Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

January 2025. Vol. 13, No. 1
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 107-122

Research Patterns in Formative Assessment: A Bibliometric Review of Primary and Secondary School Studies

[1,2*]Sheikh Abu Toha Md Saky, [1] Nurul Latifatul Inayati, [2,3] Md Nurul Islam
[1] Universitas Muhammadiyah Surakarta, Indonesia
[2] International Islamic University Chittagong, Bangladesh
[3] Nanjing University, China

*Corresponding Author e-mail: g000224224@student.ums.ac.id

Received: December 2024; Revised: January 2025; Published: January 2025

Abstract

This study examines the evolving landscape of formative assessment in primary and secondary education through bibliometric analysis, emphasizing theoretical foundations, technological integration, and global applications. A total of 398 documents from the Scopus database (1997–2024) were analyzed using Biblioshiny for R, with an annual growth rate of 14.74%. Key metrics such as keyword co-occurrence, thematic clusters, and global collaboration networks were evaluated to identify prevailing research trends and gaps. The results highlight significant themes, including feedback mechanisms, self-assessment, peer assessment, and the integration of digital technologies like e-learning, gamification, and artificial intelligence. Collaboration patterns reveal the USA, China, and Germany as research hubs, while Southeast Asia demonstrates regional efforts. However, barriers such as inconsistent definitions, limited teacher training, and technological inequities persist. This study contributes novel insights by bridging critical gaps in the literature, particularly the lack of cultural perspectives and underexplored non-traditional educational contexts. It combines bibliometric analysis with thematic insights to illuminate the transformative potential of formative assessment across diverse educational settings. Educators and policymakers can use these findings to develop regionally tailored strategies for formative assessment, addressing implementation challenges and promoting effective practices globally. By fostering personalized learning and equitable access, formative assessment supports inclusive education, narrowing disparities across various learner demographics.

Keywords: Formative assessment, Feedback, E-learning, Bibliometric analysis, Global collaboration, Educational technology, Primary and secondary education

How to Cite: Saky, S., Inayati, N., & Islam, M. (2025). Research Patterns in Formative Assessment: A Bibliometric Review of Primary and Secondary School Studies. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *13*(1), 107-122. doi:https://doi.org/10.33394/j-ps.v13i1.14219

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INTRODUCTION

Formative assessment has been a significant focus in educational research and practice for many years. It is recognized as a powerful tool to enhance student learning by providing ongoing feedback that can be used by instructors to improve their teaching and by students to improve their learning (Zhang et al., 2023; Schütze et al., 2018). Despite its acknowledged benefits, the implementation of formative assessment has been inconsistent and often limited in scope (Torrance, 2012; Gavine et al., 2006). Recent trends indicate a shift from summative to formative evaluations, emphasizing the importance of continuous feedback and student engagement in the learning process (Sudakova et al., 2022; Underwood & Burns, 2014).

The theoretical foundation of formative assessment is deeply rooted in learning theories rather than assessment theories. It is embedded within the broader context of pedagogy,

instruction, and learning (Moeed, 2015a; Black & Wiliam, 2018a). Formative assessment aims to clarify learning goals, diagnose individual performance, and provide feedback to enhance learning outcomes (Schütze et al., 2018). The integration of formative assessment with theories of pedagogy and learning underscores its role in fostering self-regulation, motivation, and self-efficacy among students (Beekman et al., 2021; Meusen-Beekman et al., 2016).

Recent bibliometric analyses reveal a substantial increase in publications on formative assessment, particularly between 2015 and 2022 (Zhang et al., 2023). The research has expanded to include various educational contexts, such as science education, higher education, and online learning environments (Zhang et al., 2023; Sudakova et al., 2022). Key trends include the use of technology in formative assessment, the emphasis on student-centered learning, and the exploration of different formative assessment strategies like peer and self-assessment (Beekman et al., 2021; Odom et al., 2008a; Wqfubwa, 2020). Despite these advancements, challenges in consistent implementation and the need for further empirical studies remain (Torrance, 2012; Sortwell et al., 2024).

Global collaboration in formative assessment research is becoming increasingly prominent. Countries like the USA and UK are leading in publication outputs and collaborative efforts (Zhang et al., 2023; Sudakova et al., 2022). International collaborations facilitate the sharing of best practices, resources, and innovative approaches to formative assessment (Menon et al., 2013). These collaborations often involve partnerships between educational institutions and researchers across different continents, enhancing the quality and impact of research (Menon et al., 2013; Chattopadhyaya et al., 2022). However, successful collaboration requires careful management to overcome challenges such as cultural differences and logistical issues (Menon et al., 2013).

The implementation of formative assessment faces several challenges, including a lack of instructional materials, large class sizes, and insufficient teacher training (Figa et al., 2020; Young & Jackman, 2014). Additionally, traditional assessment practices and resistance to change can hinder the adoption of formative assessment strategies (Underwood & Burns, 2014; Dieste et al., 2023a). Despite these challenges, there are significant opportunities for improvement. Enhancing teacher education and professional development, integrating technology, and fostering global collaborations can support the effective use of formative assessment (Schildkamp et al., 2020; Goertzen et al., 2023). Moreover, ongoing research and innovation in formative assessment practices can lead to more informed and effective teaching and learning environments (Wqfubwa, 2020; Sortwell et al., 2024).

While prior studies, such as Zhang et al. (2023), have predominantly focused on formative assessment within specific domains like science education, this review adopts a broader disciplinary scope encompassing diverse educational contexts in primary and secondary schools. Additionally, it emphasizes regional variations in formative assessment practices, which remain underexplored in the existing literature. By addressing these gaps, this study provides a comprehensive analysis that highlights the influence of cultural, technological, and policy factors on the implementation and evolution of formative assessment worldwide.

Research Questions

1. What are the prevailing themes, trends, and methodologies in formative assessment research for primary and secondary education?
2. How does the integration of technology address existing challenges in the implementation of formative assessment practices in primary and secondary education?

Objectives

1. To identify and analyze the thematic clusters and key research patterns in formative assessment studies across primary and secondary education.
2. To evaluate how the integration of technology mitigates existing challenges in implementing formative assessment practices in primary and secondary education.

Significance of the Study

This study provides valuable insights into the evolving landscape of formative assessment research, highlighting its theoretical foundations, practical applications, and global dimensions. By identifying key themes, trends, and collaborations, it offers a comprehensive understanding of the field's current state and future directions. The findings are particularly relevant for policymakers, educators, and researchers seeking to enhance educational outcomes through innovative assessment practices.

Literature Review

The concept of formative assessment has evolved significantly over the past few decades. Initially, educational assessments focused on selection and reliability, but there has been a shift towards emphasizing validity and aligning assessment procedures with curriculum goals (Broadfoot, 2009). The "PISA shock" in Norway in 2001 led to major reforms in educational assessment, including the introduction of outcome-based curricula and national tests (Tveit, 2014). Similarly, Scotland's "Assessment is for Learning" program aimed to align research, policy, and practice in formative assessment (Hayward et al., 2004). Despite these efforts, the implementation of formative assessment remains inconsistent, with traditional summative assessments still prevalent (Dieste et al., 2023b; Dorn, 2010).

Formative assessment is grounded in various theoretical frameworks, including constructivist, sociocultural, and situated theories of learning (Allal, 2021). It is embedded within the broader context of pedagogy, instruction, and learning theories (Black & Wiliam, 2018b). Critics argue that formative assessment lacks a unified theoretical framework, suggesting that it should be viewed through the lens of learning theories rather than assessment theories (Moeed, 2015b). The integration of formative assessment with pedagogical practices is essential for its effective implementation (Black & Wiliam, 2018b).

Research on formative assessment employs diverse methodological approaches, including qualitative studies, systematic reviews, and mixed-methods research. Qualitative approaches often involve classroom observations, interviews, and thematic analysis to explore teachers' practices and perceptions (Low et al., 2018; Yang, 2023; Vattøy & Gamlem, 2024). Systematic reviews synthesize empirical studies to identify effective practices and gaps in the literature (Maier, 2014; Liang et al., 2022; See et al., 2022). Mixed-methods studies combine qualitative and quantitative data to provide a comprehensive understanding of formative assessment practices (Dieste et al., 2023b).

The integration of digital technologies in formative assessment has gained traction, offering new tools and methods for assessing student learning. Technologies such as Moodle, mobile devices, and web-based programs facilitate real-time feedback and interactive assessments (Maier, 2014; Mthethwa, 2018; Odom et al., 2008b). However, the effectiveness of these technologies varies, with some studies highlighting challenges in their implementation and the need for better alignment with pedagogical practices (See et al., 2022; Børte et al., 2023). Emerging technologies hold promise for enhancing formative assessment, but their impact on student learning requires further investigation (Irving, 2015).

Formative assessment practices vary globally, influenced by local educational policies, cultural contexts, and technological access. In Germany, there is reluctance to adopt digital formative assessments despite their potential benefits (Maier, 2014). In Brunei, teachers' awareness and use of formative assessment strategies differ significantly (Low et al., 2018). In Morocco, improving access to digital technologies is seen as a way to enhance formative assessment and reduce educational inequalities (Zaibout et al., 2024). These global perspectives highlight the diverse challenges and opportunities in implementing formative assessment across different contexts.

The implementation of formative assessment faces several challenges that hinder its effectiveness and widespread adoption. One significant issue is the lack of clear and consistent definitions of formative assessment, which creates confusion and complicates its application

in educational practices (Børte et al., 2023; Dunn & Mulvenon, 2009). Another challenge is inadequate teacher training, as many educators lack the necessary professional development and support to effectively integrate formative assessment into their teaching strategies (Volante & Beckett, 2011; Halim et al., 2024). Technological barriers also pose a critical challenge, with limited access to digital tools and a lack of alignment between technological solutions and pedagogical needs (Vattøy & Gamlem, 2024; Mthethwa, 2018). Furthermore, cultural and policy constraints, such as adherence to traditional assessment practices and the pressures of external accountability systems, further limit the adoption and implementation of formative assessment in schools (Dieste et al., 2023b; Dorn, 2010; Marinho & Fernandes, 2023). Addressing these challenges is essential to unlock the full potential of formative assessment and foster its integration into educational systems worldwide.

Research Gaps

Despite the growing body of research on formative assessment, significant gaps remain, particularly in understanding its application across diverse disciplines and cultural contexts. Existing studies often focus on specific domains like science education, leaving broader disciplinary scopes underexplored. Additionally, limited attention has been given to regional variations and the role of technology in addressing implementation challenges, such as teacher readiness, equity, and data privacy. This study aims to bridge these gaps by providing a comprehensive bibliometric analysis that highlights global patterns, emerging trends, and practical solutions for formative assessment in primary and secondary education.

METHOD

This study employs a bibliometric approach to analyze research patterns in formative assessment within primary and secondary education contexts. The data were retrieved from the Scopus database on 22nd December 2024 using the search query ("formative assessment") AND ("primary school" OR "elementary school" OR "secondary school" OR "middle school" OR "high school" OR "K-12 education") AND ("education" OR "teaching" OR "learning"), applied to the Article Title, Abstract, and Keywords fields. Initially, 798 documents were identified, which were filtered for relevance by selecting English-language documents specifically addressing formative assessment, resulting in 398 records.

The analysis was conducted using Biblioshiny, a web-based application for R programming, which provides advanced bibliometric tools for visualizing and analyzing data. Descriptive statistics were used to examine publication trends over time, key contributing journals, authors, and institutions, as well as geographical distributions. Co-occurrence analysis was applied to identify dominant and emerging research themes by mapping keyword relationships. Collaboration networks, including co-authorship and institutional affiliations, were analyzed to highlight influential contributors and partnerships. Citation analysis identified the most impactful documents, authors, and journals in the field. Furthermore, thematic evolution was explored through the development of thematic maps to assess changes in research focus over time.

The dataset underwent preprocessing to ensure consistency, including standardizing author names and affiliations, removing duplicates, and consolidating keyword variants. Ethical considerations were maintained by utilizing publicly available bibliometric data and ensuring proper citation of sources. This comprehensive methodology provides an in-depth understanding of research trends and significant contributions in formative assessment for primary and secondary education, offering insights into existing gaps and opportunities for future research.

The choice of Biblioshiny for R programming as the primary analytical tool was driven by its robust capabilities in generating interactive visualizations, thematic mapping, and detailed bibliometric metrics, offering a comprehensive framework for exploring research patterns. The sample size of 398 records was refined using clear inclusion/exclusion criteria,

such as limiting the dataset to English-language documents to ensure consistency in interpretation and analysis. However, the exclusion of non-English documents may introduce a linguistic bias, potentially underrepresenting research from non-English-speaking regions.

RESULTS AND DISCUSSION

Data Overview

Figure 1 provides an overview of the key bibliometric information related to research on formative assessment within primary and secondary education from 1997 to 2024. The analysis covers 398 documents sourced from 241 journals, books, and other outlets, reflecting a robust and diverse research base. The data indicates a significant annual growth rate of 14.74%, suggesting increasing scholarly interest in this field.

The average age of documents is 5.76 years, with each document receiving an average of 12.8 citations, emphasizing the relevance and impact of this body of work. Collectively, these documents reference 14,711 sources, demonstrating the extensive engagement with prior research.

In terms of document content, 873 Keywords Plus (ID) and 981 Author's Keywords (DE) illustrate the thematic richness and diversity of research topics. Authorship data reveals contributions from 1,024 authors, with 69 authors publishing single-authored works. There are 83 single-authored documents, while the average number of co-authors per document is 2.92, reflecting a strong collaborative trend. Notably, 12.06% of the works involve international co-authorship, indicating global collaboration in this area of study.

Document types are dominated by articles (274), followed by conference papers (93) and book chapters (26), with a few contributions in other formats such as letters (1), notes (1), and reviews (2). There is also one retracted document, highlighting the importance of maintaining academic integrity.

Figure 1. Bibliometric Overview of Research on Formative Assessment

Scientific Production and Citation Impact

Figure 2 presents a dual perspective on the evolution of scientific production and citation impact in the field of formative assessment research from 1997 to 2024. On the left, we find the "Annual Scientific Production," which highlights the number of published articles per year. The data reveal consistent growth over the years, with significant peaks in production during the last decade. Early research activity was minimal, starting with just one publication in 1997, and showing sporadic outputs through the early 2000s. A steady upward trajectory began in 2008, with notable acceleration from 2015 onward, reaching 41 articles in 2024, which underscores the growing interest and sustained effort in this research domain.

On the right, the "Average Citation Trends" depict the influence and impact of published articles, represented by the metrics MeanTCperArt (average citation per article) and MeanTCperYear (average citation per year). The highest MeanTCperArt values were recorded in earlier years, such as 2000 (40.00) and 2008 (60.75), driven by impactful studies during those periods. As the volume of publications increased in subsequent years, the MeanTCperArt showed a gradual decline, particularly in more recent years like 2022 (3.72) and 2024 (1.17), reflecting the expected lag in citation accumulation for newer works.

The MeanTCperYear metric provides additional insights into the annual citation influence of articles. Peaks were observed in 2008 (3.57) and 2012 (4.31), corresponding to years with highly influential publications. Over time, this measure stabilized, reflecting a broader distribution of influence across a growing body of work. Figure 2 provides a comprehensive view of the steady expansion in scientific production alongside evolving citation dynamics, illustrating the growing engagement with and diversification of research on formative assessment in primary and secondary education.

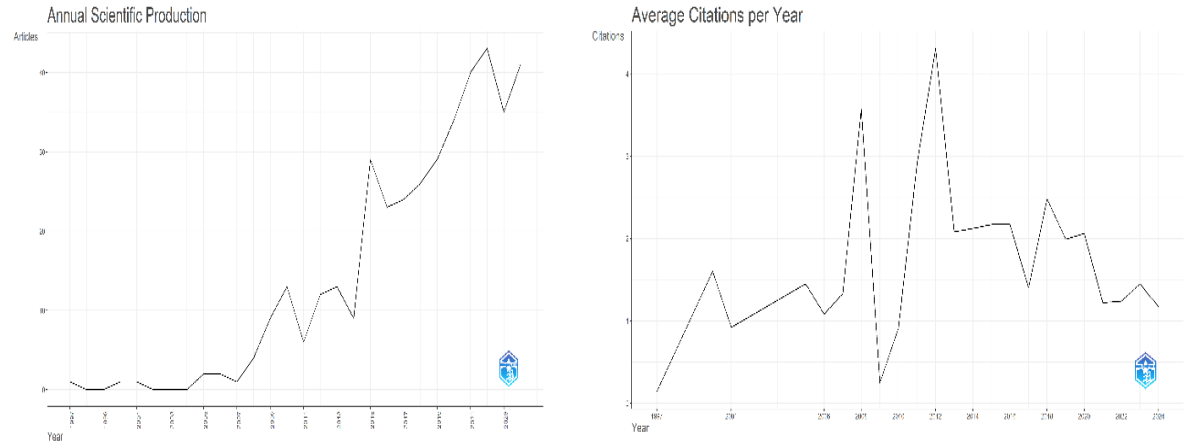

Figure 2. Annual Scientific Production and Citation Trends

Most Relevant Sources

Table 1 presents an analysis of the most relevant sources contributing to research on formative assessment and the most locally cited sources within the dataset. On the left, the "Most Relevant Sources" column highlights the publication venues with the highest number of articles in this field. Leading the list is the Journal of Physics: Conference Series, contributing 15 articles, followed by Assessment in Education: Principles, Policy and Practice with 8 articles and the International Journal of Science Education with 7 articles. Other prominent sources include proceedings and journals such as the ASEE Annual Conference and Exposition and Communications in Computer and Information Science, each contributing 6 articles, and the Curriculum Journal, also with 6 articles. This distribution illustrates the interdisciplinary nature of formative assessment research, spanning education-focused and technology-driven journals.

On the right, the "Most Local Cited Sources" column lists the sources with the highest local citations, indicating their influence within the dataset. The Journal of Research in Science Teaching leads with 493 total citations (TC) across 5 notable papers (NP), showcasing its significant impact. The Computers and Education journal follows, with 242 citations (TC) from 4 papers (NP). Similarly, Assessment in Education: Principles, Policy and Practice, a key source in formative assessment research, has garnered 144 citations (TC) with an h-index of 6. Other notable sources include the International Journal of Science Education and Educational Assessment, Evaluation and Accountability, highlighting their relevance in advancing discussions on formative assessment practices. Table 1 underscores the diversity of publication outlets and the critical sources shaping the discourse on formative assessment, reflecting a blend of theoretical, practical, and technological perspectives.

Table 1. Analysis of Most Relevant and Most Local Cited Sources

Most Relevant Sources		Most Local Cited Sources						
Sources	**Art**	**Source**	**h_index**	**g_index**	**m_index**	**TC**	**NP**	**PY_start**
Journal Of Physics: Conference Series	15	Assessment In Education: Principles, Policy And Practice	6	8	0,545	144	8	2014
Assessment In Education: Principles, Policy And Practice	8	International Journal Of Science Education	5	7	0,455	127	7	2014
International Journal Of Science Education	7	Computers And Education	4	4	0,267	242	4	2010
Asee Annual Conference And Exposition, Conference Proceedings	6	Curriculum Journal	4	6	0,143	90	6	1997
Communications In Computer And Information Science	6	Educational Assessment, Evaluation And Accountability	4	6	0,364	99	6	2014
Curriculum Journal	6	Interactive Learning Environments	4	5	0,5	99	5	2017
Educational Assessment, Evaluation And Accountability	6	International Journal Of Technology And Design Education	4	4	0,16	81	4	2000
Proceedings Of International Conference Of The Learning Sciences, Icls	6	Journal Of Research In Science Teaching	4	5	0,286	493	5	2011
Ceur Workshop Proceedings	5	Asia Pacific Journal Of Education	3	3	0,429	41	3	2018
Frontiers In Education	5	British Journal Of Educational Technology	3	3	0,3	51	3	2015

Most Relevant Affiliations and Countries

Table 2 provides insights into the most active affiliations and countries contributing to research on formative assessment. On the left, the "Most Relevant Affiliations" column highlights institutions with the highest number of contributions. Universitas Negeri Malang emerges as the leading institution, contributing 18 articles, reflecting its strong focus on formative assessment research. Hiroshima University and the University of Nigeria follow with 10 articles each, demonstrating their substantial engagement in this field. Other notable contributors include Dublin City University and Utrecht University, each with 8 articles, and the German Institute for International Educational Research, Open University of the Netherlands, and Umeå University, each contributing 7 articles. These affiliations reflect a diverse geographic representation, emphasizing the global interest in formative assessment practices.

On the right, the "Most Relevant Countries by Corresponding Authors" column identifies countries based on the number of articles authored. The USA leads with 54 articles, accounting for 13.6% of the total, showcasing its dominant role in advancing formative assessment research. The United Kingdom ranks second with 25 articles (6.3%), followed by China with 19 articles (4.8%). European countries, such as the Netherlands (16 articles, 4%) and Germany (13 articles, 3.3%), also feature prominently.

The table further provides collaboration metrics: Single Country Publications (SCP) and Multiple Country Publications (MCP). Notable trends include a high MCP percentage for

countries like China (36.8%) and Indonesia (38.5%), indicating significant international collaborations. Conversely, countries like Spain and Turkey display lower MCP percentages, suggesting a preference for domestic research networks. Table 2 highlights both institutional and geographic patterns of research activity, underscoring the global collaboration and diverse contributions shaping the field of formative assessment.

Table 2. Analysis of Most Relevant Affiliations and Countries by Corresponding Authors

Most Relevant Affiliations		**Most Relevant Countries by Corresponding Authors**					
Affiliation	**Doc.**	**Country**	**Doc.**	**Doc. %**	**SCP**	**MCP**	**MCP %**
Universitas Negeri Malang	18	USA	54	13,6	51	3	5,6
Hiroshima University	10	United Kingdom	25	6,3	22	3	12
University of Nigeria	10	China	19	4,8	12	7	36,8
Dublin City University	8	Netherlands	16	4	15	1	6,3
Utrecht University	8	Germany	13	3,3	11	2	15,4
German Institute for International Educational Research	7	Indonesia	13	3,3	8	5	38,5
Open University of The Netherlands	7	Australia	10	2,5	8	2	20
Umeå University	7	Norway	10	2,5	7	3	30
Batumi Shota Rustaveli State University	6	Spain	10	2,5	10	0	0
Beijing Normal University	6	Turkey	8	2	7	1	12,5

Country's Scientific Production

Table 3 presents an in-depth analysis of the scientific production and citation impact of countries, along with the contributions of the most relevant authors in formative assessment research. On the left, the "Country's Scientific Production" column highlights the frequency of articles published by various countries. The USA leads with a significant 307 articles, underscoring its dominant role in advancing research on formative assessment. Other notable contributors include the United Kingdom (70 articles), Germany (66 articles), and the Netherlands (59 articles). Asian countries such as China (54 articles) and Indonesia (52 articles) also feature prominently, showcasing their growing research output in this domain.

In the center, the "Most Cited Countries" column examines the citation impact of these nations. The USA again takes the lead with 1,376 citations, reflecting the high influence of its research, with an average of 25.5 citations per article. Interestingly, Norway records the highest average citations per article (32.7), followed closely by Thailand (42.7) and Hong Kong (31.5), despite their lower overall production. This indicates that while their output is smaller, their research carries substantial impact.

On the right, the "Most Relevant Authors" column identifies prolific researchers in the field. Furtak EM is the most active, contributing 11 articles, followed by Barana A and Marchisio M, each with 6 articles. Authors like Parno (5 articles) and Ali M (4 articles) also stand out. The diversity in author affiliations reflects the global nature of formative assessment research.

Key insights from Table 3 reveal the USA's dominance in both production and citations, affirming its leadership in formative assessment research. European nations like the UK, Germany, and the Netherlands also show significant contributions, supported by strong research networks. Meanwhile, countries like China and Indonesia are emerging as notable contributors, highlighting a growing focus in Asia. Prominent authors, such as Furtak EM and Barana A, play a pivotal role in advancing the field, with their works frequently cited, reflecting their influence. Overall, Table 3 underscores the global and collaborative nature of formative assessment research.

Table 3. Analysis of Country's Scientific Production, Most Cited Countries, and Most Relevant Authors

Country's scientific production		Most cited countries			Most Relavant Authors	
Country	**Freq**	**Country**	**TC**	**Average Citations**	**Authors**	**Articles**
USA	307	USA	1376	25,5	Furtak EM	11
UK	70	Norway	327	32,7	Barana A	6
Germany	66	UK	320	12,8	Marchisio M	6
Netherlands	59	China	293	15,4	Parno	5
China	54	Germany	262	20,2	Ali M	4
Indonesia	52	Spain	203	20,3	Fissore C	4
Italy	42	Netherlands	134	8,4	Arnold J	3
Spain	34	Thailand	128	42,7	Basu S	3
Norway	28	Hong Kong	126	31,5	Hertel S	3
Australia	27	Australia	103	10,3	Hondrich AL	3

Most Globally Cited Documents

Table 4 highlights the most globally cited documents in formative assessment research, showcasing their significant impact within the field. The paper by Coffey JE (2011) in the *Journal of Research in Science Teaching* leads with 213 total citations, averaging 15.21 citations per year and a normalized citation count of 5.24. Chu H-C (2013) in *Educational Technology and Society* follows closely with 199 citations, an annual average of 16.58, and the highest normalized citation score of 7.98, indicating exceptional influence.

Havnes A (2012) and Andrade HL (2008) contribute notably, with 178 and 170 citations, respectively, highlighting their foundational role in advancing the field. Other key contributions include works by Panadero E (2012) and Furtak EM, whose research appears twice (2012 and 2016), underscoring their consistent impact on formative assessment scholarship.

The table also emphasizes recent impactful works, such as Xiao Y (2019) with 85 citations and a normalized citation of 7.12, reflecting the growing recognition of newer studies. Overall, Table 4 identifies pivotal publications that have shaped the trajectory of formative assessment research globally.

Table 4. Most Globally Cited Documents

Most globally cited documents				
Paper	**DOI**	**TC**	**TC/ Year**	**Normalized TC**
COFFEY JE, 2011, J RES SCI TEACH	10.1002/tea.20440	213	15,21	5,24
CHU H-C, 2013, EDUCATIONAL TECHNOLOGY AND SOCIETY		199	16,58	7,98
HAVNES A, 2012, STUD EDUC EVAL	10.1016/j.stueduc.2012.04.001	178	13,69	3,18
ANDRADE HL, 2008, EDUC MEAS ISSUES PRACT	10.1111/j.1745-3992.2008.00118.x	170	10	2,8
PANADERO E, 2012, LEARN INDIVID DIFFER	10.1016/j.lindif.2012.04.007	163	12,54	2,91
FURTAK EM, 2012, J RES SCI TEACH	10.1002/tea.21054	135	10,38	2,41
TSAI F-H, 2015, COMPUT EDUC	10.1016/j.compedu.2014.10.013	104	10,4	4,79
GLOGGER I, 2012, J EDUC PSYCHOL	10.1037/a0026683	104	8	1,86
FURTAK EM, 2016, INSTR SCI	10.1007/s11251-016-9371-3	100	11,11	5,11
XIAO Y, 2019, SYSTEM	10.1016/j.system.2019.01.004	85	14,17	7,12

Co-occurrence Network

Figure 3 illustrates the co-occurrence network of terms associated with formative assessment research, revealing key clusters of interconnected concepts and their relative importance within the field. The network is structured into distinct clusters, each representing a thematic grouping, with nodes indicating terms and edges showing co-occurrence relationships. Key metrics such as betweenness centrality, closeness centrality, and PageRank are used to assess the significance of each node in the network.

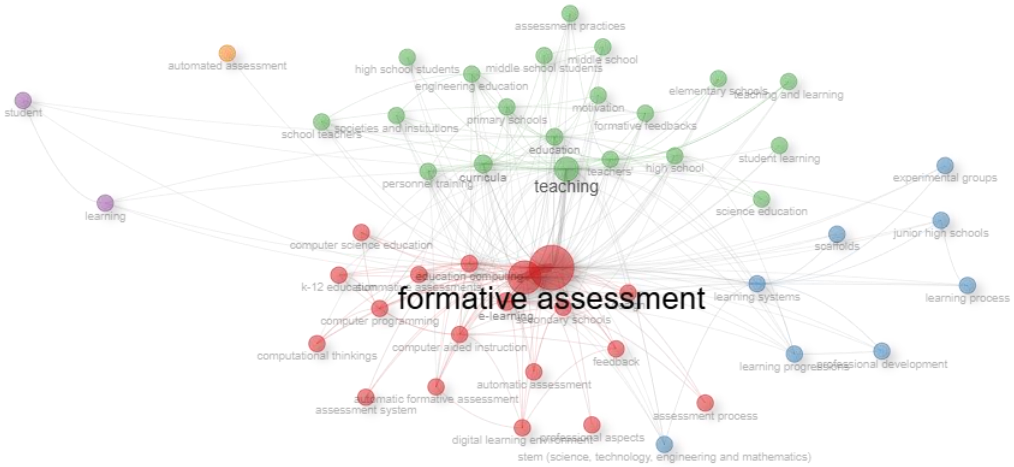

Figure 3. Co-occurrence Network

The dominant term in the network is "formative assessment," which serves as the central node in the first cluster. It holds the highest betweenness centrality (580.855), closeness centrality (0.02), and PageRank (0.176), signifying its crucial role in formative assessment research. Other significant terms within this cluster include "students" (betweenness: 261.161, closeness: 0.02, PageRank: 0.124) and "e-learning" (betweenness: 19.015, closeness: 0.014, PageRank: 0.047), highlighting the integration of formative assessment with digital tools and student engagement.

The second cluster revolves around learning systems and progressions. Key terms such as "learning systems" (betweenness: 5.438) and "learning progressions" (betweenness: 0.242) indicate the significance of structured frameworks in assessment practices. Additionally, the presence of STEM-related terms within this cluster underscores the application of formative assessment in science, technology, engineering, and mathematics education.

In the third cluster, the relationship between formative assessment and teaching practices is emphasized. Terms such as "teaching" (betweenness: 57.353, closeness: 0.015, PageRank: 0.075) and "curricula" (betweenness: 8.327) appear as prominent nodes. Other related terms like "education," "teachers," and "formative feedback" reflect the focus on instructional strategies and teacher training aimed at enhancing assessment practices.

The fourth cluster is characterized by terms related to student learning and motivation. Words such as "learning" (betweenness: 0.033) and "student" (betweenness: 0) highlight the emphasis on improving individual learning outcomes. This cluster underscores student-centered approaches in formative assessment, which play a critical role in shaping personalized educational experiences.

Lastly, the fifth cluster represents the integration of automated technologies into formative assessment. The key term "automated assessment" (betweenness: 0, closeness: 0.01, PageRank: 0.004) suggests an emerging focus on technological advancements in evaluation methods. This smaller yet significant cluster signals the growing reliance on automated tools to streamline assessment processes.

Implications

The co-occurrence network presented in Figure 3 provides a comprehensive overview of the thematic structure of formative assessment research. The dominance of "formative assessment" and its close association with "students," "teaching," and "learning systems" illustrates the centrality of student-centered and technology-integrated practices. Emerging areas such as STEM education and automated assessment highlight the evolving nature of the field. Figure 3 demonstrates the interconnectedness of diverse research themes and underscores the multidisciplinary nature of formative assessment studies.

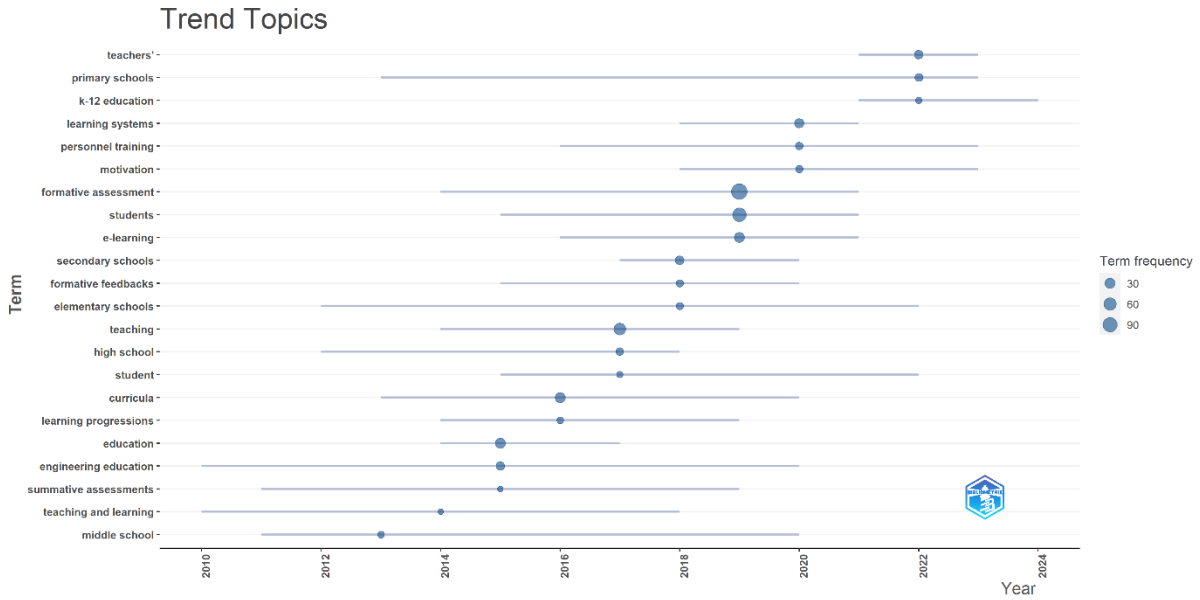

Figure 4. Trending Topics in Formative Assessment Research

Figure 4 highlights the trending topics in formative assessment research by analyzing their frequency of occurrence and temporal progression. The data reveal key terms and their respective patterns over time, represented by quartiles (Q1, Median, Q3) indicating the early, mid, and later points of research focus.

The term "formative assessment" dominates the field with the highest frequency (119 mentions), showing a steady rise in prominence, particularly from 2014 (Q1) through 2021 (Q3). Similarly, "students" (77 mentions) and "teaching" (50 mentions) have been consistent focal points, reflecting the emphasis on learner-centered approaches and instructional strategies. Terms like "e-learning" (29 mentions), "curricula" (28 mentions), and "education" (28 mentions) underscore the integration of technology and structured educational frameworks, with peaks observed around 2019-2021.

Emerging themes include "learning systems" (21 mentions), "motivation" (8 mentions), and "personnel training" (10 mentions), which gain relevance in recent years (2020-2023), reflecting the evolving focus on technology-driven tools, learner engagement, and professional development. Notably, "teachers'" (16 mentions), "k-12 education" (6 mentions), and "primary schools" (11 mentions) show heightened attention from 2021 onward, indicating a growing interest in practical applications of formative assessment across various educational levels.

Earlier trends are evident in topics like "middle school" and "high school," which gained initial attention between 2010 and 2013 but exhibit diminishing prominence post-2020. Similarly, "engineering education" (15 mentions) and "secondary schools" (16 mentions) show sustained interest over a broader timeline but align with the overarching focus on applying formative assessment across disciplines.

Overall, Figure 4 illustrates the dynamic and evolving nature of formative assessment research. The prevalence of core themes like "formative assessment," "teaching," and

"students," coupled with the emergence of new areas such as "e-learning" and "learning systems," reflects the field's adaptation to contemporary educational demands and technological advancements. The temporal trends emphasize the importance of both foundational and innovative topics in shaping the future of formative assessment practices.

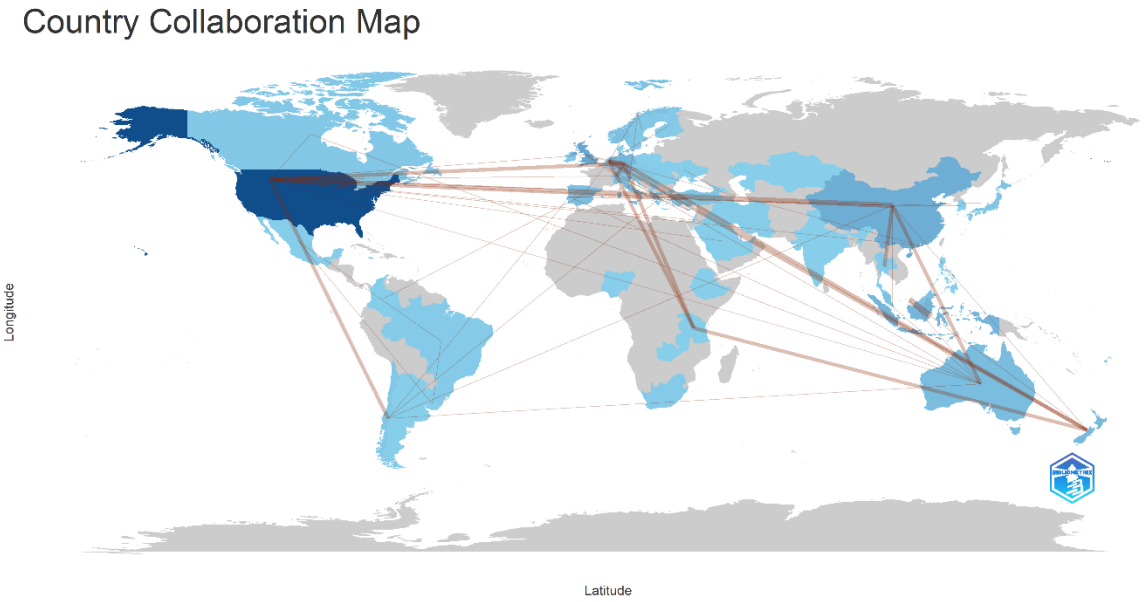

Figure 5. World Collaboration Map

Figure 5 illustrates the global research collaborations in formative assessment, highlighting the frequency and strength of partnerships between countries. The map reveals that the strongest collaboration occurs between Indonesia and Malaysia, with a frequency of 4, indicating a close regional research network in Southeast Asia. Other notable partnerships include the USA and China, with a frequency of 3, reflecting a significant academic exchange between two of the world's research powerhouses. Europe is also a major player, with Germany collaborating with the Netherlands, New Zealand, Switzerland, and Tanzania (each with a frequency of 2), showcasing its central role in both European and global research networks. Similarly, the Netherlands is involved in multiple collaborations with countries such as New Zealand, Tanzania, and Spain, further solidifying its importance in global research.

Cross-continental collaborations are also evident, with the USA maintaining strong ties with countries such as Chile, Germany, and the United Kingdom (each with a frequency of 2), as well as other nations like Australia, Canada, and Hong Kong (each with a frequency of 1). China, too, has a diverse network, collaborating with Australia, Thailand, Japan, and Korea. Emerging regional collaboration patterns are observed between countries like Italy and Slovenia, Georgia and Ukraine, and Spain and Colombia, highlighting a growing academic exchange in specific regions. Countries such as Norway, Sweden, Portugal, and Greece, while having fewer connections, still play an important role in global research.

In terms of regional focus, Southeast Asia is prominently featured with collaborations between Indonesia and Malaysia, and connections involving Australia with Malaysia, Singapore, and New Zealand. South America also sees notable partnerships, such as Brazil-Mexico and Mexico-Uruguay. The collaboration patterns in Figure 5 reflect the increasingly global nature of formative assessment research, with countries like the USA, Germany, China, and the Netherlands emerging as key hubs for academic exchange. The diverse and emerging links indicate the expanding scope of scholarly activities in this field, reinforcing the international and interdisciplinary nature of formative assessment research.

CONCLUSION

Formative assessment has emerged as a cornerstone of modern educational practices,

with its evolving research landscape reflecting significant advancements in pedagogy, technology, and global collaboration. The co-occurrence network analysis reveals that "formative assessment" remains the central theme, closely interconnected with terms such as "students," "teaching," and "e-learning." This interconnectedness underscores the field's emphasis on fostering student-centered learning and integrating digital tools to enhance educational outcomes.The trending topics analysis highlights the temporal evolution of formative assessment research, with a gradual shift from traditional pedagogical themes to technologically driven approaches. Terms like "e-learning," "learning systems," and "automated assessment" underscore the growing focus on personalized and adaptive learning environments, aligning with the global digital transformation in education. Additionally, the increasing prominence of STEM-related terms reflects the strategic integration of formative assessment into specialized fields of education, addressing contemporary learning challenges in science and technology.

The world collaboration map provides a comprehensive view of global academic partnerships, showcasing robust research networks between countries like the USA, Germany, and China. Regional collaborations in Southeast Asia, particularly between Indonesia and Malaysia, highlight localized efforts to address specific educational needs. These global and regional partnerships underscore the collaborative spirit of formative assessment research, facilitating the exchange of ideas and best practices across diverse cultural and academic contexts.

RECOMMENDATION

To enhance the practical applicability of formative assessment, governments and policymakers should prioritize investments in digital infrastructure to ensure equitable access to technology, particularly in under-resourced regions. Educators should be provided with targeted professional development programs to effectively integrate digital tools, such as AI and gamification, into formative practices. However, the ethical implications of these technologies must be carefully addressed, including concerns about data privacy, algorithmic fairness, and potential biases in AI-driven assessments. Establishing robust guidelines and transparent practices can mitigate these risks, ensuring that formative assessment technologies are both effective and equitable.

Formative assessment research is marked by its interdisciplinary integration, technological innovation, and global collaboration. These trends signify the field’s dynamic nature and its potential to drive transformative change in education. As the landscape continues to evolve, future research should focus on addressing emerging challenges, such as equitable access to digital tools and the ethical implications of automated assessment systems, ensuring that formative assessment remains an inclusive and impactful force in education worldwide.

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