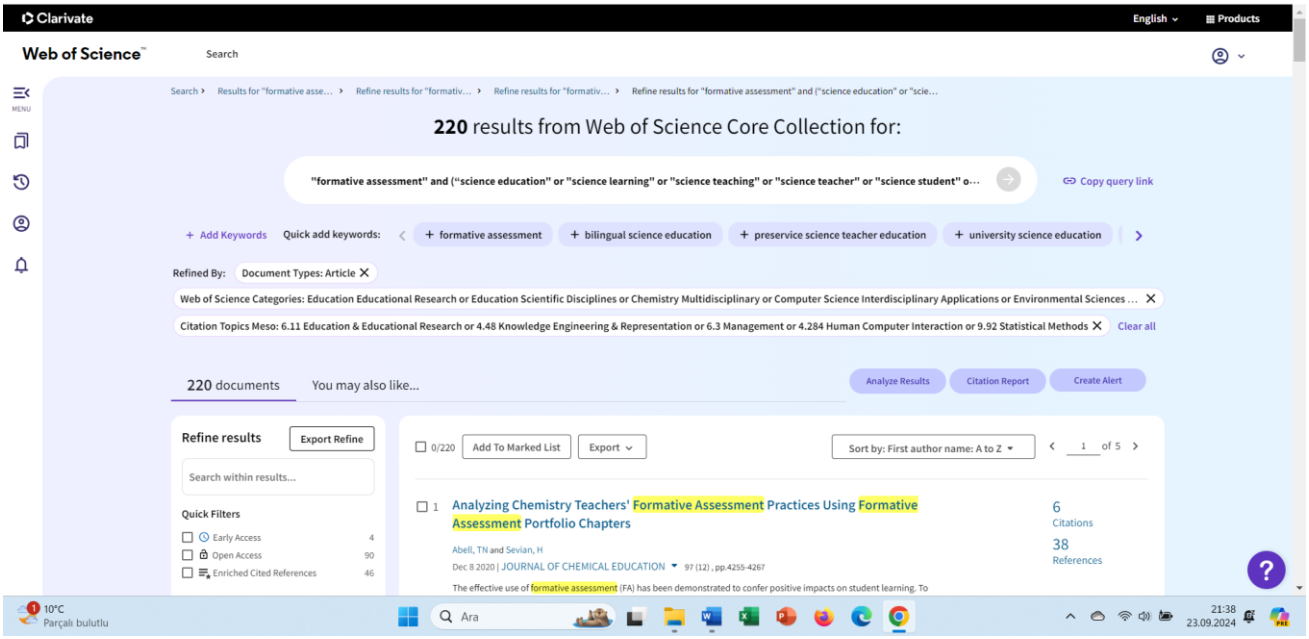

Figure 12. *"Refine by Citation Topics Meso" screenshot showing preferred search options result*

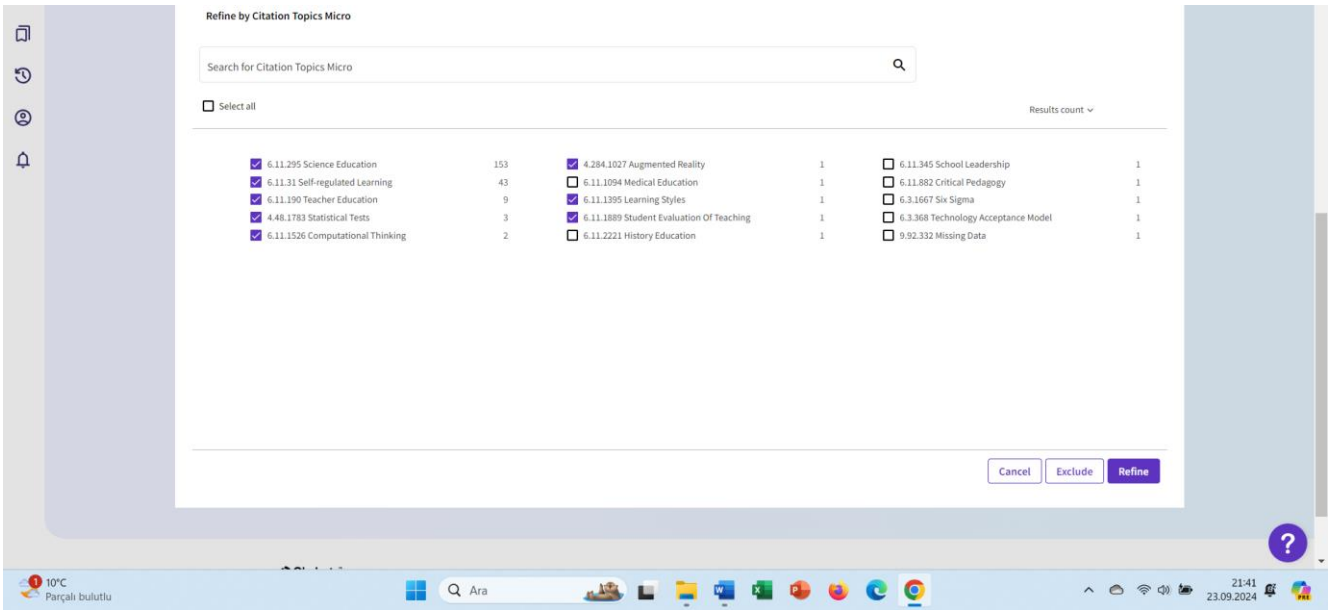

Figure *"Refine by Citation Topics Micro" screenshot showing preferred search options result*

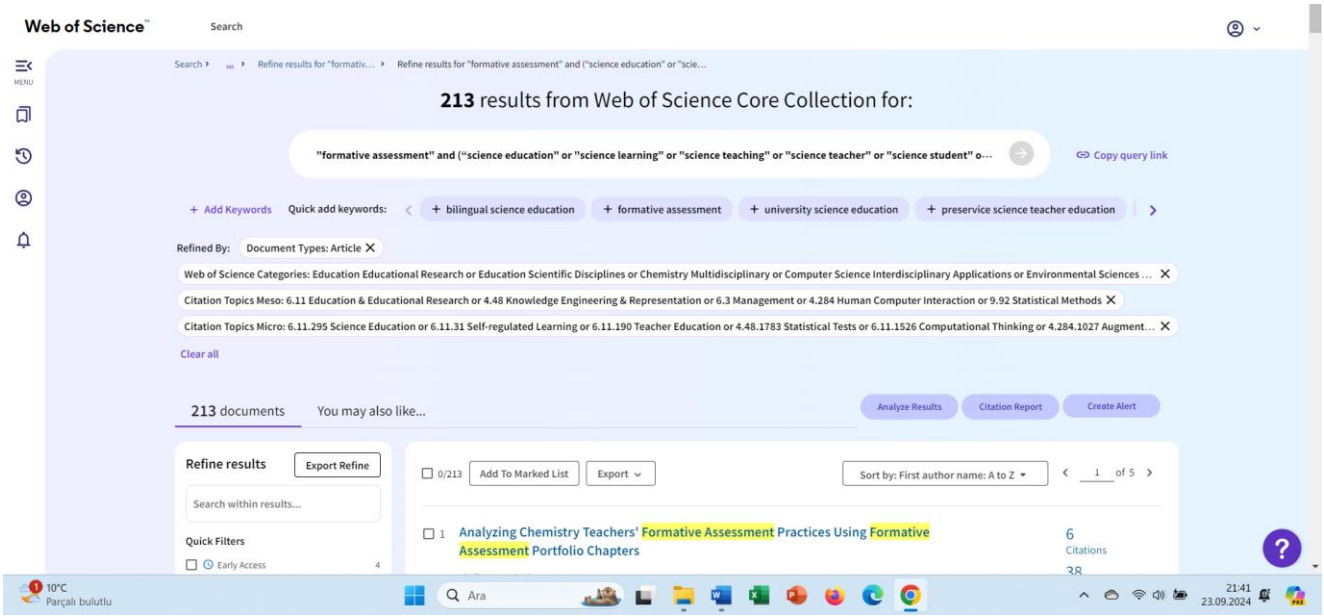

Figure 14. *"Refines by Citation Topics Micro" screenshot showing preferred search options result*

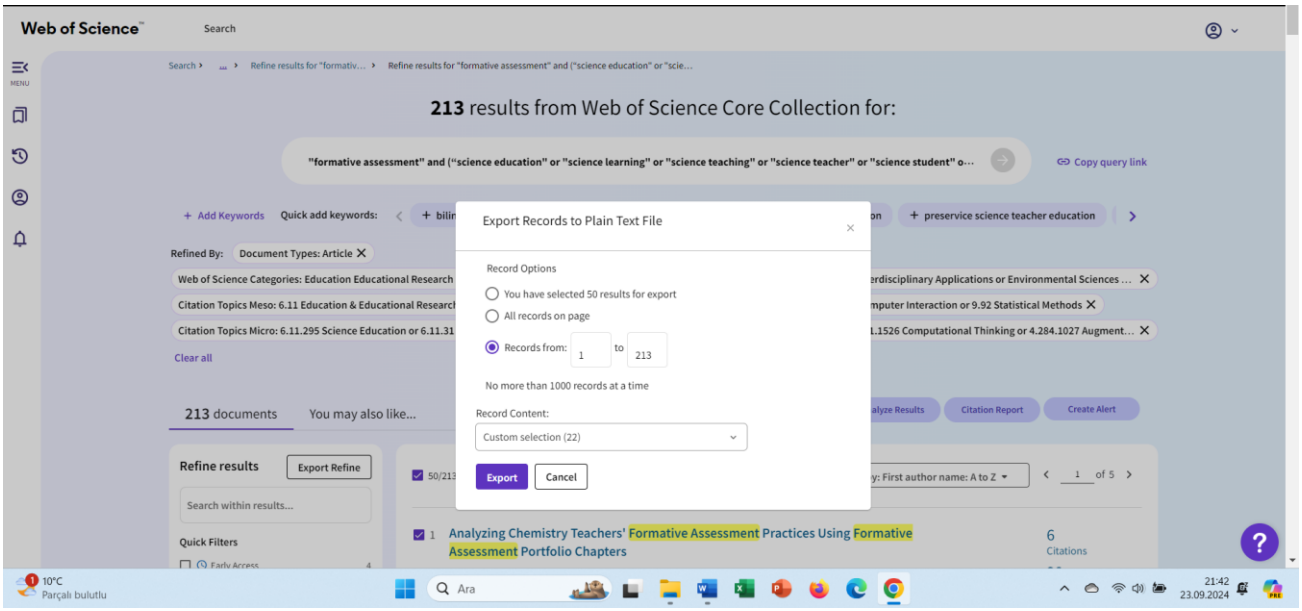

Figure 15. *Screenshot of the resulting data being saved*