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## A Bibliometric Review on Exploring Digital Literacy Assessment Dynamics in Education

**Abstract:** The increasing role of technology in education underscores the need for strong digital literacy skills among teachers. However, assessing these skills in pre-service teachers remains an under-researched area. This study employed a quantitative approach with the help of RStudio, analyzing 664 articles (2015-2024) to investigate trends and patterns in digital literacy assessment for teacher education. The analysis revealed a robust field with a 5.07% annual growth rate and strong author collaboration (only 58 single-authored works). Average citations per document (24.08) indicated impactful research, with China emerging as a leading contributor. Beyond mere skills testing, keyword analysis uncovered broader research themes like education, e-learning, and digital technologies. Network analyses further highlighted the interdisciplinary nature of the field. This study emphasizes the need for comprehensive assessment tools encompassing the multifaceted aspects of digital literacy to ensure teacher students' preparedness for the modern educational landscape.

**Keywords:** digital literacy, cognitive tests, teacher, students, education.

### Introduction

Digital literacy has emerged as a critical skill set for educators in today's technologically driven society (Sheriyev et al., 2016; Falloon, 2020, Ahmad, 2020; Sharma, Suri, Sijariya & Jindal, 2023). As classrooms increasingly integrate digital tools and resources, teachers are expected to possess related necessary competencies to effectively leverage these technologies for instructional purposes (Bowman, Vongkulluksn, Jiang & Xie, 2022). However, despite the growing recognition of the importance of digital literacy in teacher education, there remains a notable gap in the availability of robust assessment tools tailored to evaluate teacher students' digital instructional skills (Castellví, Díez-Bedmar & Santisteban, 2020).

**Digital Literacy Skills for Teacher Students.** Digital literacy encompasses a broad range of skills, including the ability to access, evaluate, and utilize digital information effectively and responsibly (Pangrazio, Godhe & Ledesma 2020; Reddy, Sharma & Chaudhary 2022; Rohde et al., 2023). In the context of teacher education, digital literacy extends beyond basic technical skills to encompass pedagogical knowledge and the ability to integrate technology into teaching practices, (Reddy, Sharma, Chaudhary, 2020). Researchers

emphasize the importance of preparing future educators to navigate digital environments, communicate digitally, and critically evaluate online resources (Morgan, Sibson, & Jackson, 2022). A teacher-student who masters digital literacy skills, especially instructional technologies, has already a strong aspect of career readiness. In the modern era, teachers are expected to leverage cutting-edge instructional technologies to enhance rich teaching-learning experiences (Alenezi, 2023; Pepkolaj and Dhimitri, 2023; Begimbetova, 2022).

**Assessing Digital Literacy Skills.** To assess digital literacy skills, one has to consider first the various aspects involved, especially other intricate competencies, (Sillat, Tammets & Laanpere, 2021). On this matter, Tomczyk (2020) also hinted that the context of assessing those skills is very crucial. According to those researchers, individuals, groups, and systemic levels of digital competence involvement should be considered (List, 2019). While recognizing the needs and urgency in assessing digital literacy competencies, Perdana et al. (2019) highlight the need for educational assessments to be tailored to the diverse needs and abilities of learners.

In the same perspective, the rapid evolution of digital technologies necessitates ongoing research into the level of digital literacy skills a modern teacher should have (Su, 2023). Older generation teachers might have been left behind and their learners maybe even better (Gómez-Trigueros, Ruiz-Bañuls & Ortega-Sánchez, 2019), but this does not mean that they should not try to have basics of digital literacy skills to render their lessons more appealing to students (Akayoglu, Satar, Dikilitas, Cirit & Korkmazgil, 2020; Begimbetova, Retnawati, Triyono, & Imangalieva, 2023). Digital literacy tests or other related assessment forms should be varied for teachers and students. But the field of developing accurate digital literacy skills tests for teachers, old generation or modern, students, or even library staff is an under-explored field, (Komlayut and Srivatanakul, 2017). The implementation of e-learning systems has been shown to significantly upgrade the quality of learning, as demonstrated by Kassymova et al. (2021) and Mutarah et al. (2024).

However, works related to students' digital literacy assessment started emerging. There is a new stream of integrating digital literacy into educational curricula, which is a very essential consideration to broaden students' horizons during this digital era (Gruszczynska, Merchant, & Pountney, 2013). For instance, Öncül (2021) suggested the development of context-specific batteries to assess first-year university students' digital literacy skills, which echoes (Martínez-Bravo, Sádaba Chalezquer, & Serrano-Puche, 2022) findings about the challenges of conceptualizing digital literacy and the need for multiple frameworks to situate digital competencies effectively. To measure digital literacy, a researcher is challenged to navigate diverse definitions, address context-specific needs, and ensure equitable access, which often requires multidisciplinary expertise.

Despite acknowledging the importance of digital literacy in teacher education, researchers find it challenging to assess pre-service teachers' or students' digital proficiency (Stockless, Villeneuve, Bisailon, Fournier & Venant, 2022). Unlike traditional subjects like reading and mathematics, digital literacy lacks a standardized curriculum (Pangrazio, Godhe & Ledesma, 2020; Rusydiyah, Purwati & Prabowo, 2020; Nikou & Aavakare, 2021). As a result, digital competencies cognitive tests might have kept varying significantly, if UNESCO had not established a digital literacy framework that most researchers adapt or modify according to their contexts (Khan, Sarwar, Chen, & Khan, 2022). In addition, digital literacy skills tests might cover a broader spectrum of skills, including technical proficiency, media literacy, online safety, and problem-solving, (Martínez-Bravo, Sádaba-Chalezquer & Serrano-Puche, 2022).

Conversely, determining the most relevant digital literacy skills to assess and developing valid and reliable measurement tools pose challenges. Existing measures often focus on basic computer skills or fail to capture the complex or multifaceted nature of digital literacy context amid the existing divide between those who access digital information easily from those who do not due to their economic background (Falloon, 2020; List, Brante & Klee, 2020). Since digital literacy has economic implications (Kass-Hanna, Lyons & Liu, 2022), standardized tests are hard to develop. Consequently, there is a need for the development of comprehensive assessment tests that can effectively assess the diverse dimensions or layers encompassed by digital literacy without loosening the contexts of those assessment tools.

On the cognitive aspect, the development of robust tests to assess digital literacy proficiency requires careful consideration of various factors, including test validity, reliability, and alignment with learning objectives. Researchers emphasize the importance of incorporating authentic tasks and real-world scenarios to assess digital skills in context (Pellegrino et al., 2001; Jonassen & Rohrer-Murphy, 1999). Additionally, cognitive tests should be designed to measure higher-order thinking skills, such as problem-solving, critical

thinking, and information literacy, which are essential components of digital literacy (Mishra & Koehler, 2006; Voogt et al., 2011).

**Digital Literacy Higher Order of Thinking Skills.** Developing Higher-Order Thinking (HOT) digital literacy skills tests aims to collect information about a test taker's ability to analyze, evaluate, and apply digital information effectively, (Utama & Nurkamto, 2020). Research suggests that integrating HOTS into assessment tasks can provide a more comprehensive understanding of students' digital literacy proficiency (Anderson & Krathwohl, 2001; Bloom, 1956). Furthermore, the development of cognitive tests should aim to foster the development of these critical thinking skills among teacher students, enhancing their capacity to engage with digital technologies in meaningful ways (Dede, 2007; Jonassen, 2000).

This bibliometric analysis article aims to analyze patterns and trends in the scientific literature related to pre-service teachers' or teacher students' digital literacy competencies testing.

**The research questions** guiding this research are:

- 1) How are digital literacy skills related to the publication and citation performances of researchers/authors, institutions/universities, countries, and journals?
- 2) How can digital literacy skills testing related scientific works be mapped spatially?

### Research Methods

This is a bibliometric analysis research that uses quantitative methods to report on the impact, distribution, and development metrics of studies related to measuring teachers-to-be digital literacy skills. The dataset used records from the Scopus database that were collected based on these search queries and filters:

TITLE-ABS-KEY (digital AND literacy AND skills AND cognitive AND tests AND for AND teacher AND students AND PUBYEAR > 2014 AND PUBYEAR < 2025 AND ( LIMIT-TO (SUBJAREA, "SOC") OR LIMIT-TO (SUBJAREA, "ARTS") OR LIMIT-TO (SUBJAREA, "MULT") ) AND (LIMIT-TO (EXACT KEYWORD, "Education") OR LIMIT-TO (EXACTKEYWORD, "Higher Education") OR LIMIT-TO (EXACTKEYWORD, "Online Learning") OR LIMIT-TO (EXACTKEYWORD, "Digital Literacy") OR LIMIT-TO (EXACTKEYWORD, "Educational Technology") OR LIMIT-TO (EXACT KEYWORD, "Digital Competence") OR LIMIT-TO (EXACTKEYWORD, "Digital Technologies") OR LIMIT-TO (EXACTKEYWORD, "Pre-service Teachers") OR LIMIT-TO (EXACTKEYWORD, "Digital Reading") OR LIMIT-TO (EXACTKEYWORD, "Digital Skills") OR LIMIT-TO (EXACTKEYWORD, "TPACK") OR LIMIT-TO (EXACTKEYWORD, "Distance Education") OR LIMIT-TO (EXACTKEYWORD, "Digital Devices")).

The number of records used is n=664 documents or articles in the English language. Two main types of analysis were carried out, namely the:

- publication and citation performances of researchers/authors, institutions/universities, countries, and journals;
- digital literacy skills testing related works spatial representation or mapping, especially the interaction between authors, concepts or keywords, and citations

### Research Results

In Figure 1 below, it can be seen that the dataset offers information on scholarly publications between 2015 and 2024. It comprises 664 articles, with an annual growth rate of 5.07%. The average article age is 3.29 and the citation average is 24.08 times per document.

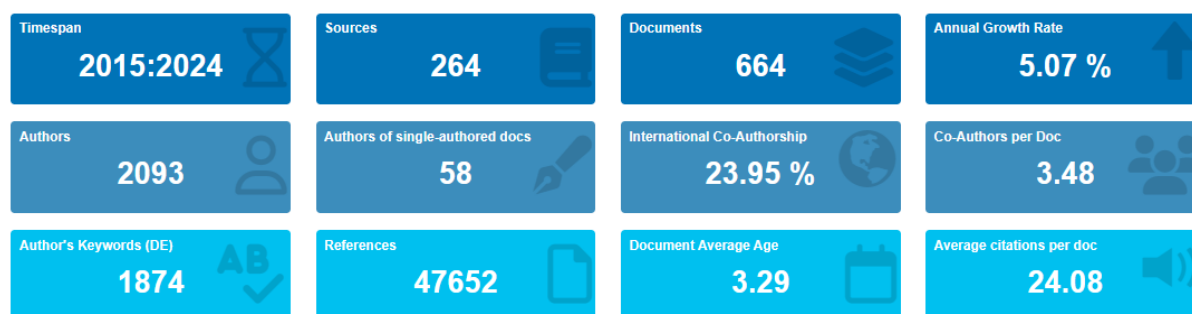


Figure 1. Main Information

The dataset also includes information on 47,652 references and 2093 authors. Interestingly, collaboration on research peaked at 23.95% and among the 664 documents, only 58 were single-authored.

As far as Figure 2 is concerned, it pictorially displays authors' production from 2015 to 2024. The most productive year, thus the peak interest in the digital literacy skills tests, was 2023 whereby 159 articles about digital literacy testing were produced; the least productive year about this research interest was registered in 2015 during which only 25 articles were produced.

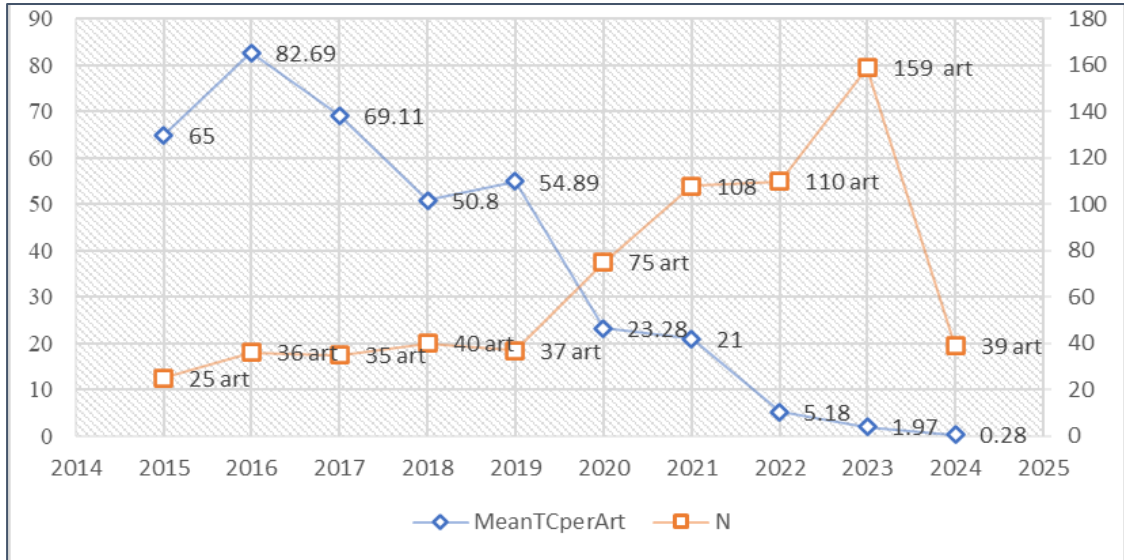


Figure 2. Article Production from 2015-2024

In terms of being cited, the highest total citation mean per article was in 2016, whereas for articles written outside the target timespan, this article had an average total mean citation per article of 82.69 and the sink citations sank flat to a total citation per article mean is 0.28 were previous works total. So, a peak shift in research focus was noticeable in 2023.

**Affiliation Overtime.** This section is about the publication output of various universities across different years. At the University of Tübingen, the peak years of interest in digital literacy measurement were 2023 and 2024 with 30 articles published by researchers based on that university each year. Similarly, a notable jump in publication output at the University of Granada became even between 2021 and 2024 where a consistent output of 17 articles was observed yearly. As far as the University of Granada is concerned, its staff published 17 per year between 2020 and 2024 while the University of California on its turn output 18 articles per year between 2022 and 2024. Equally, the publication output for the University of Sanford was 18 articles for years 2023 and 2024 while 17 were published in 2022. The last but not the least affiliation with a notable interest in the topic is the University of Taiwan. Its staff's interest in digital literacy skills testing picked up constantly from the year 2021 and stabilized up to 2024 and 16 articles were published annually.

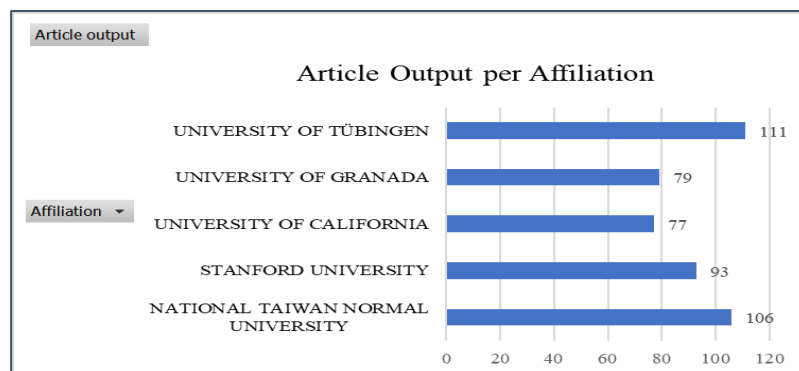
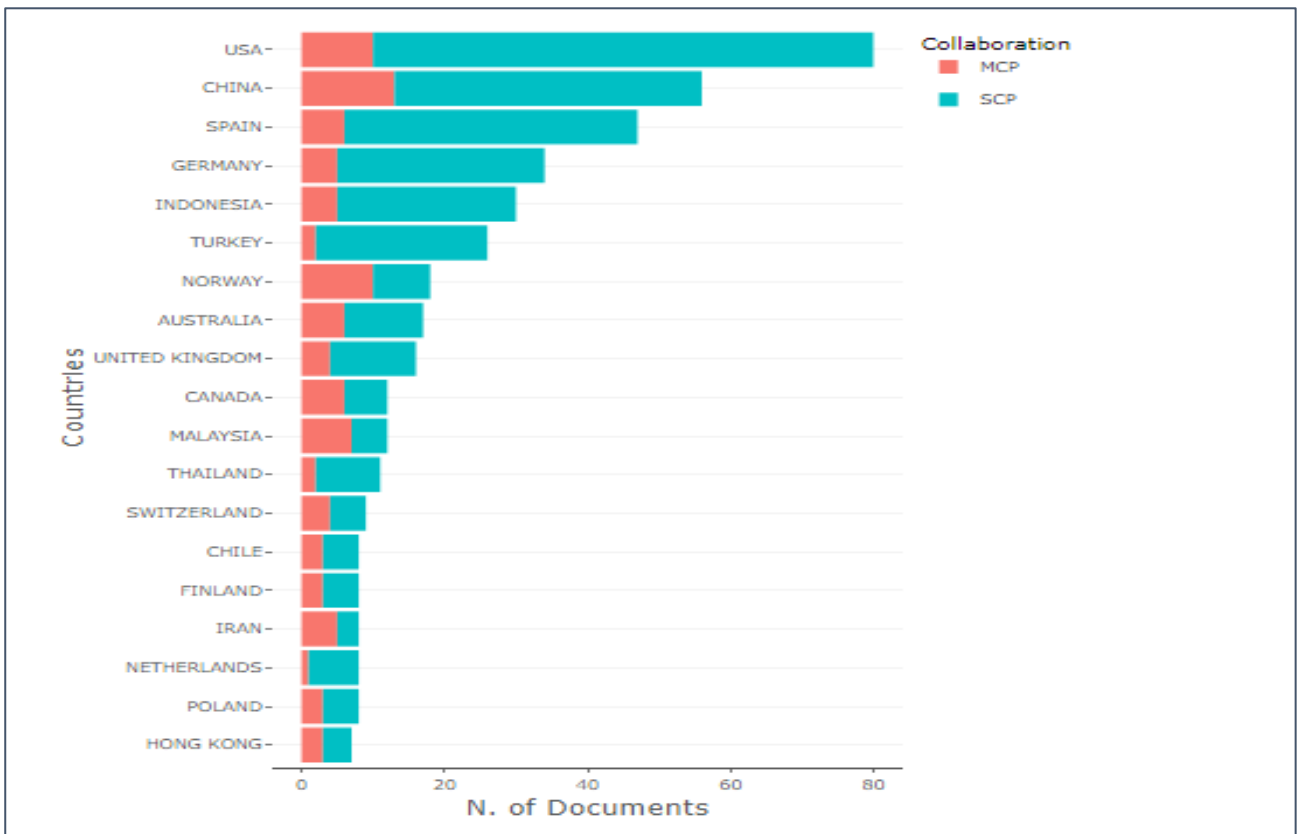


Figure 3. Article Publication Output

Based on the timespan 2015-2024, the affiliation with many publications about digital literacy skills assessment is the University of Tübingen with 111 articles published, followed by the University of Taiwan which outputs 106 articles. The University of Sanford staff published up to 93 articles on that matter, while the University of Granada and that of California researchers published 79 and 77 respectively.

**Corresponding Author’s Countries.** Figure 4 outlines the distribution of articles, Source Citation Potential (SCP), Multiple Citation Potential (MCP), Frequency (Freq), and MCP Ratio across different countries. For instance, the US ranks highest in terms of articles with 80, followed by China with 56 articles. However, when considering the SCP and MCP, which indicate the potential impact of publications, China exhibits a higher MCP ratio of 0.232 compared to the USA’s 0.125, implying that Chinese publications are more likely to receive multiple citations.



**Figure 4.** Corresponding Author's Countries

Norway, although having fewer articles, stands out with a remarkably high MCP ratio of 0.556, suggesting that its publications have a higher probability of being cited multiple times. So, that figure shows explicitly the digital literacy skills related to research productivity and citation impact of various countries, which transcends implicitly in a form of comparison and assessments of their scholarly contributions on a global scale on that research interest.

**Word Clouding.** Table 1 lists keywords related to the field of interest: digital literacy skills. But as it can be seen, although the filtering process ensured the inclusion of digital literacy testing or cognitive tests, Table 1 barely has any keywords related to testing, measuring or assessing digital literacy skills.

**Table 1:** Relevant Digital Literacy Skills Keywords

Keyword	Frequency
computer aided instruction	30
education computing	26
educational technology	24

digital devices	21
academic performance	19
digital technologies	17
information literacy	14
online learning	14
human computer interaction	13
Internet	13
digital literacies	12
digital skills	12



Figure 5. Word Cloud

What is more, it does not mention teacher students or pre-service teachers, however, the word cloud has bold education, student, learning, teaching, and then e-learning. This means that digital literacy skills cognitive tests, especially for students in teacher education programs have not held researchers' attention.

The keywords bolded in the word cloud also indicate that they are the ones trending. Although the interest is about digital literacy skills tests or measurement, is a field of the broader term “education”, and “teaching”, which are “human” unique activities where “male” or “female” “students” learn in person or through “e-learning”, in the latter scenario “educational technologies” through computer-assisted.

With that said, other possible interpretations, especially those that are theoretically-based can be made. Indeed, connections can be established between "digital literacies" and "students": after all, the subjects whose digital literacy skills are tested are those students. In the same view, "e-learning" or 'online learning both serve an “education” agenda.

**Clustering by Coupling.** For the data collected, the coupling map determined the existence of 8 groups, but 4 are worth commenting:

- 1) The one with the second highest frequency (52), first centrality and impact respectively of 0.40 and 3.17 is the *students - conf 25.5% education - conf 13% digital literacies - conf 75%* coupling. Its centrality or most important keyword (75%) is "digital literacies".
- 2) The coupling *\_education - conf 7.4% computer science - conf 25% digital environment - conf 33.3%* hosts the second most weighing keyword "digital environment" (33%.3), and 2nd highest impact 2.56.
- 3) This is another coupling built-in *education - conf 25.9% e-learning - conf 28.9% self-efficacy - conf 66.7%*\_its most weighing keyword or centrality is "self-efficacy". What is special about this grouping is its highest frequency in the dataset (62); this implies that e-learning requires self-efficacy or how the two serve educational purposes a balance between the two is kept intact; its impact is 1.74.
- 4) *\_Students - conf 17.6% e-learning - conf 21.1% education - conf 13%*\_ with impact of 1.71 and anchored in the “e-learning” centrality or weighing keyword, this coupling shows how e-learning plays a non-neglectful role: it is one of the means through which students can access education and learn. Figure 9 illustrates how the 4 groups close the perpendicular line:

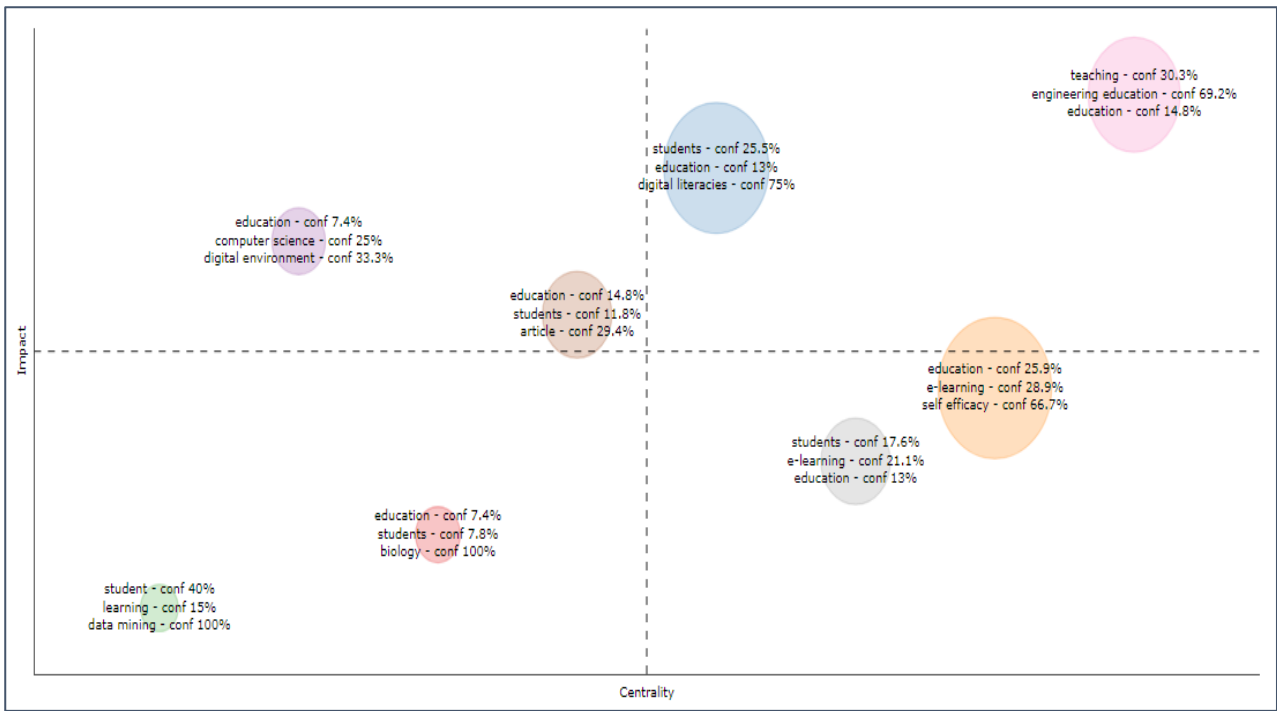


Figure 6: Clustering by Coupling

These findings demonstrate the diverse dynamics at play within educational contexts, emphasizing the significance of digital literacy, digital environments, self-efficacy, and e-learning in modern educational practices.

**Co-occurrence Network.** Figure 7 provided data outlines various educational themes, categorized into clusters based on their relevance. Cluster 1 primarily encompasses topics related to technology and instructional methods, such as "e-learning," "engineering education," and "digital literacies." Cluster 2 focuses on broader educational concepts like "education," "students," and "teaching," indicating a holistic approach to pedagogy. In contrast, Cluster 3 delves into more specific areas such as "learning," "human behaviour," and "academic performance," suggesting a deeper exploration of psychology and human development within education.

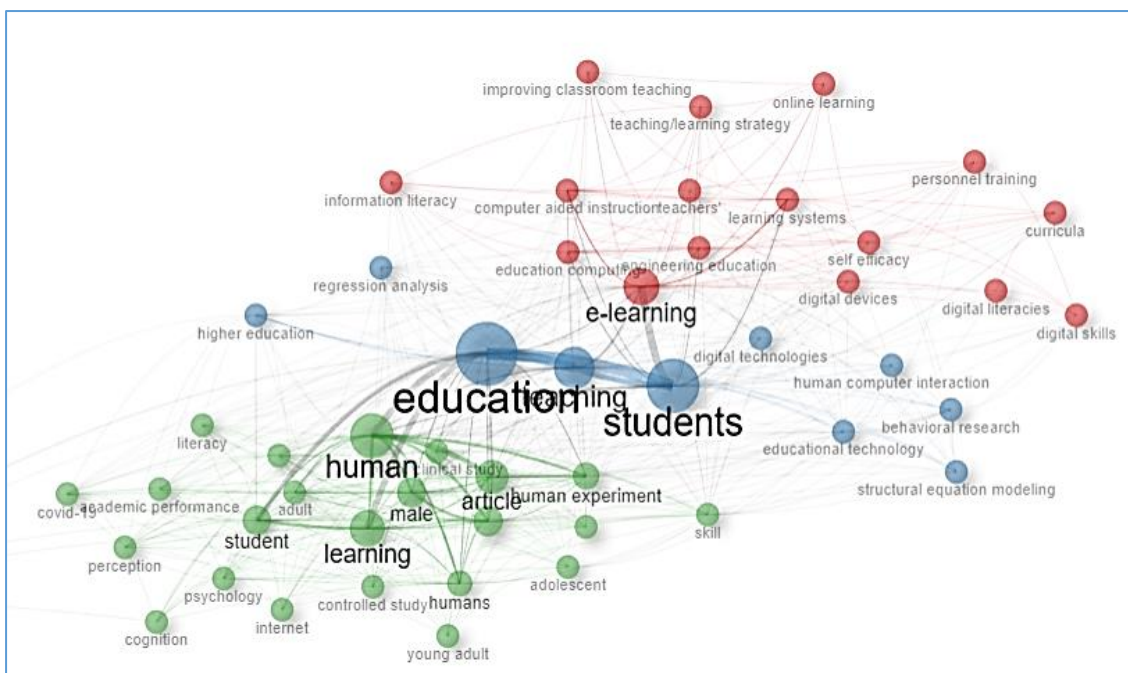


Figure 7. Co-occurrence Network

Each cluster offers insights into different facets of the educational landscape, ranging from technological advancements to human-centric approaches, providing a comprehensive view of the diverse dimensions within the field of education.

**Thematic map.** Figure 8 presents a comprehensive analysis of educational themes based on occurrence frequencies and centrality measures. Noteworthy occurrences include "education" with 167 instances, "students" with 137, and "teaching" with 94, indicating their prevalence in scholarly discourse. Centrality metrics such as betweenness centrality, closeness centrality, and PageRank centrality provide insights into the prominence of these topics within the educational domain.

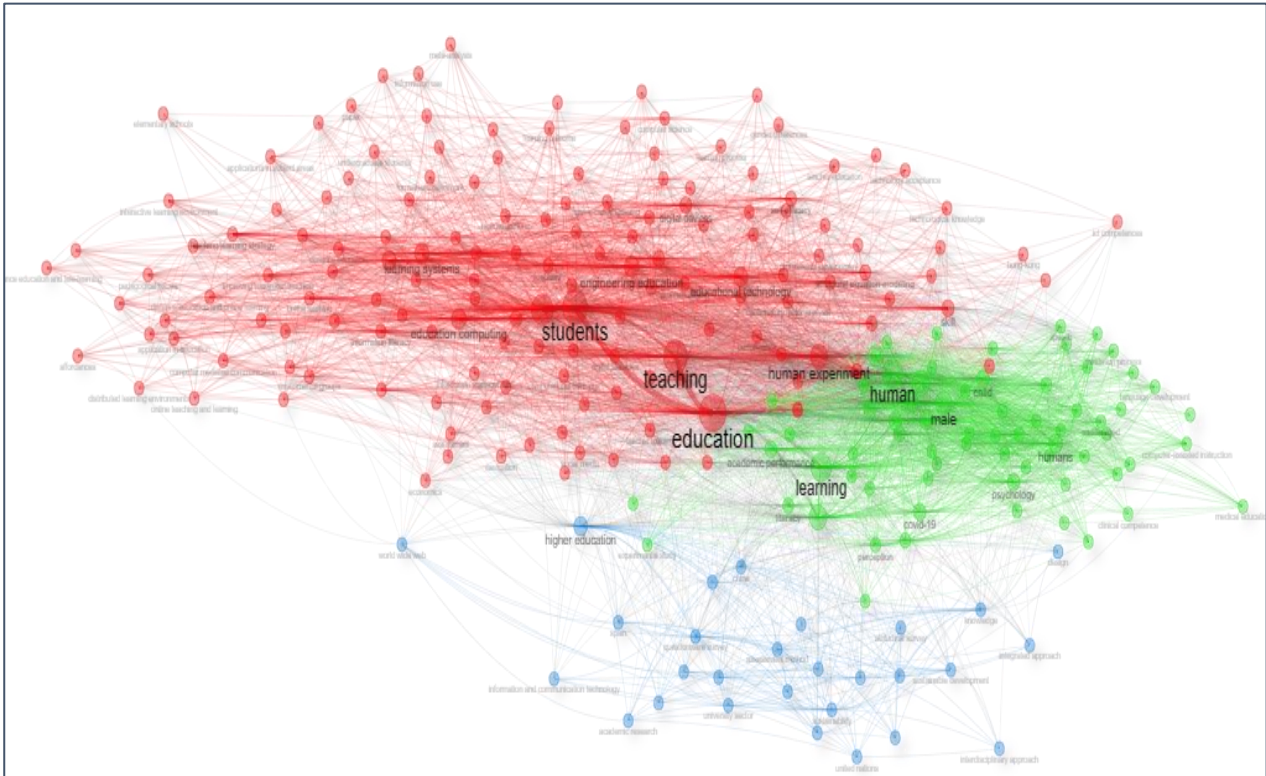


Figure 8. Thematic map

For instance, "education" exhibits high centrality measures across all metrics, with betweenness centrality at 203.53, closeness centrality at 0.0020, and PageRank centrality at 0.0491. This suggests that "education" plays a crucial role as a central theme in educational research, being frequently referenced and interconnected with other topics.

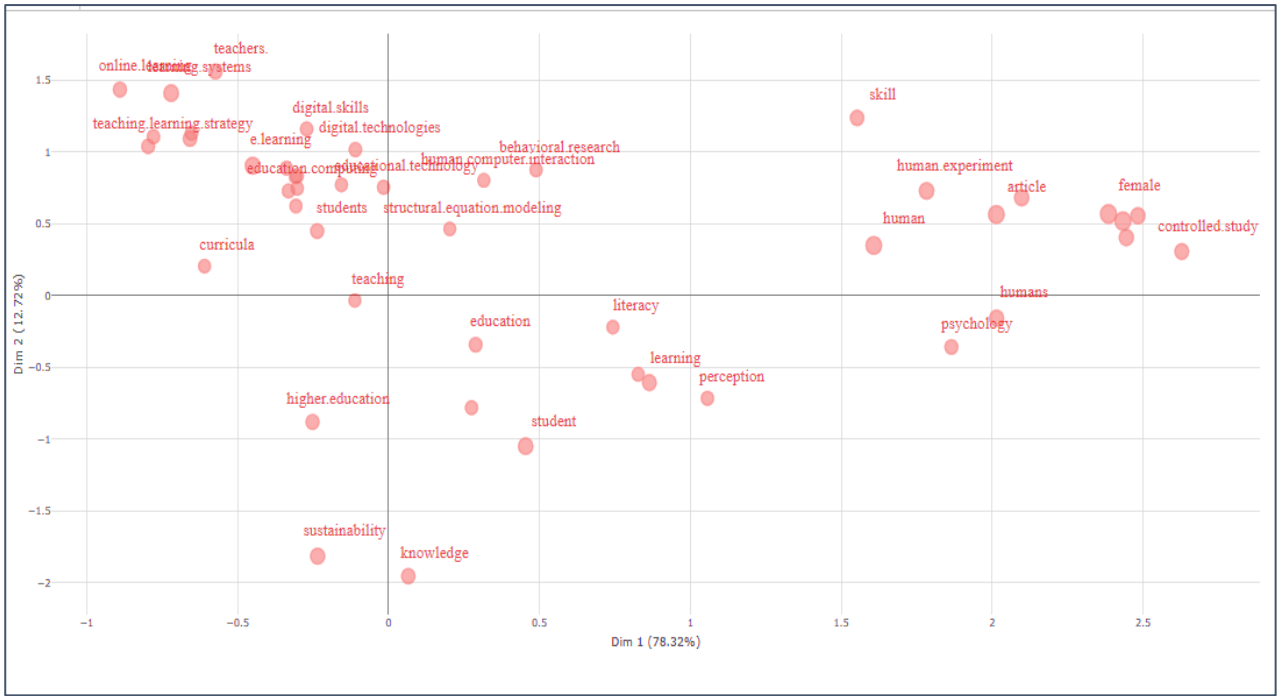
**Factorial Analysis.** In this factorial analysis of documents within the realm of education and related fields, a multidimensional perspective reveals significant insights. Each document's position on two extracted dimensions, termed dim1 and dim2, underscores its unique contribution to the overall analysis. For instance, Sung et al. (2016) exhibited a moderate influence on dim2 with a score of 0.09 but had a lesser impact on dim1 with a score of -0.22. Conversely, Abbas et al. (2019) demonstrated a stronger influence on dim1 (0.09) but a contrasting impact on dim2 (-0.53).

These dimensions not only facilitate the clustering of documents but also gauge their relative importance within the factorial space. Such analyses provide a structured approach to understanding complex datasets, offering researchers valuable insights into underlying patterns and relationships.

**Co-citation Network.** The exported data contains information about nodes (likely representing authors or publications) along with their cluster assignments and network metrics such as Betweenness, Closeness, and PageRank. These metrics provide insights into the importance and centrality of each node within its respective cluster.

**Node and Cluster Assignment:** Each node is labeled with its name or identifier and assigned to one of the clusters (1, 2, 3, 4, or -1 and -2, possibly representing outliers or separate groups).



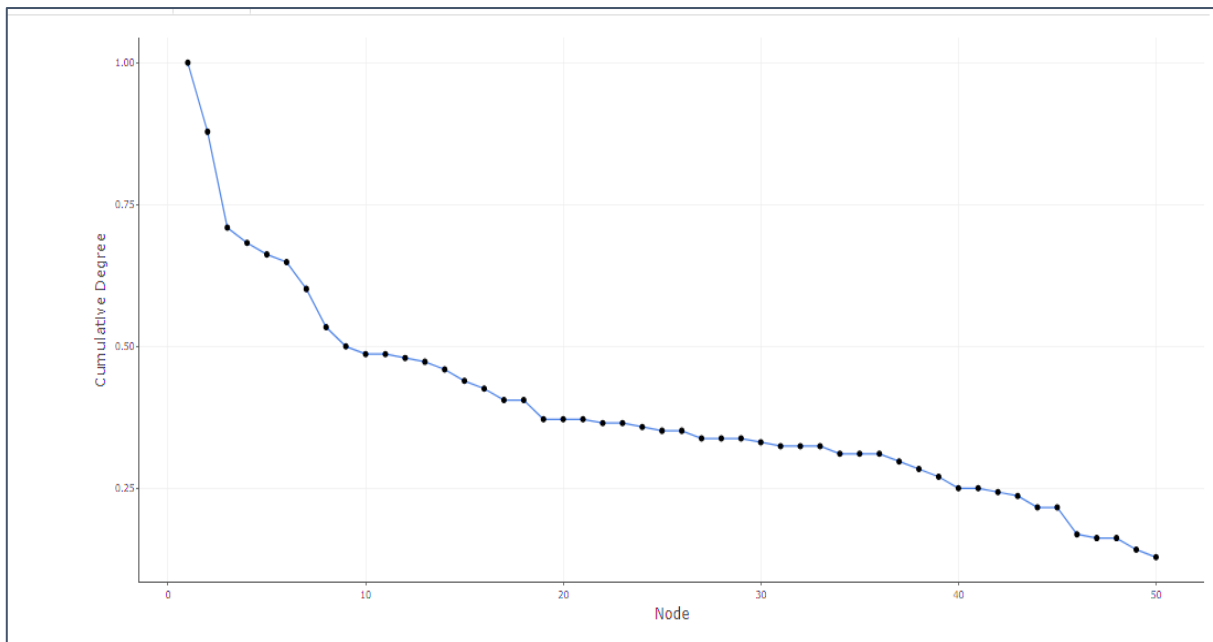


**Figure 9.** Factorial analysis

**Betweenness Centrality:** This metric measures the extent to which a node lies on the shortest paths between other nodes in the network. Nodes with high betweenness centrality, such as "bandura a. 1997" in Cluster 3 with a value of 446.16, act as crucial connectors within the network.

**Closeness Centrality:** Closeness centrality quantifies how close a node is to all other nodes in the network. Nodes with high closeness centrality, like "Scherer r. -1" in Cluster 4 with a value of 0.00775, can efficiently interact with other nodes in their cluster.

**PageRank:** This algorithm assigns a numerical weight to each node in the network based on the number and quality of incoming links. Nodes with high PageRank scores, such as "Scherer r. -2" in Cluster 4 with a value of 0.04591, are considered influential within their cluster.



**Figure 10.** Co-citation Network

By examining these metrics across clusters, we can identify key nodes and understand their roles within their respective research domains. Additionally, outliers or nodes in clusters -1 and -2 might represent distinct topics or outliers within the dataset, warranting further investigation.

### **Research Discussion**

This study delved into the world of research on assessing digital literacy skills in future teachers. The researchers, like detectives following a trail of clues, used a technique called bibliometrics to analyze a mountain of academic articles. Their investigation was driven by two burning questions:

**The Power of Digital Literacy.** Does having strong digital literacy skills affect how well a researcher's work gets published and recognized by others? The analysis revealed a surge in studies on testing these skills, highlighting a growing concern for ensuring future teachers are digitally fluent. The research community also displayed a strong spirit of collaboration, unsurprising given the multifaceted nature of digital literacy assessment in teacher education. Interestingly, a trend emerged: some countries and universities published more on the topic, while others garnered more citations for their work. This finding emphasizes the importance of both the quantity and quality of research – not just how much is published, but also how influential it is. Citation metrics act as a window into the impact of research, allowing us to see how much other researchers are using and building upon someone's work. In essence, this paints a vivid picture of a dynamic and collaborative research landscape, where valuable contributions flow from a diverse range of researchers, institutions, and nations across the globe.

**Mapping the Landscape.** The researchers took their analysis a step further by asking: Can we map where research on digital literacy skills testing is geographically concentrated? Here, they employed special mapping techniques to visualize the geographical spread and collaborative networks within the research community. This approach illuminated areas with high research activity and collaboration hotspots, revealing which institutions were working together the most. However, the benefits extended beyond simply identifying global trends and prolific institutions. The mapping also unearthed budding collaborative networks, fostering interdisciplinary connections that are crucial for advancing knowledge in this domain. It even pinpointed "research deserts," areas with limited scholarly activity. This knowledge is vital because it allows for targeted interventions and collaborative efforts to bridge these knowledge gaps and encourage wider research participation.

By incorporating spatial mapping techniques, the researchers gained a richer understanding of the global research landscape. Visualizing the geographical distribution of research activity provided valuable insights into trends, collaborative networks, and emerging research clusters. This knowledge empowers researchers to navigate the complex terrain of digital literacy assessment research with greater clarity and purpose.

### **Conclusion**

In conclusion, this study serves as a beacon, illuminating the path toward a deeper understanding of how we evaluate digital literacy skills in aspiring educators. The findings depict a landscape brimming with burgeoning interest and collaborative spirit, where researchers, institutions, and nations are joining forces to unravel the intricacies of digital literacy assessment in teacher education. As the academic discourse on this topic continues to evolve, spatial mapping emerges as a powerful tool, not just for visualization, but also for fostering interdisciplinary collaborations that transcend geographical boundaries. This approach empowers researchers to identify research priorities, collaborative opportunities, and emerging trends, equipping them to navigate the complexities of digital literacy assessment research with renewed focus and direction. Ultimately, this study not only enhances our understanding of digital literacy assessment, but also lays a strong foundation for future explorations in this vital area of educational research, with the potential to inform policy, practice, and teaching methods for teacher education on a global scale.

**CRedit author statement:** **G.A. Begimbetova:** Conceptualization, Methodology, Software, Validation, Writing draft preparation. **H. Retnawati:** Supervision, Data curation. **O. Ndayizeye:** Visualization, Investigation. **N. Flindt:** Reviewing. **G.K. Kassymova:** Editing.

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