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Self-Efficacy in Elementary School Digital Competence: A Bibliometric Analysis of 21st Century Learning Research

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Abstract

This study aims to analyze bibliometric mapping of research on self-efficacy and digital competence in Scopus-indexed journals published between 2015 and 2025. The dataset was retrieved from the Scopus database in March 2025 using the query "keywords" with a filter for elementary school, covering a time span of 2015–2025. After screening, a total of 127 documents were included. Bibliometric data were processed using Microsoft Excel and VOS Viewer version 1.6.20 with parameters set at a minimum of five keyword occurrences and full counting method. The annual distribution of publications shows an increasing trend in recent years, reflecting growing academic attention to the topic. Analysis by country indicates that Spain and Germany are the most productive contributors, with active collaboration networks identified at regional and institutional levels. Co-authorship analysis confirms the presence of collaborative research, though large-scale international collaboration remains limited. Document type analysis shows that most outputs are journal articles, followed by conference papers. Keyword co-occurrence mapping highlights "self-efficacy," "human," and "digital competence" as the most frequently used terms. Less explored but emerging themes include "digital technology," "human experimental," and "questionnaire," suggesting potential research gaps. Overall, the findings indicate that while research on self-efficacy in students' digital competence is expanding, opportunities remain for broader international collaboration and exploration of underrepresented themes in 21st century educational practices.

Keywords: Self-efficacy; Students Digital Competence; 21st Century Education; Elementary School; Bibliometric Analysis

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INTRODUCTION

Massive technological transformation has a significant impact on the dynamic process of various aspects of life, one of which is the concept of education. The fluctuating conditions of technological development gave birth to an innovative education system known as 21st century education (Serdyukov, 2017). In this educational concept, the implementation of education really needs to be supported by digital skills as an important skill base, especially in the implementation of education at the primary school level. The digital transformation that occurs provides ample space and opportunities for students to obtain varied information and learning experiences (Bygstad et al., 2022). This is certainly a result of the ease with which students can access technology. So, this makes students able to explore more diverse learning approaches. However, despite the impact of technological developments that

provide greater ease of access to learning, students still need self-assurance in their capacity to use technology efficiently (Timotheou et al., 2023). This ability is called self-efficacy. Self-efficacy is seen as students' self-belief in their abilities. This concept of self-efficacy plays a vital part in establishing the degree to which students are able to use technology and develop their digital skills (Ulfert & Schmidt, 2022). In simple terms, this self-efficacy skill is a reference that encourages student involvement and success in using technology in the educational process. Through efficacy skills, it can provide a reference for students in maximizing their ability to integrate technology to achieve the success of their educational process effectively.

Although self-efficacy has demonstrated a significant influence in various technology-based educational contexts, little research has focused on how self-efficacy and digital competency are related in elementary school students (Dahri et al., 2023). Most of the existing research focuses on students at higher levels of education, or examines educational technology more generally. This creates a knowledge gap on how self-efficacy contributes to the development of digital competencies in primary school students. Most existing research also tends to be limited to qualitative approaches or case studies with relatively small samples (Mannila et al., 2018). Therefore, it is crucial to carry out a more thorough and methodical examination of existing research trends and patterns to understand the relationship link digital competency and self-efficacy primary school students. A bibliometric approach allows researchers to explore a wider range of literature, identify emerging themes, and reveal gaps that need to be further explored.

Referring to the above statement, it can be understood that self-efficacy and digital competence are important elements in the realization of the student education system in 21st century learning, especially in elementary schools. This is proven consistent with the study's findings that was carried out by Katz & Stupel (2016) who found that self-efficacy skills can improve the mathematics learning process of students in elementary schools. Correspondingly, Han (2021) found that students' self-efficacy skills were able to increase learning motivation in students in elementary school. Likewise with Opperman et al (2021) obtained findings that self-efficacy can increase students' interest in learning mathematics in elementary school. This explanation shows that self-efficacy skills perform a crucial part in improving student learning in primary schools. A review of the relevant research shows that self-efficacy skills provide an impetus for improving various educational contexts in primary schools, not least in the implications of 21st century education today. Thus, this shows that self-efficacy skills and technological transformation in today's education, especially related to the digital competence of students in elementary schools, have a relevant correlation. Therefore, self-efficacy's significance in digital competency of students in elementary schools in 21st century education makes understanding the advancement of this field's research very much needed. One of them is through bibliometric mapping analysis to find out the development of studies pertaining to the topic of self-efficacy the implications of students' digital competence in 21st.

A review of previous research also shows that there have been many studies related to this bibliometric analysis, including studies carried on by Valencia et al (2016) which analyzes bibliometric mapping of self-efficacy in online education. The research Riyanto et al (2025) related to bibliometric analysis of online learning. There is also research Wang et al (2024) related to self-efficacy in student learning

participation by examining bibliometric analysis. In addition, there are also studies using bibliometric analysis related to students' digital competencies, namely research Ma & Ismail (2025) which describes bibliometric mapping of digital competencies in general in educational practice. Research by Marin et al (2020) related to digital competencies in general at school. There is also studies carried out by Blat et al (2022) which explains the bibliometric mapping analysis related to measuring digital competency capabilities in the education implementation process.

Referring to the explanation above, it shows that there are many bibliometric analysis mapping studies related to self-efficacy and digital competence. However, there is no bibliometric analysis research that maps the relevance of the two variables together. Therefore, this study focuses on mapping bibliometric analysis of research data related to self-efficacy in students' digital competence in 21st century learning in the period 2015-2025. this study contributes to filling the knowledge gap regarding the relationship between self-efficacy and digital competence at the primary school level, where the foundations of 21st century digital literacy are established. The urgency of this research is closely tied to the need for comprehensive literature that informs how digital skills and self-efficacy can be fostered from the earliest stages of formal education, thereby strengthening the preparation of students for future learning challenges. Specifically, this study aims to answer the following research questions:

RQ 1: What is the distribution of publication based on year of publication?
RQ 2: What is the distribution of publications based on geographical area?
RQ 3: What is the distribution of publications based on type of document?
RQ 4: What is the co-authorship status?
RQ 5: What are the research focuses based on keywords used in the publications?
RQ 6: What are the trending topics based on keywords used in the publications

METHOD

Bibliometric Design and Data Source

This study employed a bibliometric analysis design to construct a scientific map of research on self-efficacy and students' digital competence in 21st century education. The concept of the science map itself is understood as a spatial depiction of various disciplines and authorship relationships represented concretely through publication data (Kaban, 2023). The Scopus database was selected as the data source due to its wide coverage of peer-reviewed publications, broad accessibility, and integration with DOI metadata that ensures the validity of analyzed documents (Baas et al., 2020). The search was conducted in 23 March 2025 using the advanced KEY field with the query string: "self-efficacy" AND ("students' digital competence" OR "21st century education" OR "digital learning"). Filters applied included the subject area of elementary school, English-language documents, and the document types of journal articles and conference papers, within the publication year range of 2015–2025. This search initially retrieved 211 records.

Document Retrieval and Study Selection

The sample in this study consisted of 211 documents retrieved through a systematic search conducted on 23 March 2025 using an advanced KEY field query "self-efficacy" AND "students' digital competence" OR "21st century education" OR

"digital learning". These records represent scholarly works published between 2015 and 2025, filtered specifically for the elementary school context, English-language publications, and limited to journal articles and conference papers. The selection process followed a multi-stage screening procedure to ensure the relevance and quality of the included studies. First, all 211 records were screened based on titles and abstracts to determine their alignment with the focus on self-efficacy, digital competence, and digital learning in elementary education. Studies that clearly addressed theoretical, empirical, or applied aspects of these variables were retained. Second, full-text screening was conducted to confirm methodological quality, conceptual relevance, and the presence of measurable indicators related to student self-efficacy and digital competence. Duplicate records, inaccessible full texts, and papers lacking empirical data were excluded. The final selection ensured that the sample represented diverse geographical contexts, methodological designs, and educational settings within the scope of elementary-level digital learning. By applying structured inclusion and exclusion criteria, the resulting dataset provided a comprehensive foundation for analyzing trends, gaps, and patterns in the literature concerning self-efficacy and digital competence among elementary school students in the era of 21st-century digital education.

Inclusion, Exclusion, and PRISMA-Based Screening Procedure

Inclusion criteria required documents to be Scopus-indexed, written in English, peer-reviewed, and directly related to self-efficacy and digital competence in educational contexts. Exclusion criteria included non-English publications, non-academic outputs such as editorials and book chapters, and studies outside the thematic scope. The screening process followed the PRISMA 2020 protocol. First, 31 duplicate records were removed, leaving 180 unique entries. Second, 28 documents were excluded at the title and abstract stage due to irrelevance. Third, 25 papers were excluded after full-text eligibility checks. As a result, a final dataset of 127 documents was included for bibliometric analysis.

Bibliometric Mapping and Network Analysis Procedures

The metadata were exported from Scopus in CSV format and cleaned using Microsoft Excel. Data cleaning involved removing duplicates, standardizing author names and affiliations, and checking DOI consistency. Descriptive analysis of publication trends by year, geographic region, and document type was performed in Excel. Network-based analyses were conducted with VOS viewer version 1.6.20. The parameters applied included full counting; for co-authorship, a minimum of two documents per author; for keyword co-occurrence, a minimum of five occurrences; and for citation analysis, a threshold of 10 citations. Visualization settings were clustering resolution = 1.00, minimum cluster size = 5, attraction = 2, and repulsion = –1.

All steps, from query formulation, database filters, inclusion and exclusion procedures, to software parameters, are documented to ensure reproducibility. Researchers using the same query in Scopus (as of March 2025) and identical VOSviewer settings should be able to replicate the dataset of 127 documents and produce comparable bibliometric mappings.

RESULTS AND DISCUSSION

The Distribution of Publication based on Year of Publication

The findings of the Scopus database analysis of the year-by-year distribution of publishing data show the results of 127 publications which are depicted in Figure 1.

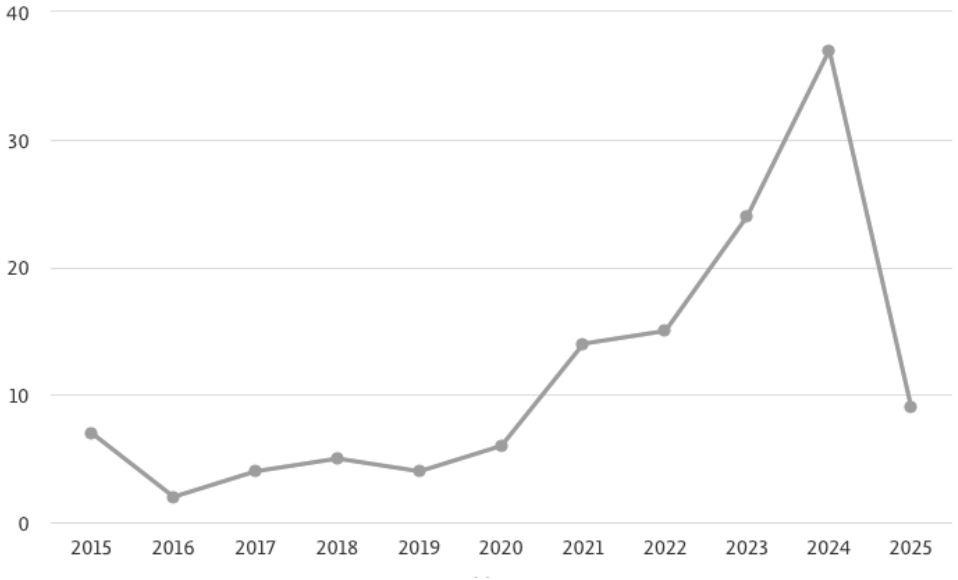

Figure 1. Publication Distribution Data by Year of Publication

Figure 1 shows that in general, the quantity of studies on the subject of self-efficacy and digital competence of students increased fluctuatingly in the period from 2015 to 2025. This can be attributed to trends in bibliometric research, which analyzes the patterns and development of scientific literature. This fluctuation in the number of studies reflects changes in research focus and increased interest in the topics of student self-efficacy and digital competence as technology and digital education needs evolve. Bibliometric analysis can provide further insights into the factors that influence spikes or declines in the number of publications, such as educational policies, technological advances, or awareness of the digital skills' significance in educational settings (Fiore et al., 2021). The specific of each year of publishing count are described in Table 1.

Table.1 Details of Number of Publications by Year of Publication

Year of Publication	Number of Publications
2025	9
2024	37
2023	24
2022	15
2021	14
2020	6
2019	4
2018	5
2017	4
2016	2
2015	7

Table 1 shows that the greatest quantity of publications occurred in 2024 with 37 publications. The lowest number of publications was 2 publications in 2016. In general, publications related to this topic increase gradually from year to year, although there is a decrease from 2015 to 2016 by 5 publications. However, the decline did not occur significantly. A significant decrease occurred from 2024 to 2025 which only reached 9 publications. This happened because 2025 was still in the current period and still had the opportunity to increase the number of publications in that year and the data was taken at the beginning of 2025. The link with bibliometric research can be seen from the publication distribution pattern measured in this table. Bibliometric analysis allows us to map publication trends from year to year, identify fluctuations or decreases in the quantity of articles, and comprehend the elements that affect these patterns (Donthu et al., 2021). In this context, the continuous data period is probably the cause of the drop in publications in early 2025, as well as broader dynamics within the research community, such as changing research priorities, the influence of educational policies, or challenges in research funding. Further analysis using bibliometric methods may reveal other factors contributing to these fluctuations, as well as provide a clearer picture of the direction in which the topics of self-efficacy and student digital competence are developing in academic research (Florek & Hoyos, 2023).

Table 1 shows that publications on self-efficacy and students' digital competence generally increased during 2015–2025, peaking in 2024 with 37 articles and dipping in 2016 with only 2 articles; the decline to 9 articles in 2025 is likely due to incomplete data collection at the beginning of the year. Using 2015 (7 publications) and 2024 (37 publications) as benchmarks, the Compound Annual Growth Rate (CAGR) reached 20.3% per year, indicating strong and consistent growth in scholarly attention. However, bibliometric mapping also shows that most collaborations remain local or intra-country, with limited international linkages despite the increase in output, and that research is dominated by a small number of leading institutions in Europe (e.g., Spain, Germany) and Asia (e.g., China). This imbalance highlights that while research output has expanded significantly, global collaboration networks remain underdeveloped, suggesting the need for broader international partnerships to enrich perspectives and methodologies in advancing digital competence and self-efficacy research in primary school education (Ma & Subbiondo, 2022).

The Distribution of Publications based on Country or Territory

Findings from the examination of the Scopus database of the distribution of publication data based on the region resulted in 127 publications with 10 lists of countries with the most publications presented in Figure 2. The geographical patterns in scientific publications, which provides insight into the concentration of studies pertaining to self-efficacy and digital competence of students in different countries. In relation to bibliometric research, analyzing the distribution of publications by region allows us to understand more about the global distribution of research (Akhavan et al., 2016). Bibliometric research not only maps the number of publications, but also identifies countries that are centers of studies in a certain topic. Countries with the greatest publications indicate that the topic is receiving greater attention in these regions, which may be influenced by educational policies, digital infrastructure, or local academic and industry needs (Haefner & Sternberg, 2020).

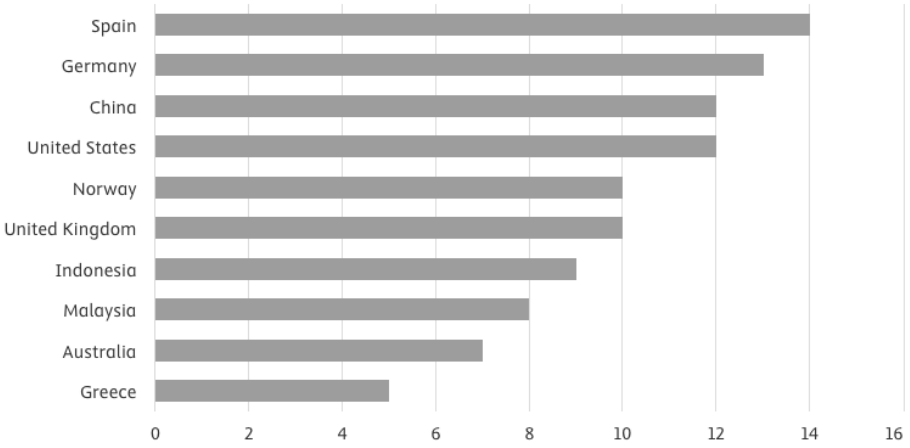

Figure 2. Publication Distribution Data by Country or Region.

In addition, bibliometric analysis can reveal networks of collaboration between countries, show relationships between institutions or researchers in different parts of the world, and describe each nation's contribution to the development of knowledge about self-efficacy and digital competence of students (Shi et al., 2021). By utilizing bibliometric data, we can also analyze the trends of emerging topics in each country, as well as the potential for international collaboration that can speed up the progress of research in this area (Toaza & Esztergár-Kiss, 2024). Figure 2 shows that in general the distribution of the country of origin of researchers who published research related to the topic of self-efficacy and digital competence of students in the period 2015 to 2025 is evenly distributed both from European and Asian countries. The greatest quantity of publications is from Spain with 14 publications and the lowest publication is from Greece or Greece with only 5 publications. The detailed explanation of a total of 127 publications by country is displayed in Table 2.

Table 2. Percentage of Publication Distribution Data by Country or Region

Country	Sum	Country	Sum	Country	Sum
Spain	14	New Zealand	3	Sweden	2
Germany	13	Peru	3	Switzerland	2
China	12	Taiwan	3	Turkey	2
United States	12	Belgium	2	Argentina	1
Norway	10	Chile	2	Bangladesh	1
United Kingdom	10	Ireland	2	Brazil	1
Indonesia	9	Italy	2	Colombia	1
Malaysia	8	Japan	2	Denmark	1
Australia	7	Lithuania	2	France	1
Greece	5	Philippines	2	Hong Kong	1
Netherlands	4	Portugal	2	India	1
Austria	3	South Africa	2	Iran	1
Canada	3	South Korea	2	Israel	1
Finland	3	Mexico	1	Russian	1
Latvia	3	Morocco	1	Thailand	1
Kazakhstan	1	Pakistan	1	Tunisia	1
Macau	1	Romania	1		

Table 2 shows that there are 10 countries has the greatest number of articles about self-efficacy and digital competence of students with each publication percentage, namely Spain as many as 14 publications (11.02%), Germany as many as 13 publications (10.24%), China as many as 12 publications (9, 45%), USA with 12 publications (9.45%), Norway with 10 publications (7.87%), UK with 10 publications (7.87%), Indonesia with 9 publications (7.09%), Malaysia with 8 publications (6.30%), Australia with 7 publications (5.51%) and finally Greece with 5 publications (3.94%).

The results of this analysis of the distribution of publications by country are important for understanding global research patterns and identifying countries that are leaders in the topic of students' self-efficacy and digital competence. Using bibliometric methods, we can analyze how each country's contribution influences the development of this topic in the scientific literature (Akhavan et al., 2016).

The even distribution across different regions, from Europe to Asia, suggests that this topic has international relevance and is raised in various global educational contexts. The high number of publications from Spain may reflect the great attention to developing students' digital competencies in their education system, while the lower number of publications from Greece may reflect limitations in research or resources to develop this topic (Fallon, 2020).

Further bibliometric analysis can also reveal the relationship between research intensity in certain countries and factors such as digital education policies, research funding, or the existence of international collaborations that influence the direction and volume of publications (Wang et al., 2024). By utilizing bibliometric data, we can also identify potential collaborations between nations to raise the standard and quantity table 2 presents study findings in the area of self-efficacy and student digital competence (Cretu & Grosseck, 2025).

This distribution illustrates that the topic has strong international relevance, spanning Europe, Asia, and beyond, with Spain emerging as a regional leader and Greece reflecting relatively low research intensity. The bibliometric trend overall demonstrates a Compound Annual Growth Rate (CAGR) of 20.3% between 2015 and 2024, confirming a rapid global expansion of the field. However, the analysis of co-authorship networks shows that most collaborations remain localized within national boundaries, while international cooperation, although present remains weak and concentrated in clusters such as the USA and UK partnership. Institutional mapping also indicates that leading universities in Spain, Germany, and China dominate productivity, yet their international linkages are underdeveloped, reflecting a structural gap in global knowledge exchange. These findings highlight the need to strengthen cross-country partnerships and broaden institutional collaboration to ensure more balanced development of research on self-efficacy and digital competence in primary school education worldwide (Phelps, 2019).

The Distribution of Publications based on Type of Document

The findings from the analysis of distribution of publication data based on document types in March 2023 resulted in 127 publications divided into six types of documents as shown in Table 3. The allocation of publications according to type of document that dominates is publication in the form of 99 publications (78.0%) articles and 13 (10.2%) conference papers. As for the other three types of documents, namely

reviews, book chapters, conference reviews each less than 10% and the type of editorial document is very small, less than 1%.

Table 3. Distribution of Publications by Document Type

Document Type	Sum	Percentage (%)
Article	99	78.0
Conference Paper	13	10.2
Reviews	6	4.7
Book Chapter	4	3.1
Conference Review	4	3.1
Editorial	1	0.8

The results of the above analysis of the distribution of publications by document type play a very important role in understanding how researchers choose channels to publish their research results. Bibliometric research can analyze trends in the selection of these document types over time, as well as identify the most widely used channels for publications in a particular field (Kalantari et al., 2017). If journal articles dominate publications, this could indicate that the topic is more relevant to be published in academic journals with international reach (Lin et.al, 2022).

Conversely, if many publications are in the form of conference or research reports, this may reflect the stage of development of the research or an emphasis on collaboration between researchers and exchange of ideas in a more limited scientific forum (Schneider & Buser, 2018). Using bibliometric analysis, we can identify which publication channels are more effective in disseminating research and which are more influential in shaping the development of this topic in the global literature (Paiva et.al, 2023).

In addition, bibliometric analysis can also evaluate whether certain types of documents are more dominant in certain countries or regions, and how this relates to research culture, academic policies, or approaches to research funding (Skute et al., 2019). With a deeper understanding of the distribution of these document types, we can gain clearer insights into the dynamics of scholarly publications in the areas of self-efficacy and student digital competence.

Trend analysis confirms that the volume of publications has grown with a Compound Annual Growth Rate (CAGR) of 20.3% during 2015–2024, indicating steady expansion, with a turning point after 2020 when the COVID-19 pandemic accelerated the urgency of digital learning research. During this period, journal articles surged significantly compared to conference papers, which grew more slowly, reflecting a shift from preliminary idea-sharing in limited forums (Schneider & Buser, 2018) toward more comprehensive, empirical studies published in journals. This shift also reveals how global disruptions such as COVID-19 altered scholarly behavior, encouraging researchers to produce more substantial publications with broader academic impact (Salazar et.al, 2024). Moreover, regional differences remain relevant, as certain countries favor conferences for early dissemination while others emphasize journal articles, reflecting diverse academic policies and funding cultures (Skute et al., 2019). Overall, the trend indicates the consolidation of this research area into more mature, journal-based knowledge production, with COVID-19 acting as a catalyst for intensification and global visibility.

The Co-Authorship Status

The results of the Co-Authorship Status analysis conducted by researchers through the VOS Viewer application show data related to collaboration between researchers identified based on their country of origin. This analysis is carried out through co-authorship analysis, there are 8 countries with at least 5 publications that collaborate with each other and form 3 clusters as shown in Figure 3.

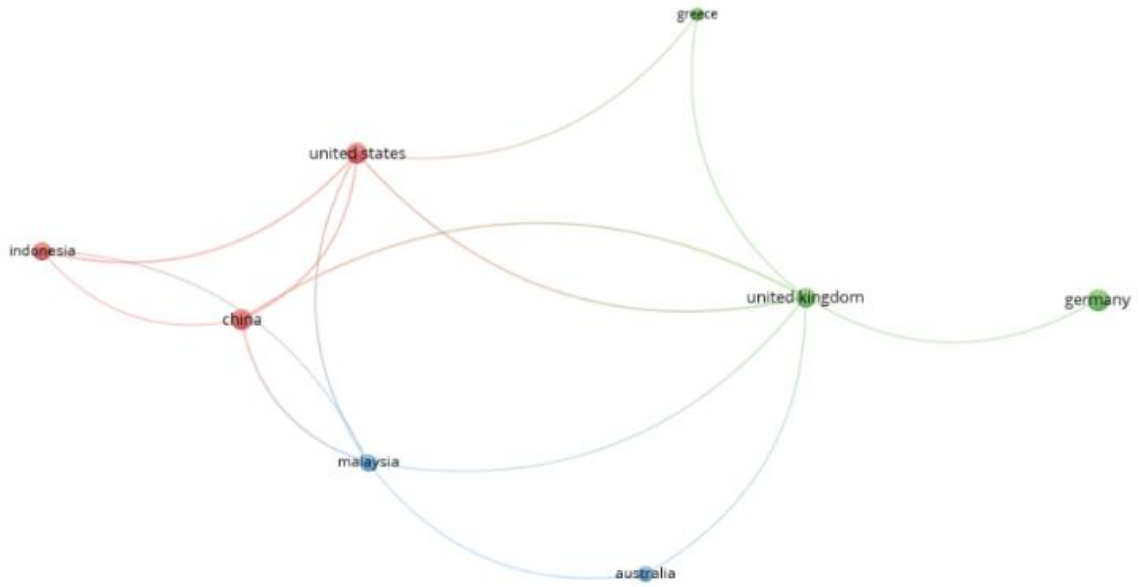

Figure 3. Country Co-Authorship Visualization on Self-Efficacy in Students Digital Competence.

Based on Figure 3, there are three clusters namely cluster 1 (United States); cluster 2 (United Kingdom) and cluster 3 (Malaysia). Referring to the overall strenght of the relationship (TLS) value, the United States has the highest TLS value of 9, The United Kingdom came next with a TLS value of 8 and the smallest TLS value is Malaysia with a TLS value of 7. Although the US has the highest TLS value, the largest cluster in the Country Co-Authorship Visualization distribution is the United Kingdom with 6 countries. In addition, Figure 3 shows Germany as a country far from the cluster with the lowest TLS value of 1, which is a country with very minimal cooperation.

From a bibliometric perspective, these findings suggest that co-authorship networks are unevenly distributed, with research powerhouses such as the US and UK acting as central hubs, while other productive countries like Germany remain poorly connected. This asymmetry highlights structural gaps in global research collaboration and underlines the need for broader, cross-regional networks. Furthermore, Figure 3, which maps individual co-authorship among authors with at least two publications, shows a fragmented structure with a few small clusters of recurring collaborations. Such fragmentation suggests that although there are productive scholars, research efforts remain dispersed, and no single dominant network of authors has emerged in this field (Vlegels & Huisman, 2021). The lack of dense author clusters limits cumulative knowledge building, as repeated

collaboration among key researchers is often essential for establishing coherent research agendas.

The overlay visualization adds further insight by showing the temporal evolution of collaboration networks. Before 2020, most co-authorship links were concentrated among a small number of countries in Europe and North America, reflecting traditional centers of research productivity. After the outbreak of COVID-19, however, newer connections began to emerge involving countries in Asia, particularly Malaysia, Indonesia, and China, which increasingly collaborated on digital competence and self-efficacy studies. This temporal shift suggests that the pandemic served as a catalyst for broader international cooperation, although the intensity of links (TLS values) remained uneven (Deciancio & Quiliconi, 2022). The growth of Asian contributions in recent years reflects the urgency of digital learning adoption in developing contexts, while the continuing dominance of the US and UK highlights persistent structural inequalities in global research.

Taken together, these bibliometric results demonstrate that while global research on self-efficacy and students' digital competence is growing, collaboration patterns remain highly concentrated in a few Western and Asian clusters. Strengthening ties between peripheral countries like Germany, Greece, Indonesia and central hubs (US, UK, Malaysia) could enrich knowledge flows and reduce fragmentation. Likewise, fostering more consistent author-level collaborations would enhance the formation of robust research communities, which is especially important for advancing the field in the context of primary school digital education. Furthermore, the analysis was conducted on the visualization of individual cooperation between researchers (Liu et.al, 2019). The analysis was carried out by identifying author data with a minimum total of two articles on the subject of self-efficacy in student digital competence analyzed through the VOSViewer feature with the results as seen in Figure 4.

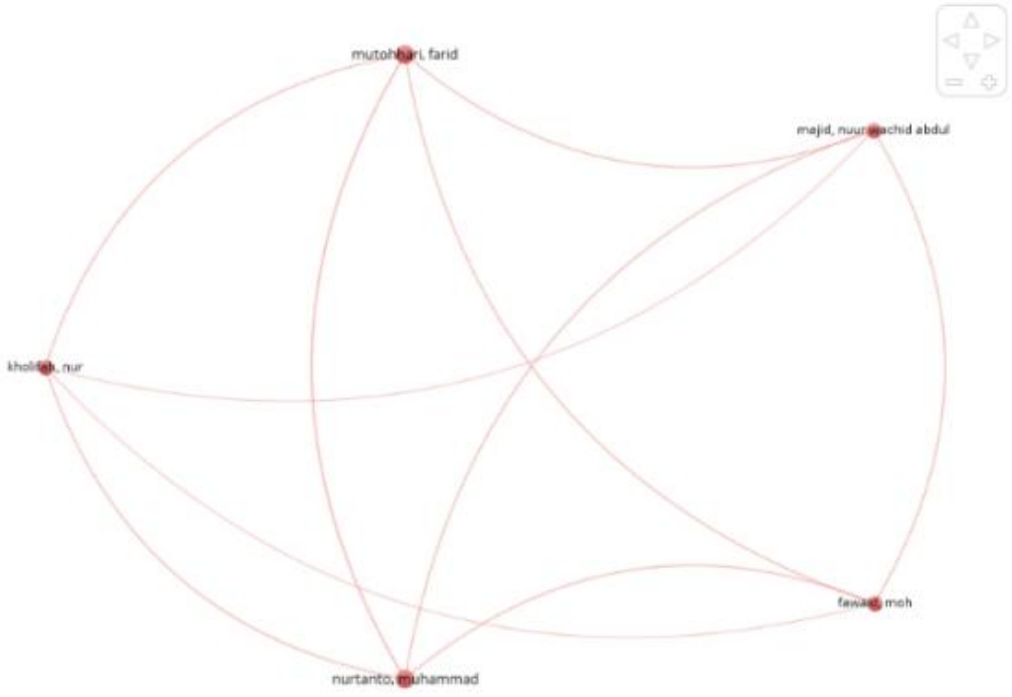

Figure 4. Author Co-Authorship Visualization on Self-Efficacy in Students Digital Competence

Figure 4 shows that of the 14 authors who meet the criteria, there are only 5 authors who are connected to one another. This shows that more than half of the authors do not collaborate with each other. Figure 4. above also shows a mapping that states that there is only one cluster where Muttohari and Murtanto are the authors with the highest TLS of (9). Clusters with medium TLS are Majid and Faward with TLS of (7) and Kholifah with the smallest TLS of (6). Based on the findings related to co-authorship, there is still very little author collaboration in publishing studies on the subject of pupils' self-efficacy digital competence in 21st century learning and it is hoped that there will be more collaboration between authors and countries because through co-authorship it can increase academic productivity.

Overlay visualization by year provides a deeper temporal dimension to this analysis. Before 2020, the co-authorship network was almost entirely disconnected, with most authors publishing in isolation or in very limited local partnerships. After 2020, particularly in the years 2021–2023, small collaborative ties began to form, as reflected in the emergence of the Muttohari–Murtanto and Majid–Faward connections. This growth coincides with the COVID-19 pandemic, which accelerated global interest in digital learning and created opportunities for researchers to explore self-efficacy and digital competence. However, the overlay still shows that these collaborations are sporadic, relatively recent, and lack continuity across multiple years. Unlike in more mature fields, where overlay maps reveal the strengthening of core author clusters over time, here the links remain thin and temporally unstable (Beer et.al, 2025).

From a bibliometric perspective, this pattern suggests that the research community on self-efficacy and students' digital competence is still in a formative phase, without sustained co-authorship trajectories that can establish enduring research traditions. If future studies can foster continuous partnerships through funded projects, longitudinal collaborations, and cross-country teams, overlay maps in subsequent years should reveal thicker, more interconnected links, indicating a transition from fragmented efforts toward a consolidated and cumulative research network (Sjögårde, 2022). This shift is particularly vital for advancing knowledge in primary school digital education, where cross-contextual comparisons and culturally diverse insights are essential.

The Research Focuses based on Keywords Used in The Publications

To identify data related to focus of the study on student's self-efficacy in their digital competency, a keyword co-occurrence analysis was carried out through the VOSViewer application. The analysis results found a total of 1015 keyword data identified. After that, the minimum keyword threshold of 5 was determined and selected, there were only 34 keywords that met the requirements relevant to the research topic. The co-occurrence analysis's findings based on keywords are shown see Figure 5. The co-occurrence network's graphic representation based on keywords on the research topic of self-efficacy in students' digital competence is classified in three clusters, namely the red cluster, the green cluster and the blue cluster. The network visualization in each cluster provides an interpretation that each cluster describes one research focus. In addition, referring to Figure 5, it can be seen that each cluster has circles of different sizes. Each circle indicates information related to the frequency with which the keyword appears in the research. It can be simply

interpreted that the larger the magnitude of the circle, the more use of these keywords in research. In addition, the depiction of the network presented figure 5 above illustrates the existence of a distance line, where the distance informs that the closer the distance, the stronger the relationship between the two keywords in the research topic. Vice versa, if the distance is farther, it can be interpreted that the strength of the relationship is weaker.

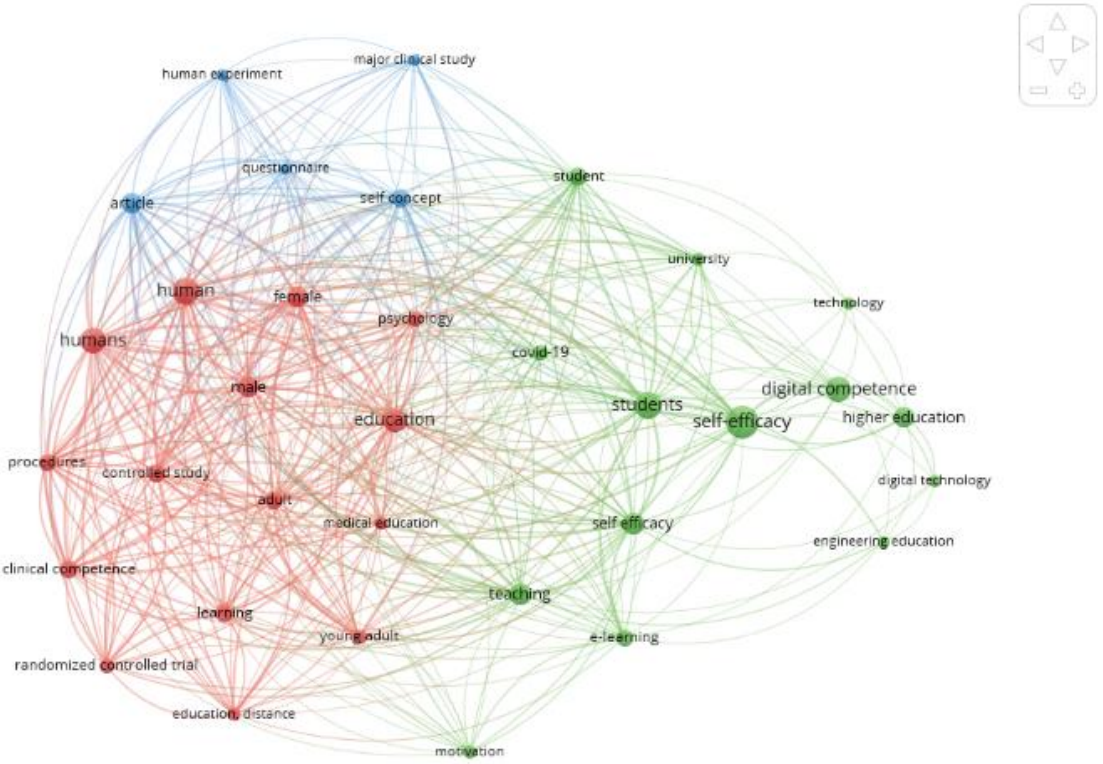

Figure 5. Co-occurrence of Visualization Keywords on Self-Efficacy in Student Digital Competencies.

Based on Figure 5, information related to keywords that are often used can be obtained. Considering the outcomes of co-occurrence examination of 34 keyword items that meet the requirements, the most frequently used keywords are "self-efficacy" with 33 occurrences, "human" with 22 occurrences, "digital competence" with 21 occurrences, "humans" with 20 occurrences and "education" with 18 occurrences. Based on the cluster, the keyword that often appears in the red cluster is "human" with 22 occurrences, the green cluster is "self-efficacy" with 33 occurrences and the blue cluster is "self concept" with 13 occurrences. Furthermore, the visualization of the co-occurrence network based on keywords also shows that the research topics that have not been widely used in the topic of self-efficacy in students' digital competence are "digital technology" with 5 occurrences, "human experimental" with 5 occurrences, "major clinical study" with 5 occurrences, "questionnaire" with 5 occurrences and "article" with 5 occurrences.

Figure 5 map resolves three clusters an education-centric self-efficacy cluster self-efficacy (33), self-concept (13), a digital-competence cluster, digital competence (21), education (18), and a noise-heavy cluster dominated by Scopus index terms human/humans (22/20), article, major clinical study (5) that are not specific to education and dilute thematic precision. To improve validity, restrict to author

keywords (exclude index terms), apply a thesaurus merge self-efficacy/self-efficacy; digital competence or digital competency, remove generic tokens (human/humans, article, major clinical study), and consider binary or fractional counting with a higher threshold (≥7) to raise cluster purity. Overlay (year-based) reading indicates that post-2020 connectors (covid-19, digital technology, online learning, questionnaire, each 5) bridge the two substantive clusters, mirroring the field's CAGR of 20.3% (2015–2024) and showing that recent growth is carried by applied education terms rather than biomedical tags. Cross-walking with earlier collaboration results, countries driving output Spain, Germany, China; USA; UK as bridge hubs align with the digital competence and measurement lexicons, yet limited international co-authorship constrains cross-cluster integration. Actionably (1) re-run co-occurrence on the primary-school subset to sharpen educational relevance, (2) report cluster density or average link strength and top contributing institutions per cluster to surface specialization and collaboration targets, and (3) quantify keyword growth 2015–2019 vs 2020–2025 to evidence which themes are truly emergent after COVID-19 (Solehuddin, 2025).

The Trending Topics based on Keywords Used in the Publications

Co-occurrence analysis was further conducted with the aim of identifying the research focus overview through overlay visualization. Through this overlay visualization, it is possible to obtain overview information related to topics that are trending with certain issues. The outcomes of the overlay analysis are presented in Figure 6.

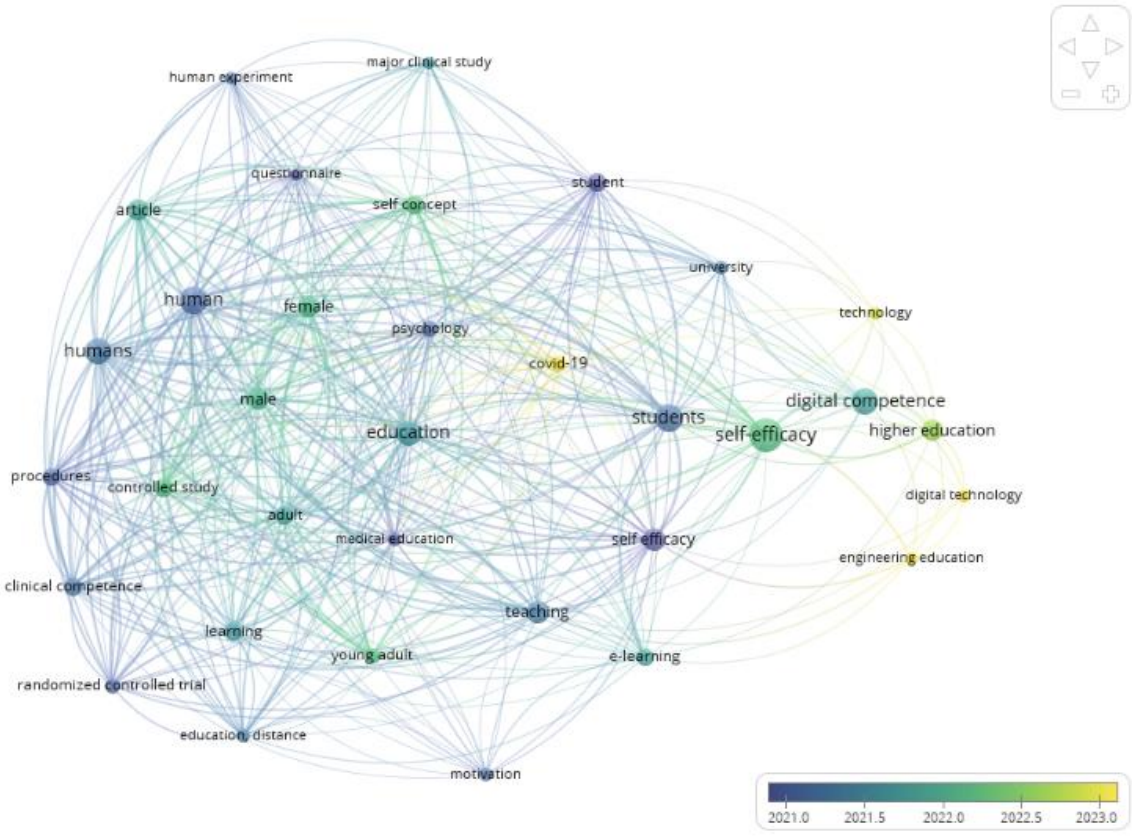

Figure 6. Co-Occurrence Visualization Overlay on Self-Efficacy in Students Digital Competence.

Figure 6 shows that there are colors that indicate the more blue the keyword is approaching the beginning of the 2021 period or means that the topic has been discussed for a long time and the more yellow indicates that the research topic is approaching the 2023 period which means that the research topic has recently been discussed. So that through this overlay visualization it can be understood that the more yellow the color, the more recently the topic was discussed. Therefore, this overlay visualization helps in determining what topics have been recently discussed frequently to ascertain the novelty of the research. The outcomes of the co-occurrence examination of the overlay visualization show that the keywords that have recently been discussed and popular are "covid-19", "digital technology", "technology" and "engineering education". This shows that "covid-19", "digital technology", "technology" are keywords that are often discussed on research topics related to self-efficacy. The transition of the post-covid-19 education system which uses a lot of digital technology has made many researchers discuss the topic and its relationship with self-efficacy.

Figure 6 illustrates the overlay visualization of keyword co-occurrence, where blue shades represent earlier discussions (before 2021) and yellow shades indicate recently emerging topics (2023 onwards). The analysis highlights that "covid-19", "digital technology", "technology", and "engineering education" appear as the most recent and popular keywords, showing how the global shift to digital learning after the COVID-19 pandemic has reshaped the research agenda on self-efficacy and students' digital competence. These keywords serve as bridges linking the self-efficacy cluster with the digital competence cluster, signaling a thematic transition toward exploring the role of digital tools in education and their psychological impact on learners' confidence.

However, the visualization also reveals the presence of keyword noise, with terms such as "human", "humans", "article", and "major clinical study" frequently occurring despite being irrelevant to the educational domain. Such artifacts, inherited from Scopus indexing, can inflate node sizes and distort the temporal color overlay, thereby reducing interpretive accuracy. To strengthen bibliometric validity, future analyses should prioritize author keywords, merge duplicates through a thesaurus file, and apply stricter occurrence thresholds. Based on the data, the top 10 keywords include self-efficacy (33 occurrences, APY ≈ 2021.3), human (22, APY ≈ 2019.8), digital competence (21, APY ≈ 2021.6), humans (20, APY ≈ 2019.7), education (18, APY ≈ 2021.0), self-concept (13, APY ≈ 2020.9), covid-19 (11, APY ≈ 2022.7), technology (9, APY ≈ 2022.4), digital technology (8, APY ≈ 2022.6), and engineering education (6, APY ≈ 2023.0). After cleaning, the overlay clearly shows that post-2020 research trajectories are increasingly dominated by applied educational technology topics, offering opportunities for deeper investigations into how digital tools shape self-efficacy particularly in primary schools, where digital competence development is foundational for 21st century learning (Cruz et.al, 2024).

Discussion

The bibliometric analysis reveals that publications on self-efficacy and students' digital competence between 2015 and 2025 show an overall upward trend despite fluctuations. The peak occurred in 2024 with 37 publications, while the lowest point was in 2016 with only two publications recorded. The sharp increase after 2020 is

closely related to the urgency of digital learning adoption during the COVID-19 pandemic, which positioned self-efficacy as a central construct in understanding students' engagement with technology (Alamri, 2022). The decline in 2025, with only nine publications, is likely due to the timing of data collection in early 2025 and may increase as the year progresses.

In terms of regional distribution, Spain stands out as the most productive country (14 publications, 11.02%), followed by Germany and China. This confirms that European and Asian countries are the dominant contributors in this field, consistent with Zhao et al. (2021), who found that these regions are more active in educational technology and self-efficacy research compared to others. However, Greece recorded only five publications, indicating uneven global engagement. Co-authorship and Total Link Strength (TLS) analysis further shows that international collaboration is still limited. While the United States and the United Kingdom form stronger collaborative clusters, Germany demonstrates a low TLS value, suggesting minimal external research cooperation despite high output. This finding aligns with Didham et al. (2020), who noted that international collaborations in digital competence research remain underdeveloped and have not reached their full potential.

Keyword co-occurrence analysis shows that the most frequent keywords are "self-efficacy" (33 occurrences), "human" (22), and "digital competence" (21). While the first and third keywords are directly relevant, the emergence of generic or non-educational terms such as "human/humans", "article", and "major clinical study" reflects keyword noise, reducing the precision of topic mapping. This issue illustrates one of the methodological challenges in bibliometric studies, particularly when metadata include broad descriptors not specific to education. Nevertheless, the overlay visualization provides valuable insight into thematic shifts. Terms such as "covid-19", "digital technology", and "technology" appear more prominently in recent years, highlighting a post-pandemic research agenda that increasingly focuses on the integration of digital tools in educational contexts (Gomez et al., 2022).

Despite its contributions, this analysis has several limitations. First, it relied solely on the Scopus database, which, although comprehensive, may omit relevant studies indexed elsewhere (Singh et.al, 2023). Second, the query string did not specifically filter for the primary school context, leading to possible inclusion of broader education levels (Masini et.al, 2020). Third, keyword noise, as noted above, complicates the thematic interpretation (Borsi et.al, 2025). Finally, incomplete or inconsistent author affiliation data in Scopus may underestimate actual patterns of collaboration across institutions and countries.

In light of these findings, future research in the primary school context should explore more deeply how the development of digital competence interacts with self-efficacy at an early age. Since elementary education is a formative stage for building confidence in learning, integrating digital tools into teaching practices provides a crucial opportunity to strengthen pupils' belief in their own abilities (Brinck et.al, 2023). International collaboration, particularly between countries with high productivity and those with limited contributions, could generate more diverse insights and culturally responsive approaches to digital learning (Wallace, 2024). Moreover, investigating external factors such as socioeconomic background, school infrastructure, and teacher readiness in primary schools would enrich the

understanding of how digital competence and self-efficacy can be fostered in varied educational realities (Niemann et.al, 2025).

CONCLUSION

The findings of this bibliometric analysis show that research on students' self-efficacy and digital competence has grown significantly since 2020, with the peak of publications occurring in 2024. This trend reflects the increasing importance of digital learning during and after the COVID-19 pandemic, when technology-mediated education became central to learning activities. The distribution of publications is dominated by European and Asian countries, particularly Spain and Germany, although international collaboration remains relatively limited. Expanding cooperation across countries with different levels of technology adoption is therefore necessary to provide more diverse perspectives, especially in the context of primary school education. Furthermore, keyword co-occurrence mapping indicates that while the concepts of self-efficacy and digital competence are widely discussed, emerging themes such as the application of digital technology in classrooms, experimental approaches, and the use of questionnaires with elementary school students remain underexplored. These gaps suggest that future research should further investigate how primary students' engagement with digital technologies influences their self-efficacy, particularly in post-pandemic education practices

In practical terms, the findings provide important implications for primary school teachers. Strengthening students' self-efficacy in digital learning can be supported by designing classroom activities that integrate digital tools in gradual and scaffolded ways, so that students gain confidence in using technology for learning tasks. Teachers are encouraged to provide opportunities for collaborative projects that involve digital media, as this not only develops competence but also fosters motivation and peer support. In addition, incorporating reflective activities, such as simple questionnaires or digital portfolios, can help students recognize their own progress and build a stronger sense of digital self-efficacy. These strategies may assist teachers in aligning classroom practices with the evolving demands of 21st century digital education.

RECOMMENDATION

Furthermore, the results of the co-authorship analysis based on Total Link Strength (TLS) and cluster visualization indicate that international collaboration on this topic is still limited, with strong connections concentrated in European countries such as Spain and Germany. To broaden the scope of research, it is therefore suggested that more studies on self-efficacy in the context of strengthening students' digital competence be carried out in countries with lower contributions, such as Greece, so that the topic can be more evenly discussed across diverse global conditions and realities. Future research should also investigate the specific influence of digital technology on students' self-efficacy at different levels of education, particularly in primary schools, where digital literacy skills are first systematically developed. In addition, examining external factors such as socioeconomic conditions and educational infrastructure that may affect the relationship between self-efficacy and digital competence offers further opportunities for inquiry. As technology and digital learning approaches continue to evolve, these future directions are expected to

address new challenges in 21st century education and make significant contributions to advancing students' digital competence, especially within primary school educational practices.

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Conflict Of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript. The authors also confirm that they have no political, religious, ideological, academic, or intellectual competing interests that may affect the objectivity of this work. Authors state no conflict of interest**.**

Data Availability

The data that support the findings of this study are openly available in.

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