



Formative Assessment in Educational Research Published at the Beginning of the New Millennium: Bibliometric Analysis

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Abstract

Today, many educational reforms emphasize the importance of formative assessment (FA) for effectiveness in teaching. Considering the importance of FA in education and a perceived lack of same, it is clear that much more research is needed on this subject. However, it is also very important for researchers to formulate new studies and not to repeat exiting ones, and to increase the visibility of exiting effective studies that can make teachers in service understand the importance of FA. In this context, being able to review qualified academic research is very valuable. Therefore, we aimed to conduct a bibliometric analysis using the VOSviewer to determine the focus of research on formative assessment in education (FAE). This bibliometric analysis included 447 studies on FA published in the Web of Science (WoS) from 2000 to 2021. We performed the citation analysis, created a co-authored network map, and performed an analysis of author keywords in FA publications. Results showed that Erin M. Furtak has been the most prolific author in FAE in terms of the number of publications. Moreover, David J. Nicol and Debra Macfarlane-Dick, who had a co-authored publication, were the most influential authors in terms of citations. Results indicated that Univ Colorado/USA with 13 publications was the most productive institution. However, the USA and England were the most productive countries in terms of both numbers of publications and citations. Of the 19 documents with over a hundred citations, Nicol and Macfarlane-Dick (2006) and Black and Wiliam (2009) were the most influential documents. According to the number of publications and citations, “Assessment & Evaluation in Higher Education” and “Computers & Education” came to the fore among the top five most productive sources. The results of the co-occurrence analysis showed that the terms “assessment,” “mathematics,” and “professional development” were most often co-occurrence. Moreover, FA, which was the focus of this bibliometric analysis, had a high degree of co-occurrence with feedback, followed by summative evaluation, self-regulation, and professional development. These results will contribute significantly to the efforts of the scientific community towards FA research.

Keywords Formative assessment · Bibliometric analysis · VOSviewer · Web of Science

Introduction

Assessment has a very important place in education. Researchers emphasize the importance of moving away from the traditional “one-size-fits-all” approach to new assessment practices and procedures based on students’ needs for accurate feedback about their efforts (De Backer et al., 2017; Ysenbaert et al., 2020). Many teachers see assessment as always the most valuable goal of pedagogy, but a component that threatens to

undermine their students’ development of learning capacity (Black, 2015). Weurlander et al. (2012) describe the effects of formative assessment (FA) and summative assessment (SA) on the learning process as “assessments that focus on recalling factual information tend to direct students towards surface approaches to learning, while assessments that emphasize application and comprehension tend to encourage deep approaches to learning” (p.747). It has long been recognized that assessment can support learning as well as measure it. While traditional curriculum paradigms combined with behavioral learning theories supported a culture of summative assessment (SA) in the classroom, the social constructivist paradigm that emerged later supported the revealing of student learning through FA (Black & Wiliam, 2003; DeLuca et al., 2018).

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Discussions on assessment in education currently fall into two broad camps. On the one hand, national policies focus on FA, with a view to improving academic quality and making the school system accountable. Assessment theorists and educators, on the other hand, focus largely on the impact of FA on how careful observation, reasoning, and feedback on student strengths and weaknesses can aid the student learning process (Antoniou & James, 2014; Đorić et al., 2021). In traditional education, SA plays the dominant role to evaluate students' academic performance and results (Guo & Yan, 2019). However, it is increasingly recognized that FA, or assessment for learning, helps students improve their learning by providing continuous feedback for learning (Kwon et al., 2017; Nicol & Macfarlane-Dick, 2006). Recent developments in education have emphasized that teachers should continuously integrate student assessments throughout the classroom to support student learning. Classroom assessments are primarily used to guide instruction or support decisions made outside the classroom (Birenbaum et al., 2015; DeLuca, 2012; National Research Council [NRC], 2014).

Over the past 20 years, education researchers have increasingly focused on developing FA practices to enhance student learning. However, it has been noted that teachers should emphasize FA as a crucial process supporting student learning. Simultaneously, FA constitutes a vital element of effective learning (Hopster-den Otter et al., 2017; Taras, 2005). Furthermore, FA is a process that offers feedback to adjust teaching and support learning to help students achieve desired program outcomes (Ruiz-Primo & Furtak, 2007). It serves as a means of support for students, including tasks that prompt clear thinking, idea-sharing, peer or self-assessment, and feedback to enhance learning (Furtak & Heredia, 2014; Heredia et al., 2016). FA is a meticulous combination of process and purposefully designed methodology or instrumentation, rather than being classified as either a test or a process (Bennett, 2011). Black and William (1998) define FA as “a type of assessment that includes all activities carried out by teachers and students that provide feedback to adjust the teaching or learning process” (p. 36). The aim of FA is to track the student's progress towards the desired objective and to assess if instructional activities lead to the intended learning, by trying to close the gap between the student's current learning and the expected outcome (Hartmeyer et al., 2018; Wiliam, 2013). At the same time, the primary objective of this assessment is to furnish evidence that can bolster teachers' practice and aid students' learning (Marshall & Jane Drummond, 2006; McMillan et al., 2013; Wylie & Lyon, 2020). In this context, FA is carried out during instruction with the intention of using the collected information to set up future learning scenarios (Earl, 2003). Formative assessment can be based on different types of data, including diagnosing student achievement, written reports, oral conversations with

students, and teacher observation of students' actions. After collecting the data, we suggest that it is necessary to analyze and interpret this data to determine where the student stands regarding the learning objectives (Webb, 2014).

Formative assessment is more than just using a tool or strategy as it involves making decisions about ways to facilitate student learning, providing feedback, and making adjustments to instruction (Furtak et al., 2014, 2016, 2018). FA tools serve processes that elicit student thinking and provide opportunities for teachers to capture ideas shared by students (Cowie & Bell, 1999). In the FA process, the student is given feedback on how to proceed, or further instruction is shaped, based on the analysis and interpretation of student data to plan further learning (Grob et al., 2021). FA can be conceptualized under five basic strategies: (1) sharing and clarifying learning objectives and success criteria; (2) designing learning tasks that elicit effective classroom discussions and robust evidence of student understanding; (3) providing feedback that advances student learning; (4) enabling students as a resource for each other's learning; and (5) activating students to take responsibility for their own learning (Black & Wiliam, 2009). FA approach emphasizes the ability to make on-site adjustments for lessons because of the teacher identifying students' learning difficulties throughout the learning experience. Many educators employ questioning techniques to extract pupils' thoughts but struggle to use these ideas as effective stepping stones to advance student learning (Cisterna & Gotwals, 2018). Studies of both preservice and in-service teachers have revealed changes in teachers' approaches to assessment from traditional to contemporary approaches encompass assessment training and professional experience (DeLuca et al., 2018). Klenowski (2009) defines FA, or assessment for learning, as “part of daily practice by students, teachers, and peers who seek, reflect, and respond to information” (p. 264). The definition of FA highlights three main themes: (a) it is part of daily teaching practice; (b) both teachers and students are involved in the process; and (c) the information gathered during this process should help shape teaching (Gotwals, 2018). In FA, teachers set instructional goals for their students, measure their progress, and take effective steps to support their progress towards these goals (Black & Wiliam, 2009). This approach focuses on student–teacher interaction and emphasizes the flexible nature of evaluation and “just-in-time” feedback (Cagasan et al., 2020). Specifically, it refers to assessment that aims to produce performance-related feedback to improve and accelerate learning (Sadler, 1998). FA is a planned and ongoing process used by all students and teachers during teaching and learning, and it supports students' intended learning goals. To enhance their understanding of outcomes and promote self-directed learning, evidence is used (Bell & Cowie, 2001; Black & Wiliam, 2009; Cizek et al., 2019; Furtak et al., 2018).

Additionally, FA is utilized to instill self-regulated learning skills in students to enable them to master their own work (Yan & Cheng, 2015).

Effective assessment is also an important way to advance equity in education, as it involves closing the gap between students' current levels of knowledge and achieving the goal of raising low student motivation. Student assessment can have far-reaching implications for education. In particular, it is critical that assessment activities provide students with opportunities to demonstrate what they have learned (Tierney, 2014; Ysenbaert et al., 2020). FA activity requires the tools used by the teacher to practice recognizing and considering student coordination and student reflection and engagement in class activities. FA tools should provide both an opportunity for students to think about a topic and create space for teachers to respond to these ideas in their teaching, thereby advancing students' learning (Bennett, 2011; Heredia et al., 2016). Lack of alignment between instruction and assessment can hinder successful learning and have a negative impact on equity in education (James, 2006; Ysenbaert et al., 2020).

The landscape of studies on formative assessment in the education literature continues to draw the attention of the academic community more and more. Several studies have been conducted over the past two decades on FAE. Our literature review shows that research has focused more on feedback practices in FA (Havnes et al., 2012; Irons & Elkington, 2021; Mapplebeck & Dunlop, 2021; Nicol & Macfarlane-Dick, 2006; Van der Kleij, 2019). In addition, as a result of ours and others' examinations, it is understood that FA studies at primary and secondary school levels are more common (Antonioni & James, 2014; Grob et al., 2021; Guo & Yan, 2019; Hartmeyer et al., 2018). It is seen that the recent FA research mostly includes feedback (Wilkie & Liefeth, 2022), self-regulation (Xiao & Yang, 2019), and technology-assisted (Petrovic et al., 2017) practices. In addition, it is understood that the most studies on FA practices relate to the field of science education (Correia & Harrison, 2020; Dini et al., 2020; Grob et al., 2021; Hondrich et al., 2016). However, a limited number of literature reviews (Lee et al., 2020), meta-analysis (Double et al., 2020), and bibliometric analysis (Sudakova et al., 2022) have been conducted. Sudakova et al. (2022) examined 898 online FA publications in higher education in a bibliometric analysis study on FA. They found that the most effective sources for online FA-based research are "Assessment & Evaluation in Higher Education" and "Computers & Education." In addition, researchers have determined that "Aachen University" and "Universitat Oberta De Catalunya" are the most influential institutions. However, Zhang and Wang's (2022) bibliometric analysis study examined 847 articles

on teacher evaluations published between 2012 and 2021. The results showed that FA has become one of the most popular subject areas among other assessment themes in the last decade. In addition, the results showed that Studies in Educational Evaluation is the most effective resource for publications on teacher evaluations. Moreover, for these publications, Christopher DeLuca was the most prolific author; Michigan State University was the most contributing institution; and America, China, and Turkey were the countries that contributed the most.

Purpose of the Study and Questions

Considering the importance of formative assessment in education, we suggest that much more research is needed on this subject. However, it is also very important for researchers to base new studies and not to repeat publications, and to increase the visibility of effective studies that can make teachers in service understand the importance of FA. The rapid increase in publications makes literature review a challenging and time-consuming task (Tanner et al., 2019). The extensive literature on FA can often be challenging for researchers. Descriptive studies on this subject will contribute to the readability of the studies that will form the basis for new research in the field, which is growing in volume. Describing effective work on FA helps new researchers refine their work. Likewise, introducing teachers to high-quality publications on FA can help them better understand the characteristics of effective assessment practices. In addition, this bibliometric analysis will help researchers working in formative evaluation to identify potential research topics, identify appropriate research institutions to collaborate with, and identify effective academic collaborators. In this context, our study aims to present a bibliometric analysis of articles on formative assessment in education published in WoS from 2000 to 2021. In this study, the following research questions were answered in order to guide new studies on FA, to identify trends and to compare the existing literature:

RQ1. What are the most influential authors, countries, institutions, sources, and documents in the field of FAE during 2000–2021?

RQ2. What kind of co-authorship network model emerged in formative assessment research in education by authors, institutions, and countries during 2000–2021?

RQ3. What is the dominant trend of author keywords in formative assessment research in education during 2000–2021?

Methods

This study used a bibliometric analysis approach to explore FA trends in education. Bibliometric studies identify research trends in a particular field (Kasemodel et al., 2016). Bibliometric analysis is also used to analyze and map specific indicators of publications in a field's literature (Pan et al., 2019; Zeng & Chini, 2017). Moreover, bibliometric analysis reveals an overview of a research field and its leading authors (Bjork et al., 2014; Gimenez-Espert & Prado-Gasco, 2019). One of the strongest indicators of the importance of research in a subject area is trends in scientific publications and citations (Hernandez-Torrano & Ibrayeva, 2020). In this context, the Web of Science (WoS) database was used to test the trends in studies on FAE with bibliometric analyses. This study provides an academic foundation for shaping new research by assessing the progress made in research in the field of FA, identifying the most reliable and popular sources in this field, and introducing key authors, countries, and institutions.

Data Collection and Data Sources

In this study, the keyword “formative AND assessment” OR “formative AND evaluation” was searched in the WoS database on December 15, 2021, and in this context, a total of 447 academic studies were included in this review in accordance with the criteria. The Social Sciences Citation Index (SSCI) of the Web of Science (WoS) was used as the current database source. WOS is the most comprehensive and effective data source for delimiting scientific publications by fields and disciplines, as well as a citation database (Cao et al., 2022). When retrieving scientific publications from the WOS database, we restricted the document type to “article,” the

language to “English,” and the research area to “education and educational research.” The bibliometric analysis used publications that met these conditions. The source of the data used in this bibliometric analysis can be accessed at <https://www.webofscience.com/wos/woscc/summary/506d2eeb-9361-4460-8bf3-2a2bd56ed309-720760d4/date-descending/1>.

Figure 1 shows the number of FA publications by year between 2000 and 2021 that were included as the sample of the present study. The analysis of the number of publications by year reveals that FA publications gained significant momentum in three periods. The first one is between 2008 and 2010, the second one is 2018, and the last one is 2021. In addition, 2021 is the period when FA publications reached their peak.

Data Analysis and Visualization

The authors of the present study created bibliometric network maps for FA publications using the VOSviewer (see www.vosviewer.com). VOSviewer is an effective analysis tool used to visualize bibliometric networks through the distance between two nodes (e.g., source, institution, country), which indicates the relationship between two nodes (van Eck & Waltman, 2010, 2012, 2014). The data downloaded from WoS was first organized in Excel, and descriptive analyses were conducted for documents, sources, institutions, and countries according to their citation strength. The results of the descriptive analysis were presented in tables. At the end of this process, VOSviewer analyzed the bibliographic information of 447 documents downloaded from WoS. VOSviewer produced some network maps according to the purposes, which are the citation network map for sources, authors, countries, institutions, and documents (Franceschini et al., 2015); co-authorship for authors, institutions, and countries (Hou et al., 2018); and co-occurrence of author keywords (Cancino et al., 2017).

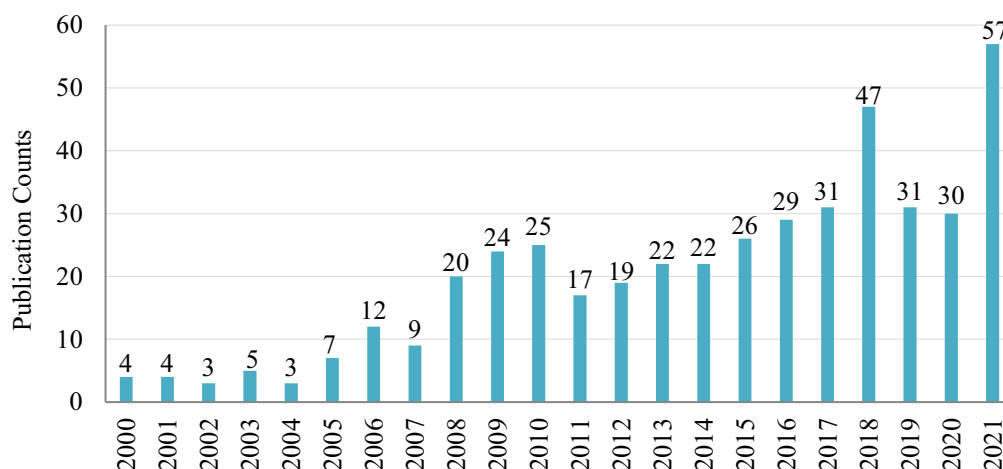


Fig. 1 Number of FA publications by years

Results

This chapter provides an analysis of the most active and influential authors, countries, and institutions in the field of FA in educational research in terms of the number of publications, collaboration (co-authorship), and citations in the early new millennium (2000–2021: the first 22 years). Citation and co-authorship analysis for authors aimed to identify the most prolific authors in the reviewed literature and to reveal collaborative relationships among authors. However, similar analyses for institutions focused on describing the research strengths and collaborative relationships of institutions contributing to the reviewed literature to determine the top rank for research activity. Moreover, analyses involving countries aimed to identify the countries that contributed most effectively to the research base and to reveal the cooperative relations between these countries. The next part of the bibliometric analysis aimed to identify the most influential and leading documents in the literature examined through citation analysis for documents. In addition, this bibliometric analysis focuses on determining the most effective sources by examining the sources that host FA publications in terms of citation count of publications and some indicators. The final part of the bibliometric analysis involved revealing the dominant trend in the reviewed literature through co-occurrence analysis of author keywords. One thousand one hundred and thirty-four researchers from 50 countries in various parts of the world contributed to the 447 publications reviewed in this study. The researchers who contributed to these publications were from 508 different institutions. At the same time, 141 sources fed the literature reviewed in this bibliometric analysis. Table 1 includes the ranking of authors who contributed most effectively to FA publications with respect to the number of publications and citations.

Table 1 shows that Erin M. Furtak is the most prolific author in FAE in terms of the number of publications. Moreover, Maria Araceli Ruiz-Primo, Barbara Crossouard, and Yue Yin are other highly productive authors. However, the number of citations is not compatible with the number of publications. David J. Nicol and Debra Macfarlane-Dick, who have a co-authored publication, are the most influential authors in terms of citations. Paul Black and Dylan William, who have two co-authored publications, followed these authors. Erin M. Furtak, who was the most prolific author with ten publications in 22 years, came after some authors with only one or two publications in terms of the number of citations. Moreover, when considering the number of citations per publication, Mantz Yorke and Hsun-Fang Chang have higher citations than authors with more publications with a single publication do.

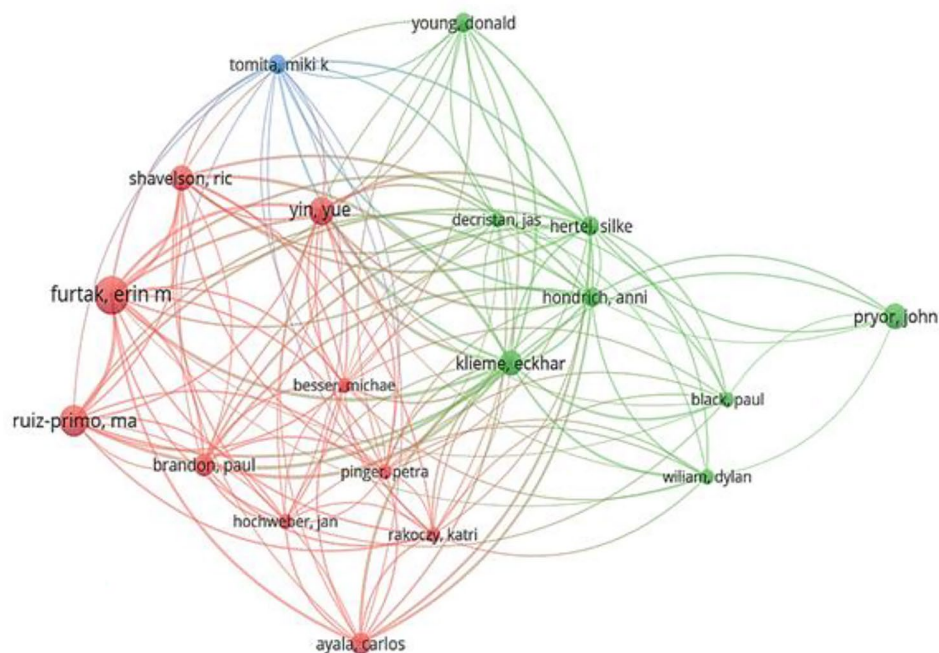
In the FA publications in education, having at least two publications was taken as a criterion for the visualization of the most effective authors with VOSviewer, and the first 20 with the highest link strength were selected according to the number of citations of 114 authors who met this criterion. Figure 2 represents the authors' citation network map.

We examined the co-authorship network to identify collaborative relationships of authors who have papers in FAE. To achieve the strongest co-authoring link, the analysis included the threshold of having more than three publications on the overall network, and 29 authors ultimately met this threshold. However, 29 authors who met the threshold showed a co-authorship network relationship. Figure 3 shows co-authorship links and the two resulting clusters. According to Fig. 3, an important cluster of collaborations in the field of FAE has come to the fore. Erin M. Furtak, who has the strongest link (link number 8) to the other authors in the network map, was the lead author of this cluster. In

Table 1 Author ranking by publication and citation numbers

Author ranking by publication			Author ranking by citations		
Author	TP	TC	Author	TP	TC
Furtak, Erin Marie	10	619	Macfarlane-Dick, Debra	1	1937
Ruiz-Primo, Maria Araceli	7	471	Nicol, David J.	1	1937
Crossouard, Barbara	6	211	Black, Paul	2	1088
Yin, Yue	6	273	William, Dylan	2	1088
Klieme, Eckhard	5	71	Furtak, Erin Marie	10	619
Pryor, John	5	312	Ruiz-Primo, Maria Araceli	7	471
Shavelson, Richard J.	5	267	Yorke, Mantz	1	441
Ayala, Carlos C.	4	234	Hwang, Gwo-Jen	4	437
Brandon, Paul R.	4	234	Chang, Hsun-Fang	1	364
Hwang, Gwo-Jen	4	437	Pryor, John	5	312
Lin, Jian-Wei	4	44	Yin, Yue	6	273
Lopez-Pastor, Victor M.	4	87	Shavelson, Richard J.	5	267

TP total publications, TC total citations

Fig. 2 Author citation network map

addition, other authors had cooperative relations with each other (link number 7).

Citation analysis for institutions revealed the institutions that provided the highest support for FA publications in terms of publication and citation counts. Table 2 shows the most productive and most cited institutions.

Table 2 shows that the most productive institution, as measured by the number of publications, is the University of Colorado/USA, which publishes 13. Apart from this, Stanford University/USA, National Taiwan University of Science and Technology/Taiwan, the University of Illinois/USA, and

the University of Hong Kong/Peoples R China are institutions with high with a high publication count. As with the authors, the number of publications and citations of institutions did not show compliance. The University of Glasgow/Scotland and the University of Strathclyde/Scotland with the highest number of citations were institutions with a low number of publications. The vast majority of citations from these two institutions belong to a single publication (Nicol & Macfarlane-Dick, 2006) with co-authors from the two institutions. In addition, some of the institutions with a high number of documents were among the highest number of

Fig. 3 Authors' co-authorship network map

Table 2 Ranking of institutions by the number of publications and citations

Institution ranking by the number of publications			Institution ranking by number of citations		
Institution	TP	TC	Institution	TP	TC
University of Colorado	13	650	University of Glasgow	3	1976
National Taiwan University of Science and Technology	9	549	University of Strathclyde	2	1953
Stanford University	9	462	King's College London	8	1203
University of Hong Kong	9	129	University of London	2	939
University of Illinois	9	313	University of Colorado	13	650
King's College London	8	1203	Liverpool John Moores University	2	569
Michigan State University	8	89	National Taiwan University of Science and Technology	9	549
University of Massachusetts	8	209	Stanford University	9	462
University of Sussex	7	347	National University of Tainan	2	411
University of North Carolina	6	59	University of Sunderland	2	348
			University of Sussex	7	347
			University of Illinois	9	313

citations (e.g., University of Colorado/USA, King's College London/UK, Stanford University/USA, and National Taiwan University of Science and Technology/Taiwan). Figure 4 represents a network map of the citation counts weighted by the total bond strength of the 20 institutions with the highest link strength.

Institutions contributing to FA publications in education differed in terms of the number of publications, citations, and bond strength. Between institutions according to bond strength, the University of Colorado/USA, King's College London/UK, and Stanford University/USA ranked at the top. In the network map of the citation numbers of the institutions, three clusters came to the fore. Figure 5 shows the co-authorship network map of institutions that contributed to the FA research.

According to the co-authorship analysis for institutions, 17 out of 508 institutions had 200 or more citations. The co-authorship of these institutions emerged in a single cluster comprising the six most highly connected institutions. The institutions represented in this cluster have been the leading institutions in terms of the cooperation of their authors. Three of these six institutions, the University of Colorado/USA, Stanford University/USA, and the University of Illinois/USA, were also among the leading institutions in terms of the number of publications and citations. However, the other three institutions Sonoma State University/USA, University of Hawaii at Mānoa/USA, and the University of Hawaii/USA emerged as pioneer institutions only in terms of cooperation relationship.

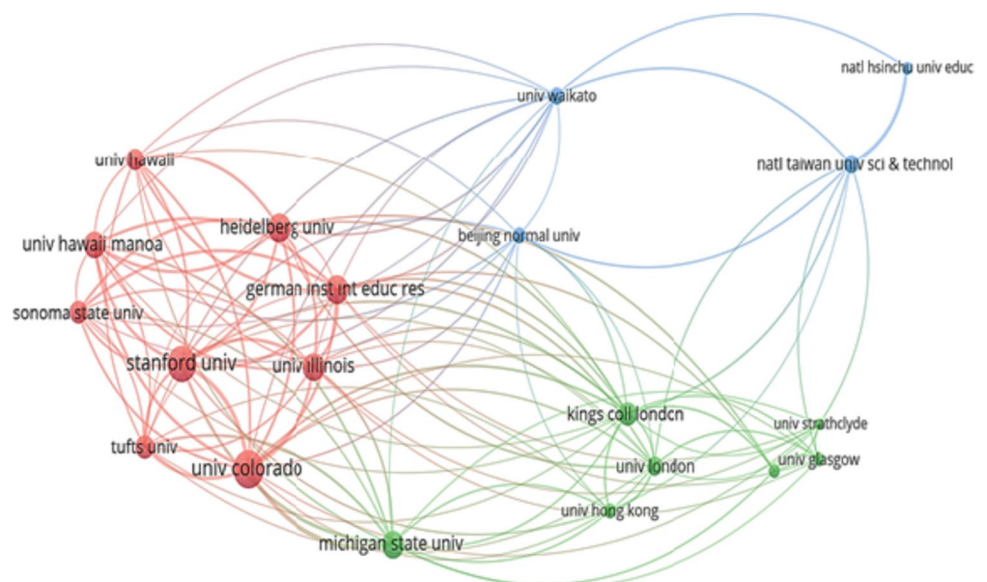
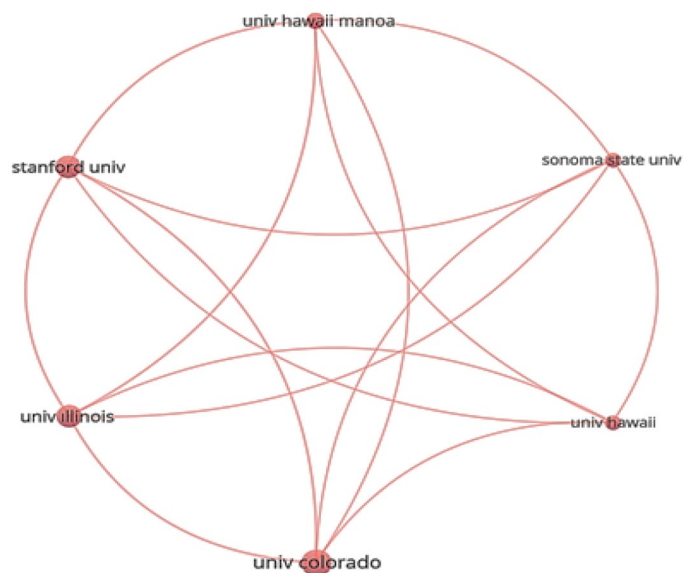
Fig. 4 Citation network map of institutions

Fig. 5 Map of the institutions' co-authorship network



For the countries where FA publications originate, the analysis of publication and citation numbers aimed to identify the most influential and prominent countries. Table 3 shows the most productive and efficient countries.

Except for Canada, which is included in the dataset and has a high ranking in terms of contributing the most to research, nine countries also ranked at the top in the number of citations. Although Scotland is not in the top ranks in terms of the number of publications, it is among the leading countries in the citation ranking. The USA and England are the most productive countries in terms of both the number of publications and the number of citations, and they are the countries that contribute to the most effective research. Figure 6 shows the citation network map of the countries.

Sixteen of the 50 countries that contributed to the research in the dataset met the threshold value of at least five publications and 50 citations. According to the timeline graph of the leading countries, Peoples R China, Germany,

Spain, Malaysia, and Sweden have come to the fore in terms of the number of citations. In addition, the two countries in the foreground in terms of the number of citations were England and Scotland. In these two countries, the contribution of research conducted especially before 2012 was dominant. The highly cited studies of David J. Nicol and Debra Macfarlane-Dick from the University of Strathclyde and the University of Glasgow in 2006 contributed greatly to Scotland's prominence in the early years of the millennium in terms of citation. Likewise, England has been at the top with the great contribution of two studies in 2003 and 2009 by Paul Black and Dylan Wiliam from King's College London and the University of London. The co-authorship network map aimed to highlight the authorship collaboration relationship between countries that met the minimum 100 citation threshold. Figure 7 shows the co-authorship network map of 12 countries that meet this limitation and show strong ties between them.

Three clusters came to the fore in co-authorship relations by country. In the first cluster, which is represented in red, the strong cooperation between America, Germany, and China has been a driving force. In the second cluster, which is indicated in green, England has come to the forefront with its collaborations with other countries as well as Belgium and Scotland. In the third cluster, which is symbolized in blue, it is seen that Australia has strong cooperation with America, China, and some European countries.

Table 4 shows the list of the most effective documents in terms of number of citations among FA publications. The three publications at the top of the list have been documents focusing on the theory of FA. In addition, all leading documents in terms of the number of citations were published before 2010, except for Hwang and Chang (2011) and Coffey et al. (2011).

Table 3 Countries ranking by publications and citation numbers

Countries ranking by publication numbers			Countries ranking by citation numbers		
Countries	TP	TC	Countries	TP	TC
USA	173	3300	USA	173	3300
England	62	3262	England	62	3262
Australia	31	523	Scotland	10	2080
Peoples R China	27	281	Taiwan	22	923
Netherlands	26	310	Australia	31	523
Spain	22	328	Spain	22	328
Taiwan	22	923	Netherlands	26	310
Germany	15	296	Germany	15	296
Canada	14	195	Peoples R China	27	281

Fig. 6 Citation network map of countries

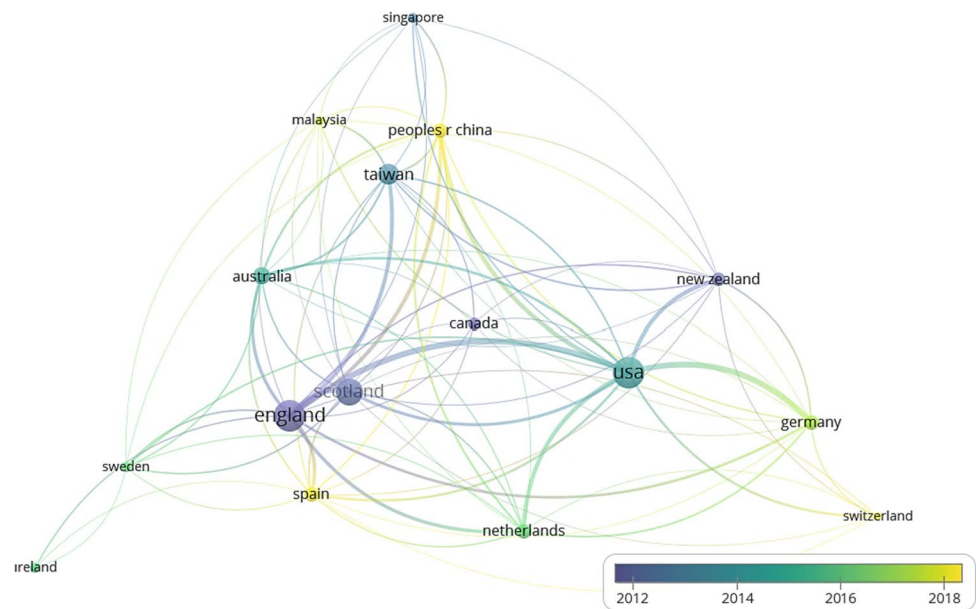


Figure 8 represents the citation network map of the documents. Nicol and Macfarlane-Dick (2006) and Black and Wiliam (2009) were the most influential among the 19 documents with a citation threshold greater than 100, containing the largest link structure.

Table 5 shows the number of publications and the citation structure of the journals that are the source of FA publications according to different limitations. Table 5 shows that there are 24 sources that meet the threshold of at least five publications. These resources constitute 17% of the total resources. The rank of the most productive journals that sourced FA articles was not similar in terms of the number

of publications and citations. According to the number of publications and citations, “Assessment & Evaluation in Higher Education” and “Computers & Education” came to the fore among the top five most productive sources. Only in terms of the number of publications, “Applied Measurement in Education,” “BMC Medical Education,” and “International Journal of Science Education” were in the top five. However, considering the number of citations, “Educational Assessment Evaluation and Accountability,” “Journal of Research in Science Teaching,” and “Science Education” replaced these. In terms of the number of citations, except for the “Educational Assessment Evaluation

Fig. 7 Map of the countries’ co-authorship network



Table 4 Documents ranked by number of citations

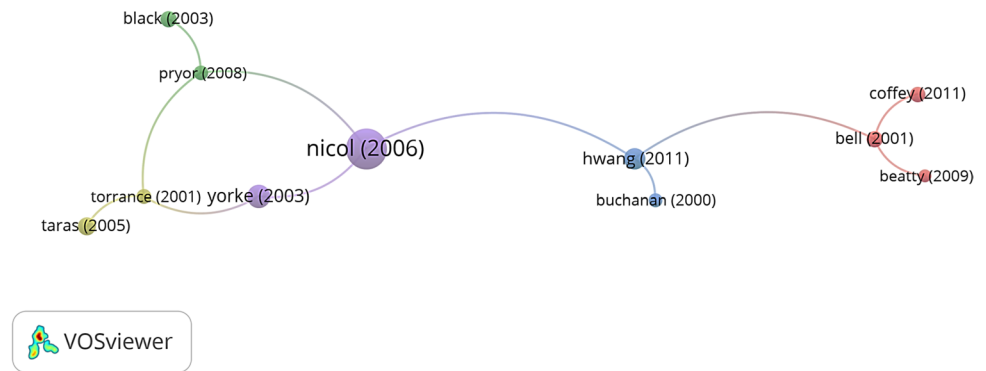
AU	TC	CPY	TI	SO
Nicol and Macfarlane-Dick (2006)	1937	129.13	“Formative assessment and self-regulated learning: a model and seven principles of good feedback practice”	“Studies in Higher Education”
Black and Wiliam (2009)	916	76.33	“Developing the theory of formative assessment”	“Educational Assessment Evaluation and Accountability”
Yorke (2003)	441	24.50	“Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice”	“Higher Education”
Hwang and Chang (2011)	364	36.40	“A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students”	“Computers & Education”
Taras (2005)	242	15.13	“Assessment—Summative and formative—Some theoretical reflections”	“British Journal of Educational Studies”
Ruiz-Primo and Furtak (2007)	179	12.79	“Exploring teachers’ informal formative assessment practices and students’ understanding in the context of scientific inquiry”	“Journal of Research in Science Teaching”
Black and Wiliam (2003)	172	9.56	“In praise of educational research: formative assessment”	“British Educational Research Journal”
Bell and Cowie (2001)	170	8.50	“The characteristics of formative assessment in science education”	“Science Education”
Coffey et al. (2011)	165	16.50	“The Missing Disciplinary Substance of Formative Assessment”	“Journal of Research in Science Teaching”
Torrance and Pryor (2001)	136	6.80	“Developing formative assessment in the classroom: using action research to explore and modify theory”	“British Educational Research Journal”
Vickerman (2009)	128	10.67	“Student perspectives on formative peer assessment: an attempt to deepen learning?”	“Assessment & Evaluation in Higher Education”
Pryor and Crossouard (2008)	124	9.54	“A socio-cultural theorisation of formative assessment”	“Oxford Review of Education”
Stiggins (2005)	118	7.38	“From formative assessment to assessment FOR learning: A path to success in standards-based schools”	“Phi Delta Kappan”
Heritage (2007)	117	8.36	“Formative assessment: What do teachers need to know and do.?”	“Phi Delta Kappan”
Triantafillou et al. (2003)	116	6.44	“The design and the formative evaluation of an adaptive educational system based on cognitive styles”	“Computers & Education”
Buchanan (2000)	106	5.05	“The efficacy of a World-Wide Web mediated formative assessment”	“Journal of Computer Assisted Learning”
Rushton (2005)	105	6.56	“Formative assessment: a key to deep learning?”	“Medical Teacher”
Beatty and Gerace (2009)	101	8.42	“Technology-Enhanced Formative Assessment: A Research-Based Pedagogy for Teaching Science with Classroom Response Technology”	“Journal of Science Education and Technology”
Gijbels and Dochy (2006)	101	6.73	“Students’ assessment preferences and approaches to learning: can formative assessment make a difference?”	“Educational Studies”

AU authors, TC total citations, CPY average citations per Year, TI document title, SO publication name

and Accountability” of the first five sources, the JCR quarterly category of four sources is Q1. At the same time, these four sources are among the most prestigious journals in

terms of other indicators (IF, 5-Year IF, H, ACPI, JCI, and rank in category). Only seven of the 24 sources that meet the threshold value of at least five publications have at least

Fig. 8 Citation network map of documents



100 citations. One publication in two sources has at least 200 citations. These two sources are “Educational Assessment Evaluation and Accountability” and “Journal of Research in Science Teaching,” which have fewer publications than others. At the same time, considering the number of citations per publication (160 and 101, respectively), these two sources emerged as the leading sources. In addition, Black and Wiliam (2009), which has the second highest number of citations (TC=916) among all publications, came to the fore as the publication that made the highest contribution to the number of citations in the “Educational Assessment Evaluation and Accountability.”

The citation analysis of the sources in the reviewed literature through VOSviewer aimed to reveal the most effective sources hosting FA publications. Figure 9 shows the citation network map of the sources with at least five publication thresholds and the highest link strength.

The four journals that source FA publications have the highest link strength. These are the two leading journals in terms of the number of citations per publication, as well as the journals “Applied Measurement in Education” and “Science Education.” While two of these journals are measurement and assessment-focused journals, the other two are the leading journals in the field of science education. Of the 12 journals with high bond strength, six focus on science education, one focuses on computer education, and the other five focus on assessment and evaluation.

According to the network structure of the resources based on the timeline in Fig. 10, “Journal of Chemical Education” and “International Journal of Science and Mathematics Education” are journals that have been the source of FA studies in the field of science and mathematics education in recent years. However, the “Journal of Research in Science Teaching” and “Science Education” have mostly been the source of FA research in science education in the first 10 years. In general, FA research in education has focused on the resources of “Assessment in Education-Principles Policy & Practice” and “Studies in Educational Evaluation” in recent years.

The purpose of the co-occurrence analysis was to reveal the dominant trend in the reviewed literature. The co-occurrence analysis included a review of author keywords in education-related FA publications. Figure 11 represents the network map showing the most frequently used words and the co-occurrence relationships between words.

According to the co-occurrence analysis of author keywords, the reviewed publications used 862 different words. The results of the applied analysis showed that 20 different words that met the threshold of at least eight occurrences emerged and that these words formed six different clusters in terms of repetition and co-occurrence bond strengths. The first cluster in the network map was the red cluster where the terms “assessment,” “mathematics,” and “professional development” were most often co-occurrence. The second cluster was the green, where FA, which was the focus of this bibliometric analysis, was the most repeated keyword of the network and had the highest co-occurrence with other words. Other important words in this cluster were “summative assessment,” “higher education,” and “teacher education.” The third cluster of the network was the blue cluster, which had an equal number of occurrences (occurrence: 14), “self-assessment” and “assessment for learning,” as well as “peer assessment,” which was the number of occurrences close to them. Self-assessment and feedback were the keywords with the highest number of links (link: 10) after formative evaluation (link: 27) in the network map. Yellow, purple, and turquoise colors highlighted the fourth, fifth, and sixth clusters of the network map, respectively, and each cluster contained two keywords. Keywords were “e-learning” and “e-formative assessment” in the yellow cluster, “feedback” and “science education” in the purple cluster, and “interactive learning environments” and “self-regulation” in the turquoise cluster. In the network map, FA had a high degree of co-occurrence with feedback (link strength: 16), followed by summative evaluation, self-regulation, and professional development (link strength: 13).

This bibliometric analysis included overlay visualizations as well as co-occurrence network mapping for author

Table 5 Sources ranked by the number of publications and citations

	The FA publications in the journals (2000–2021)										All publications of the journals (2000–2021)					Rank in category
	TP	TC	%TP	≥200	≥100	≥50	≥20	≥1	IF (Q)	2020	5-Year IF	TP	TC	H	ACPI	JCI (2020)
“Assessment & Evaluation in Higher Education”	35	751	3.05	0	1	1	17	34	4.984 (Q1)	4.585	1148	21,809	57	19	2.880	17/265
“Computers & Education”	27	1266	0.74	1	2	9	17	26	8.538 (Q1)	9.269	3653	173,772	177	47.57	3.440	3/265
“Applied Measurement in Education”	14	285	2.92	0	0	3	4	12	1.58 (Q4)	1.84	479	6917	39	14.44	0.6	200/265
“BMC Medical Education”	14	132	0.38	0	0	0	1	12	2.463 (Q2)	3.07	3680	41,823	67	11.36	1.28	118/265
“International Journal of Science Education”	13	164	0.54	0	0	0	2	13	2.241 (Q3)	2.656	2417	59,410	100	24.58	1.42	136/265
“Assessment in Education-Principles Policy & Practice”	11	63	1.88	0	0	0	0	8	2.656 (Q2)	3.633	585	7300	40	12.52	2.13	102/265
“Journal of Science Education and Technology”	11	208	1.28	0	1	1	3	10	2.315 (Q2)	3.396	862	13,755	48	15.96	1.29	129/265
“ETR&D-Educational Technology Research and Development”	10	80	0.75	0	0	0	2	8	3.565 (Q1)	4.5	1327	32,344	82	24.37	2.31	56/265
“Studies in Educational Evaluation”	10	72	1.68	0	0	0	1	8	1.953 (Q3)	2.587	595	4619	29	7.76	1.24	167/265
“Interactive Learning Environments”	10	56	0.71	0	0	0	1	9	3.928 (Q1)	3.868	1409	13,421	46	9.53	2.05	44/265
“Journal of Chemical Education”	9	30	0.09	0	0	0	0	5	2.979 (Q2)	2.716	9567	88,856	76	9.29	0.94	14/44
“British Journal of Educational Technology”	8	233	0.25	0	0	2	4	8	4.929 (Q1)	5.03	3167	49,493	88	15.65	3.16	19/265
“Teaching and Teacher Education”	8	145	0.27	0	0	0	3	8	3.272 (Q1)	4.757	3008	96,109	124	31.95	2.25	66/265
“Educational Leadership”	7	137	0.19	0	0	1	2	6	0.607 (Q4)	0.505	3697	18,546	53	5.02	0.19	254/265
“Educational Technology & Society”	7	146	0.42	0	0	0	3	7	3.522 (Q1)	3.941	1665	36,211	81	21.75	2.03	57/265
“Medical Teacher”	7	163	0.13	0	1	1	2	7	3.65 (Q1)	4.257	5375	91,355	112	17	1.46	7/044
“Theory into Practice”	7	130	0.77	0	0	1	2	6	2.329 (Q2)	2.913	904	23,686	61	26.2	1.1	126/265
“International Journal of Science and Mathematics Education”	7	61	0.63	0	0	0	1	6	2.073 (Q3)	2.281	1107	9777	38	8.83	1.48	154/265
“Educational Assessment Evaluation and Accountability”	6	957	1.97	1	1	1	1	5	2.00 (Q3)	2.419	304	3968	27	13.05	1.13	163/265
“Science Education”	6	288	0.25	0	1	1	4	6	4.593 (Q1)	5.084	2426	56,676	106	23.36	3.01	31/265
“Chemistry Education Research and Practice”	5	16	0.56	0	0	0	0	3	2.959 (Q2)	3.332	898	12,674	45	9.426	1.85	80/265
“Journal of Research in Science Teaching”	5	505	0.39	0	2	3	5	5	4.832 (Q1)	5.905	1277	63,109	118	49.42	3.08	21/265
“Teachers and Teaching”	5	38	0.70	0	0	0	0	5	2.306 (Q2)	3.646	714	10,051	46	14.08	1.71	130/265
“Innovations in Education and Teaching International”	5	81	0.43	0	0	1	2	4	1.949 (Q3)	2.315	1157	12,083	45	10.44	1.25	168/265

TC total citations, TP total publications, H H-index, %TP the percentage of FA publications in of all publications of the journal during years 2000–2021; ≥ 200 , ≥ 100 , ≥ 50 , ≥ 20 , ≥ 1 , counts of publications with more than 200, 100, 50, 20, or 1 citations, IF (Q) impact factor and JCR quartile in category for year 2020, ACPI average citations per item, JCI (2020) “The Journal Citation Indicator is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles & reviews) published by a journal over a recent three year period. It is used to help you evaluate journals based on other metrics besides the Journal Impact Factor (JIF).” Education & Educational Research in SSCI edition Source: Journal Citation Reports™ 2020

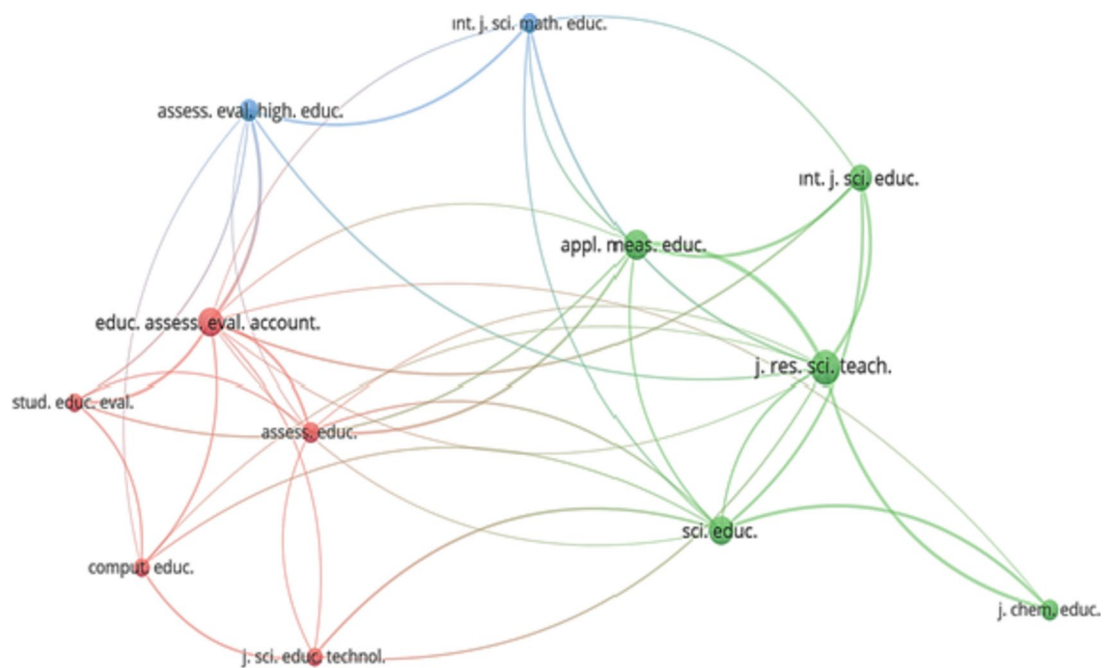


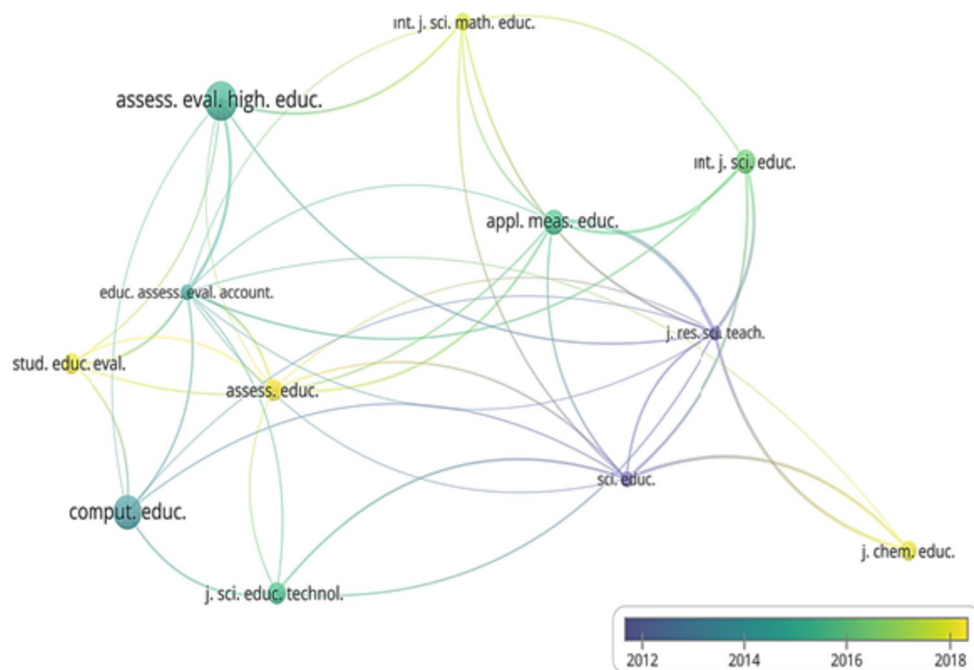
Fig. 9 Citation network map of resources

keywords. Figure 12 represented a co-occurrence overlay visualization for 20 keywords that met at least eight occurrence thresholds.

The overlay visualization showed that the keywords self-assessment, peer review, professional development, mathematics, and testing/evaluation were more prevalent, especially in publications after 2017. In addition, the keyword

“formative evaluation” (Avg. Pub. Year: 2010.56) tended to be frequently occurred in publications up to 2010, and the word “formative assessment” (Avg. Pub. Year: 2015.67) commonly in publications after 2015. On the other hand, there was a higher tendency for the keywords “e-learning,” “e-formative assessment,” “interactive learning environments,” and “computer-assisted assessment” in publications around 2013.

Fig. 10 Overlay visualization for citation analysis of sources



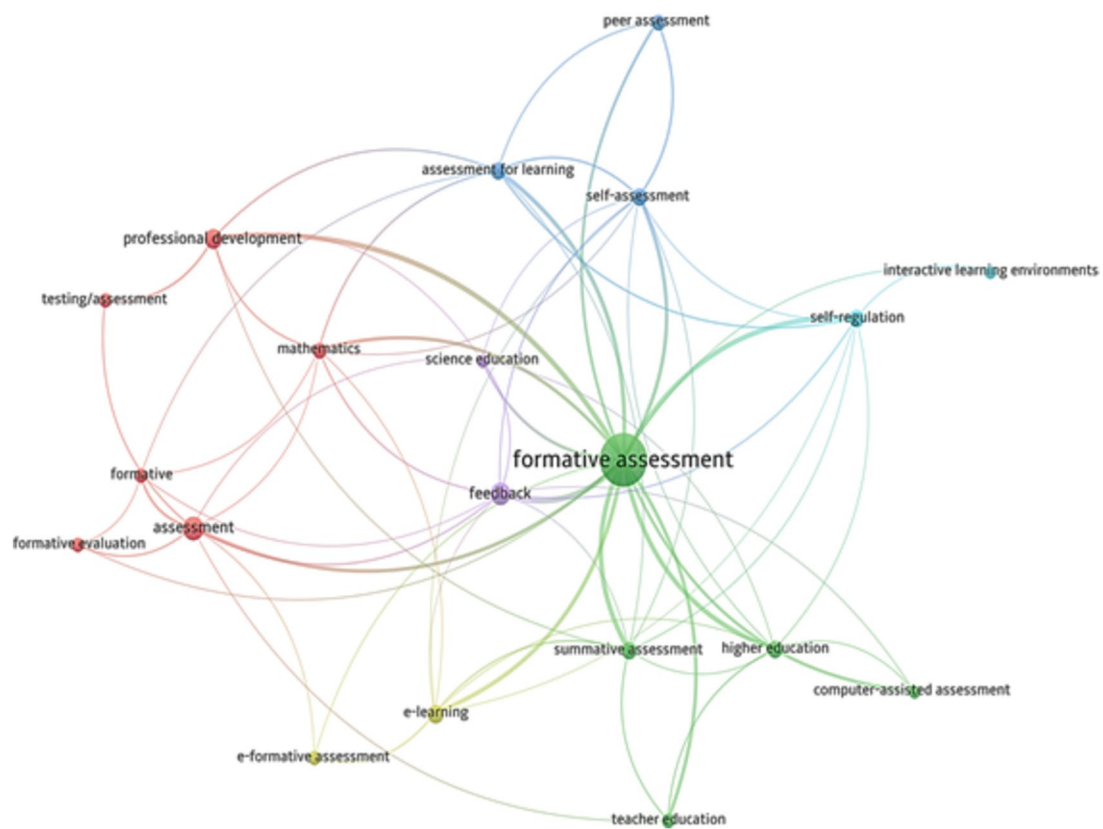


Fig. 11 Keywords' co-occurrence network

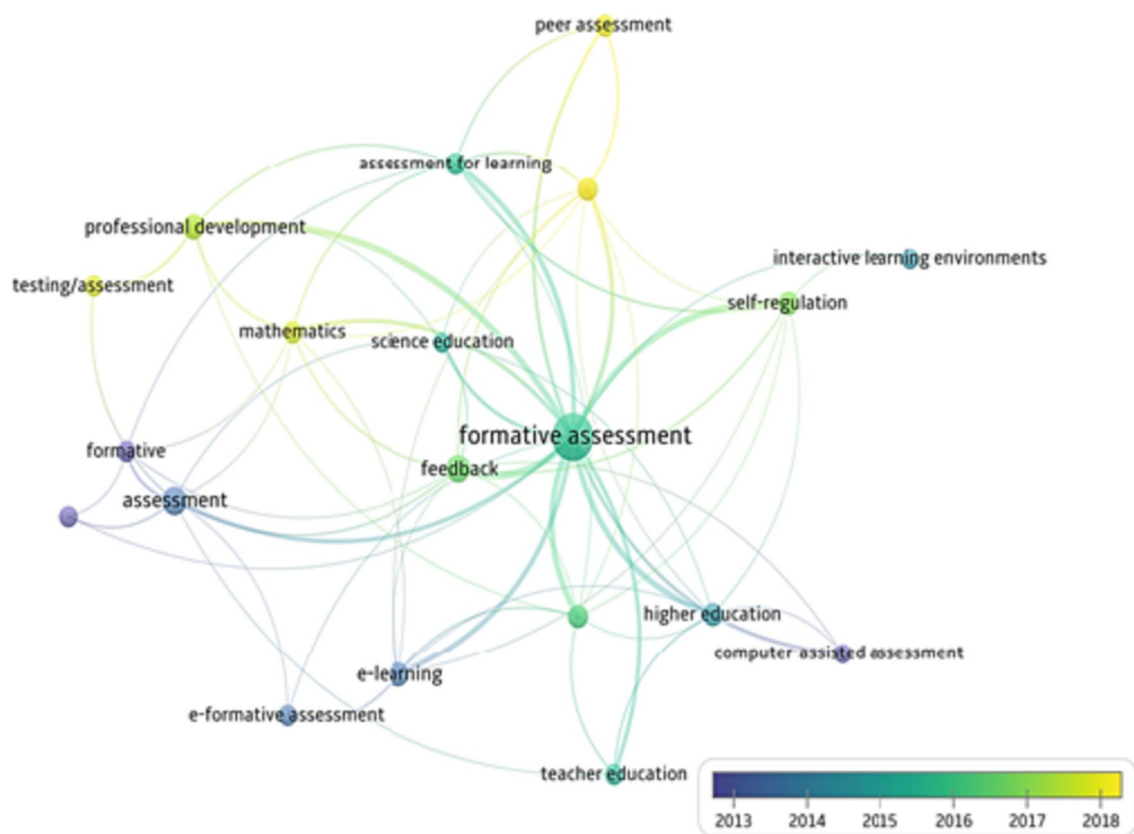


Fig. 12 Overlay visualization for co-occurrence analysis of author keywords

Discussion and Conclusion

Research on FA in education has been a very popular field of study for at least two decades, and the importance of this topic is increasing in many countries. The purpose of this bibliometric analysis was to provide a thorough understanding of the authors, sources, countries, and institutions that fed the FA literature in education from 2000 to 2021. In addition, by providing a snapshot of FA publications available during this period, we aimed to help researchers follow further developments and more easily identify scientific research gaps in this field. In the study, 447 publications on FAE were accessed from WoS and these were exposed to bibliometric analysis via VOSviewer. As far as we know, there are a few limited bibliometric analysis studies in the literature on e-assessment, teachers' understanding of assessment, and assessment with computer-assisted tools. In this context, the present study is the first to conduct a bibliometric analysis to review the FA research field, which includes all educational research without discrimination, and to identify the highlights. We can say that bibliometric studies in the field of FA are important for researchers to acquire a basic framework for future research. The study examined which of the publications on FA have the greatest impact in terms of different variables such as authors, documents, countries, institutions, and sources. The results of this study showed a rapid increase in the number of articles published on FA since 2008. This indicates a growing interest in researching FAE. This rapid increase in the number of publications may be due to several factors. One of the most important factors triggering this change seems to be the emphasis on FA in the program changes made in many countries in the last 15 years. Conversely, in countries such as Turkey, where the examination system is important at all levels of education, the dominance of SA has resulted in a lack of research on FA. Based on our results, Erin Marie Furtak was the most prolific author of FAs. However, Furtak was the most productive author with ten publications in the last 20 years, came later than some authors who had one or two publications, according to the number of citations. In addition, in terms of citations per publication, Mantz Yorke and Hsun-Fang Chang were ahead of the authors with more publications. One of the important results of this study is that the number of publications and the number of citations are not directly proportional. The two most important characteristics of good articles are clarity and relevance. Academic articles stand out as long as they are clear, practical, and interesting to the reader (Kelley et al., 2003). In the bibliometric analysis, we may say that the authors who come out on top with more citations with fewer publications serve the purpose of the target audience and are more readable.

The results of the present bibliometric analysis show that the most prolific authors in terms of citation are David

J. Nicol, Debra Macfarlane-Dick, Paul Black, and Dylan Wiliam. When comparing the methods and results of his/her paper, an author refers more to sources that focus on a similar research problem. The strength of this relationship between publications represents citation relevance (Tanner et al., 2019). In bibliometric analysis, the number of citations received by a publication is defined as the impact and quality of the publication (Van Leeuwen et al., 2003). Therefore, it can be said that the studies of Nicol and Macfarlane-Dick (2006) and Black and Wiliam (2009) have a strong scientific impact on other research in the field of FA (Van Eck & Waltman, 2017) because their studies can be considered reference articles in the FA literature. Considering the duration of visibility, publications from previous years have a higher chance of being cited than new publications. However, this does not mean that new publications will not have a significant impact in this area (Milfont & Page, 2013). The most effective and productive institution in terms of the number of publications was the University of Colorado with 13 publications. On the other hand, the University of Glasgow/Scotland and the University of Strathclyde/Scotland, two institutions with a lower number of publications, had the highest number of citations. Furthermore, the University of Glasgow/Scotland and the University of Strathclyde/Scotland ranked first in total citations in FA publications, suggesting that these institutions may have a more significant influence on the direction of research in the relevant field. The publications of researchers in these institutions contribute to the prominence of their institutions in various research fields. Therefore, the reason for the mentioned institutions to come to the fore in terms of FA publications is that they include influential researchers who are well-known and widely cited in the field. In addition, the funds and collaborations given to research in this field within the institution can also make them effective. It can be said that comparing the relevant outputs of the institutional contribution to world science, research support funds, and the publications produced based on them is useful in revealing the impact in the field. For example, the strong performance and significant leadership of economically smaller institutions in FA research, compared to larger institutions with a longer history, indicates the continuity of the academic culture in this research area. Another important result is that the USA and England are the most productive countries in terms of both the number of publications and the number of citations. Because these countries host the best universities and the most cited scientists, they are often considered leaders in scientific research and therefore form the core of scientific effectiveness (Leydesdorf & Wagner, 2008).

While the USA and England were the two most important pioneering countries to accelerate the growth of publications in the last 20 years, the growth rate of other productive countries remained slower. This also indicates the need for further internationalization in the field of FA. Of course,

scientific infrastructure and reputations for institutions and resources held by countries shape their visibility (Gomez et al., 2022). It is therefore not surprising that countries with these advantages have attracted such global interest in formative assessment research. In addition, the research findings showed that the contributions of many developing countries to this field are quite low. Based on the findings, we conclude that research capacity in FA is limited to a small number of leading countries based on the thresholds set for the analysis. The distribution of research capacity to such a small number of country groups cannot be considered a healthy research culture in a scientific discipline. In addition, the lack of international cooperation can be shown as another prominent factor. The quality problems of the scientific publications of the countries indicate the incompatibility of the subject to be researched and the method used, the non-originality of the publications, the inadequate analysis of the data, the lack of inferential findings, the inability to interpret the results well, and the lack of theoretical infrastructure on the subject studied (Bozkurt, 2021).

According to the number of citations and publications, “Assessment & Evaluation in Higher Education” and “Computers & Education” stand out as the most productive sources. It can be said that these journals have an important academic position in terms of FA studies. However, according to the number of citations per publication, “Educational Assessment Evaluation and Accountability” and “Journal of Research in Science Teaching” are the prominent sources. The prominence of a journal in the academic world is possible with its institutional identity. This can also be explained by the reliability of the editorial and evaluation processes. Therefore, a journal with these features has a high reputation in the academic community and can attract more qualified studies. The citation power and impact of the articles in the mentioned journals have raised them to the top ranks in the field of measurement and evaluation. In addition, the prominence of the “Journal of Research in Science Teaching,” which is a journal with a very strong image and where outstanding studies in the field of science education are published, can be explained by several factors. One of them is that some of the strongest names in FA research in science education have published their studies here. Another one is that FA has become more prominent in the field of science education in the last two decades, which has led to an increase in the quality of studies in this field. Therefore, science education researchers have preferred to publish their qualified studies in the field of FA in this journal.

In terms of the co-authorship relationships of the authors whose articles are in the field of FA in education, it is understood that the leading author is Erin Marie Furtak, who has the strongest connection with other authors. This can be explained by the fact that Furtak is the author who collaborates the most with other authors conducting research on FA

and triggers collaboration. When the co-authorship relationship of the institutions is analyzed, it is found that the University of Colorado/USA, Stanford University/USA, and the University of Illinois/USA are among the leading institutions in terms of the number of publications and citations. This can be explained by the fact that the prominent universities have a wider network of collaborators in FA studies. In terms of co-authorship relationships by country, the USA, Germany, and China have been the driving forces in FA studies with strong collaboration between them. This collaboration of scientists from three different continents in contributing to global science can serve as an example to motivate the collaboration of scientists from many different geographies in FA studies. In the network map of the bibliometric analysis of FA articles in education, the terms “assessment,” “mathematics,” and “professional development” were found to be the keyword cluster with the highest number of co-occurring keywords. However, the key term “formative assessment,” which is the focus of this study, was found to be in the second most repeated cluster of the network and showed the highest co-occurrence relationship with other words. The FA had the highest co-occurrence with feedback, SA, self-regulation, and professional development. Keywords play a major role in reflecting the content of articles and revealing the trends and patterns of academic research (Badaluddin et al., 2021). Moreover, the co-occurrence network of keywords provides an understanding of the structure and knowledge components of a scientific field by examining the links between keywords in the literature (Radhakrishnan et al., 2017). Analyzing the co-occurrence of keywords in FA studies can provide broad insights into trends in the literature and offer researchers a range of avenues for future research proposals.

In conclusion, our study contributes to show the status and development of FA research at the turn of the millennium (during the years 2000–2021). This bibliometric analysis on FAE allows researchers to become more aware of research hotspots when addressing a topic in this field. This study is probably the first bibliometric analysis of FA research in education from a quantitative perspective, without limitation of field, level (higher education, high school, etc.), and scope (teacher, preservice teacher, etc.). Publication and citation trend analyses indicate that more impact can be achieved with fewer articles in this field. The findings on prominent and prolific authors, institutions, countries, and journals in this field will help researchers identify and become more aware of appropriate channels and potential collaboration opportunities to share and develop their research. It will also allow FA researchers to quickly grasp trends in research. In recent years, it has been observed that the number of publications on FA has increased rapidly and the level of journals published is high. In this context, it is understood that the distribution of countries in terms of the geographies where FA studies with high impact are

produced is quite limited. Country- and institution-based collaborations in FA studies are quite limited. In other words, except for a few dominant countries in the academic world, contributions and collaborations in the field are very weak. However, in terms of institutions, the more modest Scotland universities, which are not dominant in the academic world, but have a high impact on FA studies, stand out. This analysis will help researchers to identify potential opportunities for collaboration on FA in terms of prolific authors, documents, institutions, countries, and resources (in this case journals). In this study, analyzing only the authors, documents, countries, institutions, organizations, journals, and keywords rather than the entire content of FA articles in education may have provided more superficial information. In addition, the thresholds used for the analyses may have led to some information gaps. It would be useful to perceive the findings and conclusions on the basis of these thresholds.

Suggestions

While the results obtained in this study provide an overview of FA research in education for relevant researchers, further research that can be effective in this field can be elaborated with different databases and analyses. In addition, research can be expanded to include books, conference proceedings, and theses. Researchers can plan their studies in the field accordingly by examining the distribution of prominent keywords in FA research by year. It should be noted that the findings in this study are based only on publications in the WoS database, and future research should be expanded to include other databases.

Data Availability The data that support the findings of this study are available from <https://www.webofscience.com/wos/woscc/summary/506d2eeb-9361-4460-8bf3-2a2bd56ed309-720760d4/date-descending/1>.

Declarations

Conflict of Interest The author declares no competing interests.

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