

Connecting the Dots: Bibliometric Trends in 21st Century Learning Skills and Teacher Competencies

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ABSTRACT

This bibliometric analysis explores research trends and patterns in the field of 21st-century learning skills and teacher competencies, an area critical to preparing educators and students for modern educational demands. With the rapid shift towards digitalization and skill-based learning, there is a growing need to understand how these competencies are conceptualized and studied globally. However, despite the increasing interest, limited studies have systematically analyzed the evolution of research in this field. This study addresses this gap by analyzing 1,101 relevant publications extracted from the Scopus database, using Scopus Analyzer and VOSviewer software for trend visualization and co-occurrence mapping. Key variables analyzed include publication trends by year, prominent authors and institutions, and commonly used keywords. Results show a steady increase in publications from 2004 to 2024, with a significant rise post-2016, reflecting heightened interest in aligning educational frameworks with 21st-century skills. The keyword analysis highlights terms like "critical thinking," "digital literacy," and "teacher professional development" as central themes, suggesting a focus on cognitive and technological competencies. Geographically, the United States and the United Kingdom lead in publication volume and citations, indicating a dominant influence, while countries in Asia and Europe also show notable contributions. The analysis underscores the importance of international collaboration in advancing educational competencies for the 21st century. Conclusively, this study offers valuable insights into the development and focus areas of research on learning skills and teacher competencies, providing a foundation for future studies to build upon and address emerging challenges in education.

Keywords - 21st century teaching skills, Teaching Competencies, bibliometrics trends, teaching ability, 21st century competencies

INTRODUCTION

The rapid evolution of the 21st century has necessitated a shift in educational paradigms, emphasizing the development of skills that prepare students for a dynamic and interconnected world. These skills, often referred to as 21st-century skills, encompass a range of competencies including critical thinking, creativity, communication, and collaboration (Almazroa & Alotaibi, 2023) (Belyaeva et al., 2022) (Cretu, 2017). However, the challenge lies not only in identifying these skills but also in effectively integrating them into teaching practices. Research indicates that there is a significant gap in the preparation of teachers to impart these skills, highlighting the need for targeted interventions and professional development programs (Almazroa & Alotaibi, 2023), (Kim et al., 2019), (Chalkiadaki, 2018). The P21 Framework, for instance, provides a structured approach for aligning curricula with these competencies, yet its implementation requires a nuanced understanding of both pedagogical and technological tools (Calmer, 2021), (Pellegrino, 2017).

To address these challenges, teacher education programs must evolve to include comprehensive training in 21st-century skills. This involves not only upskilling in-service teachers but also embedding these competencies into the professional development of pre-service teachers (Almazroa & Alotaibi, 2023). Studies have shown that effective teacher preparation programs should offer multiple opportunities for candidates to practice and develop these skills through interactive and reflective learning experiences (Cretu, 2017). Moreover, the integration of technology in teaching and learning processes is crucial, as it enhances the ability to teach these skills in a

meaningful and context-specific manner (Kim et al., 2019) (Sang et al., 2018). By focusing on these areas, educational institutions can better prepare teachers to meet the demands of modern education and foster a generation of learners equipped for the challenges of the 21st century.

Despite the growing importance of 21st-century learning skills and teacher competencies, there is limited clarity on the popular keywords, thematic clusters, and global collaborative efforts driving research in this area. Existing studies often fail to provide a comprehensive bibliometric analysis that maps the trends and connections among critical concepts like teacher training, digital literacy, STEM education, and professional development. Moreover, the extent of international collaboration and the disparity in research output across countries remain underexplored, leaving gaps in understanding how global and regional factors influence this field. These gaps highlight the need for a systematic bibliometric analysis to address questions on the prevalent research themes and co-authorship patterns, ultimately enabling stakeholders to identify trends, strengths, and areas for future research.

LITERATURE REVIEW

Recent research trends in 21st-century education focus heavily on STEM education and the integration of technology to cultivate essential skills in both teachers and students. (Rodríguez et al., 2024) explore STEM education as a primary strategy for developing these competencies, particularly through teacher training. Their systematic review identifies three principal intentions for STEM-focused teacher training—enhancing knowledge, building competencies, and altering attitudes—and five dominant methodologies: project-based, problem-based, collaborative, observation-discussion-reflection (ODR), and design-based learning (DBL). (Tsai et al., 2023) highlight design thinking as a valuable constructivist approach, which enhances critical problem-solving capabilities in students, aligning well with the core objectives outlined by Rodríguez et al. for STEM pedagogy, thus underscoring the need for further empirical validation of the long-term impacts of such strategies on learning outcomes. Hanifah et al., (2024) examine the TPACK framework's application in a constructivist learning environment for mathematics education students, revealing significant variations in their mastery of content knowledge (CK) compared to pedagogical (PK) and technological knowledge (TK). The research indicates that structured training positively affects TPACK competency, especially technology integration, yet calls for enhanced curriculum design to improve CK within the constructivist framework. This aligns with findings from (Gamit, 2023), whose study on ICT implementation in the Philippines suggests that younger teachers and those with less formal education may exhibit higher efficacy in integrating ICT, hinting at potential generational and experiential disparities in technological adaptation. (Tsai et al., 2023) argue that design thinking can significantly elevate students' readiness for these problems, integrating principles of self-determination theory and wicked problem-solving to boost motivation and cognitive flexibility. In Thailand, (Polyiem & Nuangchalerm, 2023) investigate novice teachers' learning management competencies, particularly within localized development initiatives. Their study reveals that targeted training can elevate teachers' abilities to design student-centered learning activities, an outcome that resonates with the broader goals of STEM and constructivist pedagogy as observed in other studies.

The emphasis on 21st-century learning skills has reshaped teacher competencies, demanding an integration of competencies like the 4C skills (critical thinking, communication, collaboration, and creativity) across diverse educational fields. Recent research reflects this shift, showcasing both advancements and challenges in training teachers for the modern classroom. This review examines six recent studies, highlighting prominent trends, strengths, weaknesses, and research gaps in the field. A significant trend is the focus on integrating 4C skills into teacher education, especially in mathematics and ICT education. For instance, (Fidiastuti et al., 2024) examined the challenges faced by teacher education institutions in preparing prospective math teachers to teach 4C skills, noting limited resources and lack of adequate training. While these studies show promising applications of modern educational approaches, they also highlight weaknesses, particularly in teacher training and resource allocation. (Fitriati et al., 2023) and (Baskaran et al., 2023) both identify a lack of adequate training and resources as primary obstacles. Additionally, (Kurniawan et al., 2023) focused on geography teachers and pointed out that teacher readiness often hinges on environmental factors, such as respecting learner diversity and solid content mastery. The findings suggest that despite the recognized need for 21st-century skills, there is insufficient infrastructure and support for teachers, especially in developing countries. Several studies identify potential research gaps, particularly concerning the development of specific competencies and the role of collaborative

learning models.

The integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) as a vehicle for developing collaboration, creativity, critical thinking, and communication (the "4Cs") is a dominant trend in educational research. (Zaqiah et al., 2024) conducted a case study at two Madrasahs in West Java, illustrating that STEAM significantly enhances student collaboration but has mixed impacts on other skills such as critical thinking and communication. This indicates that while STEAM can be effective for some aspects of skill development, it may require additional supports or extended time frames to yield improvements across the 4Cs comprehensively. S.-C. Wu & Chang, (2023) further highlight STEAM's effectiveness by linking it with a maker movement that integrates hands-on learning to foster problem-solving and innovation among students. Their quasi-experimental design with Taiwanese students underscores the benefit of interdisciplinary approaches, particularly when aligned with national curriculum reforms that prioritize "Life Technology" and "Information Technology" education. Another significant theme is the incorporation of digital and mobile technologies into classroom practices. Efendi & Qod, (2023) explore mobile game-based learning as a means to improve high school students' critical thinking in sociology. Their quasi-experimental results demonstrate the method's efficiency in developing critical thinking competencies. Similarly, (Srichailard, 2024) examines online self-learning modules aimed at enhancing pre-service teachers' ICT competencies, noting significant improvements in academic performance following the intervention. These studies suggest that technology can serve as an effective tool in enhancing critical thinking and ICT skills but also highlight challenges such as students' varied access to digital resources and potential issues with sustained engagement. (Supnoon & Chonchaiya, 2024) found that gamification-based active learning significantly enhanced critical thinking but did not improve self-efficacy among 11th-grade students. This distinction raises questions about how different educational approaches might affect cognitive versus affective student outcomes and suggests that gamification may need to be adapted to support self-efficacy explicitly. (Benjakul, 2023) investigates the application of constructionism in instructional design to promote higher-order thinking, demonstrating that thoughtful instructional design is crucial for effective 21st-century skills development. His study emphasizes that teachers' understanding of learning theories and instructional models is essential for fostering students' critical thinking, analytical skills, and adaptability. However, this research, as well as others in similar domains, reveals a gap in empirical evaluations of different instructional design models, suggesting the need for comparative studies to determine the effectiveness of various frameworks in diverse classroom settings.

A notable trend is the focus on teacher competencies necessary to implement 21st-century skills education. (Retnawati et al., 2023) investigate the effects of lesson study (LS) activities on English as a Foreign Language (EFL) teachers' competency in Indonesia, finding that LS improves professional knowledge, learning practices, and student engagement. This research supports the use of collaborative, reflective professional development models to enhance teacher competencies. Meanwhile, (Louis et al., 2024) propose a conceptual model for teacher professional development (TPD) in financial literacy, underlining the importance of content coherence, active learning, and collaboration in TPD initiatives. These studies underscore the critical need for targeted professional development that equips teachers with practical, relevant skills to address evolving curriculum demands. While existing studies provide valuable insights into effective teaching strategies for 21st-century skills, several gaps remain.

Second, current literature often examines specific competencies in isolation, such as critical thinking or ICT skills, without considering holistic skill development that integrates cognitive, affective, and interpersonal domains. Future research should focus on multifaceted competency models that reflect the interconnected nature of the 4Cs and assess interventions across broader, more diverse populations. Finally, while professional development programs for teachers are recognized as essential, few studies have quantitatively assessed the direct impact of such programs on student learning outcomes. Budiarmo et al., (2024) and Wijayanto et al., (2023) present a unique perspective on how these competencies manifest in pre-service teacher behaviors and communication skills within student-centered interactions. Both studies illustrate the relevance of compassion and mathematical communication skills as essential components in teacher education, suggesting that these soft skills are just as critical as cognitive competencies in developing professional and adaptable educators. (Budiarmo et al., 2024) focus on compassion skills, a subset of 21st-century skills that emphasize teachers' social and emotional competencies. This study reveals that compassion, encompassing generosity, friendliness, wisdom, sensitivity, and tolerance, is a core quality in pre-service science teachers, which can significantly impact

teacher-student and peer interactions. Complementing the focus on compassion, (Wijayanto et al., 2023) investigate mathematical communication skills—a vital cognitive competency that also fosters social interaction among students.

A bibliometric analysis of recent studies on 21st-century skills reveals several research trends and gaps. Both studies highlight that empathy, social skills, and collaboration are integral to effective teaching. However, there is a notable gap in exploring how these skills are consistently applied and measured across diverse teaching contexts and subjects. The emphasis on cognitive skills, like mathematical communication, is less balanced with soft skills in the broader literature, reflecting a need for more integrative studies that assess multiple competencies simultaneously.

In conclusion, while studies by (Budiarso et al., 2024). and (Wijayanto et al., 2023). contribute significantly to understanding 21st-century skills in teacher competencies, further research is essential to comprehensively address gaps in compassion and communication skills, which are critical yet under-researched. Future studies should focus on multi-contextual, longitudinal, and cross-disciplinary approaches to better align teacher training with evolving educational needs. Additionally, addressing resource disparities and scaling innovative professional development programs will be key to equipping educators with the adaptable competencies required for modern education. This integrated approach will help bridge knowledge gaps and create a more robust framework for preparing teachers and students for future challenges.

Research Question

1. What are the trend in 21st Century Learning Skills And Teacher Competencies according to the year of publication?
2. Who writes the most cited articles?
3. What is the popular subject?
4. Who is the top ten authors based on citation by research?
5. What are the most cited articles?
6. What are the popular keywords related to the study?
7. What are co-authorship countries' collaboration?

METHODOLOGY

Bibliometrics refers to the process of collecting, organizing, and analyzing bibliographic data from scientific publications (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). It involves not only basic descriptive statistics like journal titles, publication years, and main authors (Y. C. J. Wu & Wu, 2017), but also more complex methods such as document co-citation analysis. Conducting a thorough literature review requires an iterative process that includes identifying key keywords, performing literature searches, and analyzing sources to build a reliable and comprehensive bibliography (Fahimnia et al., 2015). This study focused on top-tier publications, as they offer valuable insights into the theoretical development of the research field. To ensure the data's accuracy, the research relied on the SCOPUS database for data collection (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017). Only peer-reviewed academic articles were included in the analysis, deliberately excluding books and lecture notes to maintain high publication quality (Gu et al., 2019). SCOPUS, known for its broad coverage, provided publications from 2020 to December 2023 for this study's analysis.

Data Search Strategy

Study employed a screening sequence to determine the search terms for article retrieval. Study was initiated by querying Scopus database with online TITLE-ABS-KEY ((21st AND century AND learning AND skill* AND

teacher* AND competenc*) OR "teacher abiliti*" OR "teacher proficiency" OR "teacher capability") AND (LIMIT-TO (LANGUAGE , "English")) AND (EXCLUDE (PUBYEAR , 2025)), refinement included 1101 articles which was used for bibliometric analysis. As of November 2024, all articles from Scopus database relating e 21st Century Learning Skills And Teacher Competencies, were incorporated in the study. The data only used English language.

Data Analysis

VOSviewer is an accessible bibliometric software created by Nees Jan van Eck and Ludo Waltman at Leiden University in the Netherlands (van Eck & Waltman, 2010, 2017).). Popular for its ability to visualize and analyze scientific research, the tool excels in producing clear network visualizations, clustering related data points, and creating density maps. It enables in-depth exploration of co-authorship, co-citation, and keyword co-occurrence networks, offering researchers a broad view of academic trends. With an interactive design and regular updates, VOSviewer supports dynamic analysis of extensive datasets. Its capabilities to calculate metrics, customize visuals, and work with multiple bibliometric data sources make it an invaluable tool for researchers delving into complex research areas.

A key strength of VOSviewer lies in its ability to turn complex bibliometric data into visually accessible maps and charts. Specializing in network visualization, the software is adept at clustering related items, mapping keyword co-occurrence, and creating density maps. Its intuitive interface allows both new and seasoned researchers to efficiently explore research landscapes. With ongoing updates, VOSviewer remains a leader in bibliometric analysis, offering valuable insights through metrics calculations and customizable visuals. Its flexibility with different bibliometric data types, such as co-authorship and citation networks, makes VOSviewer a versatile and essential resource for scholars seeking to gain deeper insights into their research fields.

Publication datasets, containing details such as publication year, title, author names, journal, citations, and keywords in PlainText format, were obtained from the Scopus database for the period between 1945 and November 2023. These datasets were subsequently analyzed using VOSviewer software version 1.6.19, which employed VOS clustering and mapping techniques to generate visual maps. Unlike the traditional Multidimensional Scaling (MDS) method, VOSviewer places items in low-dimensional spaces where proximity reflects their relatedness and similarity (van Eck & Waltman, 2010), offering an approach similar to MDS (Appio et al., 2014). However, rather than relying on similarity metrics like cosine and Jaccard indices, as used in MDS, VOSviewer normalizes co-occurrence frequencies using association strength (AS_{ij}), calculated as outlined by (Van Eck & Waltman, 2007).

$$AS_{ij} = \frac{C_{ij}}{W_i W_j}$$

RESULT AND FINDING

What are the research trends in 21st Century Learning Skills And Teacher Competencies according to the year of publication?

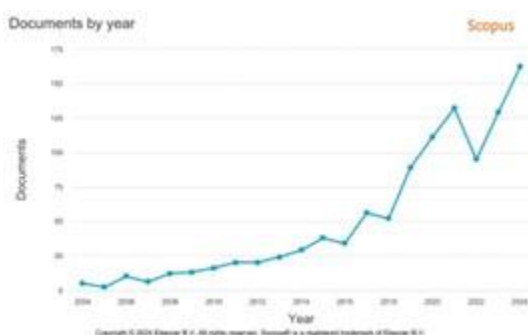


Fig. 1: Plotting document publication by years.

The graph shows the trend of Scopus document publications from 2004 to 2024. The number of documents has steadily increased over the years, with a steep rise observed from 2016 onwards. In 2004, the number of documents was around 5, which increased to over 150 by 2022. The graph suggests a growing interest and research activity in the field of "21st Century Learning Skills And Teacher Competencies" during the analyzed time period.

Who writes the most cited articles?

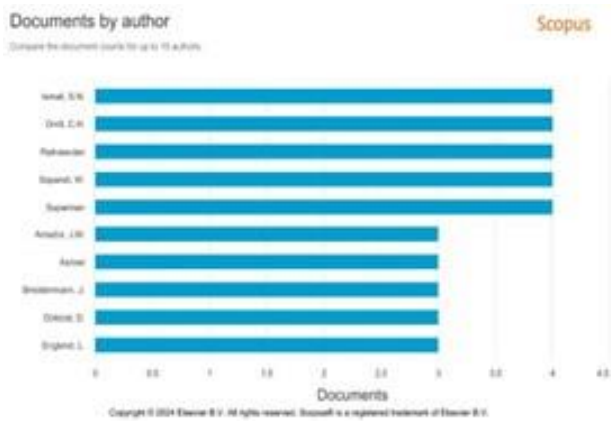


Fig 2: Top ten most cited authors

The figure presents a bar chart showing document counts for the top authors publishing research on "21st Century Learning Skills and Teacher Competencies." Five authors - Ismail S.N., Orrill C.H., Ratnawulan, Sopandi W., and Suparman - have each published 4 documents, demonstrating their consistent contribution and dedication to research in this field. These authors appear to be the most prolific researchers in terms of publication quantity.

The remaining five authors - Amador J.M., Asrowi, Breddermann J., Dolezal D., and England L. - have each published 3 documents. This indicates a strong research presence, though slightly less prolific than the top group. The relatively even distribution of publications among these top 10 authors (ranging from 3-4 documents each) suggests a healthy competitive research environment where multiple scholars are actively contributing to the advancement of knowledge in 21st century learning skills and teacher competencies.

TABLE I: TOP TEN AUTHOR

Author Name	Number Of Document	Percentages (%)
Ismail, S.N.	4	0.36
Orrill, C.H.	4	0.36
Ratnawulan	4	0.36
Sopandi, W.	4	0.36
Suparman	4	0.36
Amador, J.M.	3	0.27
Asrowi	3	0.27
Breddermann, J.	3	0.27
Dolezal, D.	3	0.27
England, L.	3	0.27

The data indicates that several authors have made modest contributions to the research on 21st-century learning skills and teacher competencies, with each leading author contributing between three and four documents. Authors like Ismail, S.N., Orrill, C.H., Ratnawulan, Sopandi, W., and Suparman each account for 0.36% of the total publications, marking them as the most frequently contributing authors within the dataset. While these percentages seem small, this level of contribution is relatively significant in a specialized research area where knowledge and expertise are often distributed across a wide field of scholars.

The second group of authors, including Amador, J.M., Asrowi, Breddermann, J., Dolezal, D., and England, L., each contributed three documents, making up 0.27% of the total publications per author. This group demonstrates the collaborative and distributed nature of bibliometric research in educational competencies, where multiple authors contribute at similar levels, collectively enriching the field's body of knowledge. Such contributions, though not high in individual document counts, highlight a collaborative framework that is typical of educational research, where insights are often built upon incremental contributions from multiple researchers.

Overall, the authors' contributions reflect a decentralized research landscape with numerous smaller contributions rather than dominance by a single researcher or small group. This structure suggests a field that values diverse perspectives and cross-institutional collaboration, likely due to the varied educational contexts across regions and countries. The data may also suggest a need for greater concentration or synthesis in the field, where further collaboration or joint publications could strengthen the impact of these dispersed efforts.

What is the popular subject?

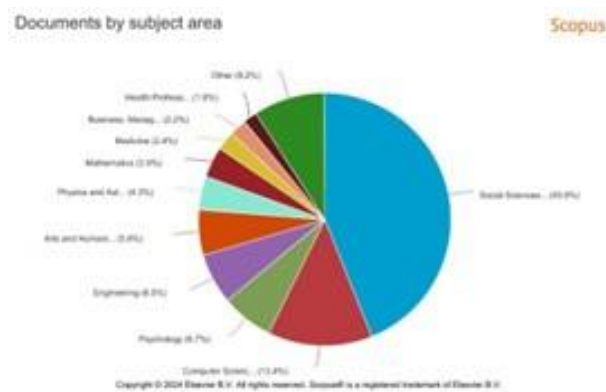


Fig. 3: Document by subject

The pie chart shows the distribution of publications in the field of "21st Century Learning Skills And Teacher Competencies" across different subject areas based on Scopus data. The dominant subject area is Social Sciences, accounting for 43.9% of the publications. This suggests a strong focus on the social and educational aspects of 21st century learning skills and teacher competencies in the research.

The next largest subject areas are Computer Science (13.4%) and Psychology (6.7%), indicating significant contributions from these disciplines as well. The remaining subject areas, such as Arts and Humanities (5.8%), Engineering (6.5%), and Mathematics (3.9%), also have notable representation, highlighting the interdisciplinary nature of this research field.

Who is the top 10 authors based on citation by research?

TABLE II: TOP 10 AUTHORS BASED ON CITATION BY RESEARCH

Authors	Title	Year	Source title	Cited by
(Darling-Hammond, 2000)	How teacher education matters	2000	Journal of Teacher Education	540

(Chai et al., 2013)	A review of technological pedagogical content knowledge	2013	Educational Technology and Society	342
(González-pérez & Ramírez-montoya, 2022).	Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review	2022	Sustainability (Switzerland)	198
(Nouri et al., 2020)	Development of computational thinking, digital competence and 21st century skills when learning programming in K-9	2020	Education Inquiry	196
(Uerz et al., 2018)	Teacher educators' competences in fostering student teachers' proficiency in teaching and learning with technology: An overview of relevant research literature	2018	Teaching and Teacher Education	177
(Looney et al., 2018).	Reconceptualising the role of teachers as assessors: teacher assessment identity	2018	Assessment in Education: Principles, Policy and Practice	166
(Santagata & Angelici, 2010)	Studying the Impact of the Lesson Analysis Framework on Preservice Teachers' Abilities to Reflect on Videos of Classroom Teaching	2010	Journal of Teacher Education	159
(Anderson & Maninger, 2007)	Preservice teachers' abilities, beliefs, and intentions regarding technology integration	2007	Journal of Educational Computing Research	157
(Granziera & Perera, 2019)	Relations among teachers' self-efficacy beliefs, engagement, and work satisfaction: A social cognitive view	2019	Contemporary Educational Psychology	156
(Romero et al., 2015)	Can serious games contribute to developing and sustaining 21st century skills?	2015	Games and Culture	151

The most-cited article in this bibliometric analysis is "How teacher education matters" by Darling-Hammond (2000), with 540 citations. This study, published in *Journal of Teacher Education*, underscores the foundational importance of teacher education in influencing teaching quality and student outcomes. Its high citation count highlights the article's influence on the field, indicating that it has been widely used as a theoretical and empirical basis in subsequent research on teacher education and competencies. Its citation frequency suggests its role in shaping perspectives on how well-prepared educators can better implement 21st-century skills in the classroom, addressing both competency and effectiveness in teaching.

Following Darling-Hammond, the 2013 article by Chai et al., titled "A review of technological pedagogical content knowledge," is the second most-cited work with 342 citations, published in *Educational Technology and Society*. This review addresses the integration of technology in education, which is crucial for developing teacher competencies in the 21st century. The high citation count reflects the importance of technological pedagogical content knowledge (TPACK) in equipping teachers with skills to integrate technology effectively. It underscores that teacher preparation programs increasingly focus on digital competence, aligning with the technological demands of contemporary education.

Additional articles, such as González-pérez and Ramírez-montoya's (2022) "Components of Education 4.0 in 21st Century Skills Frameworks," and Nouri et al.'s (2020) study on computational thinking, illustrate emerging areas of focus within the field. With 198 and 196 citations respectively, these studies highlight the increasing importance of digital competencies and Education 4.0 frameworks, which are integral for modernizing

educational systems and aligning them with industry demands. Collectively, these highly-cited works demonstrate a progression from foundational theories of teacher education to contemporary frameworks that address digital and technological skills, affirming a shift towards competencies essential for navigating the complexities of modern learning environments.

What are the popular keywords related to the study?

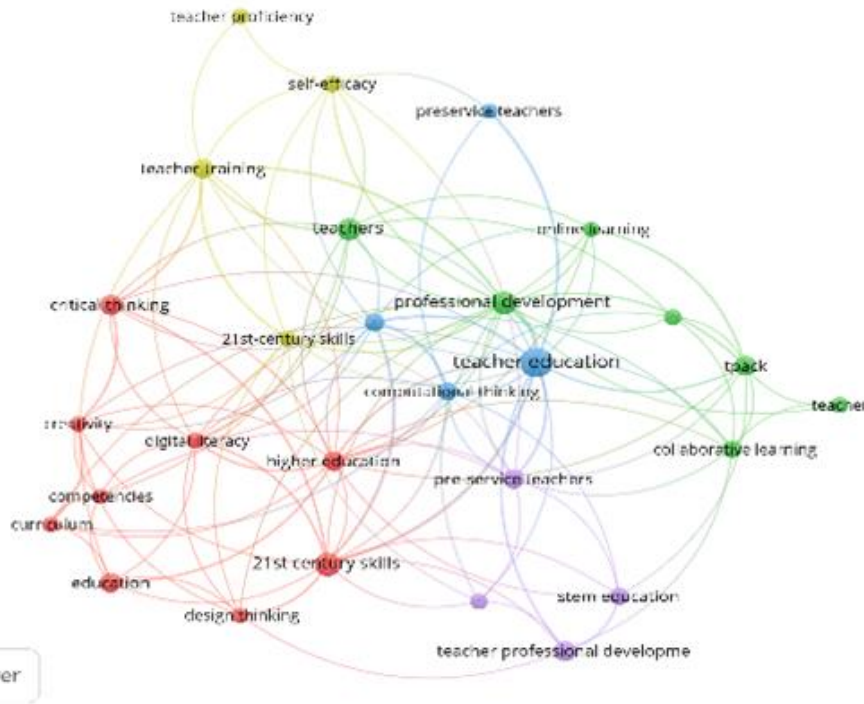


Fig. 4 : Network visualization map of keywords' co-occurrence

The keyword analysis from VOSviewer data reveals key trends in the study of 21st-century learning skills and teacher competencies. The 20 most keywords are teacher educations, 21st century skills, professional development, teachers, 21st century learning, technology intergration, teacher knowledge, higher education, preservice teacher, computational thinking, stem, self efficacy, teacher proficiency, teaching and learning, active learning, professional learning, critical thinking, communication skill, problem solving, collaboration and design thinking.

Figure 4 shows Network visualization map of keywords' co-occurrence. The analysis of keywords from VOSviewer highlights distinct thematic clusters (C1–C5) that represent major research areas in 21st-century learning skills and teacher competencies. These clusters reflect priorities in educational research, including the integration of modern teaching methods, digital skills, and teacher professional development.

- C1 : 21st century learning, 21st century skills, active learning, assessment, critical thinking skills, design thinking, formative assessment, ict, pedagogical content, physical education, pre-service teachers, primary educations, professional development, prospective teachers, self-efficacy, teacher beliefs, teacher knowledge, teacher learning, teacher noticing, teacher proficiency and teacher training. These keywords reveal a focus on equipping educators with the skills and knowledge necessary for 21st-century teaching.
- C2 : Blended learning, covid 19, digital competence, digital skills, elementary school, higher-order thinking skills, inclusive education, information literacy, instructional design, lesson study, mathematics, mathematics education, online learning, project-based learning, science education, stem, stem education, teacher professional development, teachers. The integration of digital and interactive teaching methods reflects adaptations in response to technological advancements and the global shift to online learning, particularly during the COVID-19 pandemic.

- C3 : 21st century, collaboration, communication, competency, computational thinking, creativity, critical thinking, digital literacy, e-learning, educational technology, higher education, problem solving, programming, teacher development, teacher preparation, technology. This cluster underscores the necessity of fostering these skills in students while preparing teachers to integrate them effectively into curricula.
- C4 : 21st century skills, collaboration learning, game-based learning, ict intergration, per-service teacher, rasch analysis, student teachers, teacher educations, teaching anf learning, technology intergration and tpack. The inclusion of teacher education and pre-service teacher training indicates efforts to align teacher preparation with cutting-edge educational frameworks like TPACK.
- C5: artificial intelligent, competence, competencies, curriculum, education, learning, pedagogy, teacher, teaching and training. This cluster includes overarching concepts of learning and competency, providing a macro-level view of the educational priorities related to teacher training and general education strategies.

What are co-authorship countries' collaboration?

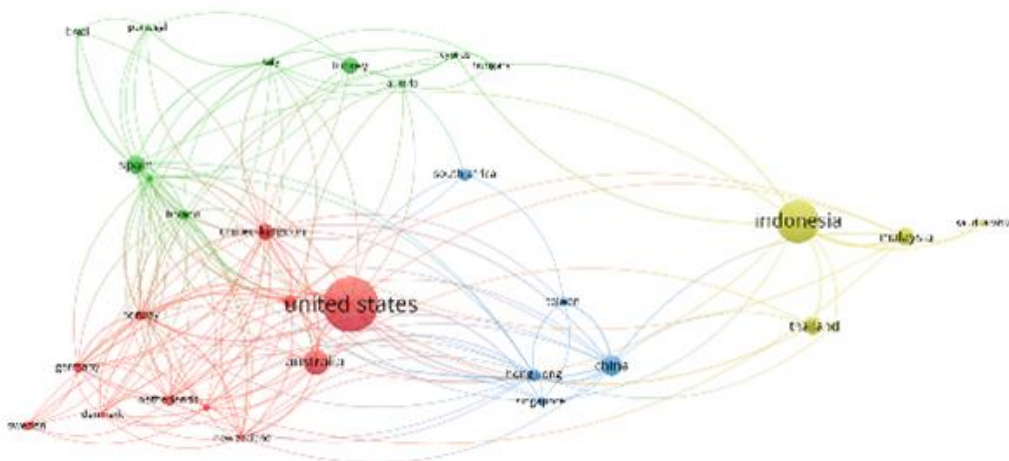


Fig. 5: Map of network visualization co-authorship countries collaboration

The data on country contributions to research in 21st-century learning skills and teacher competencies highlights significant global disparities. The United States stands out with the highest number of publications (229) and citations (4391), along with the highest co-authorship count (65), which indicates its prominent influence and active international collaboration in this field. The United Kingdom also shows strong research activity, with 41 publications, 728 citations, and 49 co-authorships, reflecting its leading role in educational research within Europe and globally. These figures suggest that both the U.S. and U.K. have well-established research frameworks and significant resources dedicated to exploring teacher competencies and 21st-century learning skills.

Several Asian countries, notably Indonesia, China, and Singapore, also show substantial research output. Indonesia leads the region with 156 publications, though its citation count (594) is relatively modest, suggesting growing but still developing impact within the international academic community. China and Singapore, with 56 and 18 publications respectively, also show considerable engagement, which aligns with these countries' investments in education reform and technology integration in schools. Hong Kong and Malaysia contribute as well, with moderate publication and citation counts, underscoring the broader trend of increasing research activity across Asia as educational systems modernize to meet 21st-century demands.

European countries like Germany, the Netherlands, and Spain also contribute notably, each with moderate publication and citation counts, reflecting strong, regionally impactful research. Smaller European countries, such as Finland, Ireland, and Italy, have fewer publications but relatively high citation counts, suggesting their research has a concentrated influence. In contrast, countries such as Chile, Kuwait, and Nigeria have low publication and citation counts, indicating emerging research activity that may reflect limited resources or differing national priorities in educational research. Overall, the data reveals both established and emerging research hubs, influenced by factors like research funding, educational policy emphasis, and regional collaboration networks.

LIMITATION AND DELIMITATION OF THE STUDY

This study presented several limitations that should be acknowledged. First, the article retrieval process relied solely on the Scopus database, potentially excluding relevant articles indexed in other databases, which may provide additional insights. The use of a specific search query targeting keywords such as "21st century learning skills" and "teacher competencies" might have limited the scope by omitting studies using different terminologies or contexts. Second, the inclusion criteria restricted the analysis to articles published in English, potentially excluding valuable research published in other languages, which may have regional or localized perspectives. Lastly, the data collection cut-off in November 2024 may have excluded recent publications, particularly those from 2025, leading to a lack of the most current research developments in the field.

These limitations suggest the need for broader and more inclusive approaches in future bibliometric studies. Specifically, incorporating multiple databases, using more comprehensive search strategies, and extending the temporal scope of analysis could provide a more holistic understanding of the evolving landscape of 21st century learning skills and teacher competencies.

CONCLUSION

The analysis of research trends in 21st-century learning skills and teacher competencies reveals a steady increase in publications over the past two decades, with notable growth from 2016 onward. This surge suggests an expanding global interest in developing competencies necessary for modern educational contexts, potentially driven by technological advancements and evolving teaching methodologies. By 2022, publications had risen significantly, indicating that these areas have become focal points for educational research. This upward trajectory reflects an ongoing commitment within the academic community to explore and address the skills and competencies needed for effective teaching in the 21st century.

The contributions of various authors show a decentralized and collaborative research landscape. Although certain scholars lead in citation counts, contributions remain broadly distributed across many researchers, with no single author or institution dominating the field. This pattern highlights a commitment to collective knowledge-building and interdisciplinary collaboration, with authors from different regions contributing unique insights. Such diversity underscores the importance of varied perspectives in shaping educational competencies across different contexts, suggesting a dynamic and inclusive approach to developing competencies for modern educational needs. This structure points to a field that is enriched by multiple viewpoints, enhancing the adaptability and relevance of the research across diverse educational systems.

The analysis of popular keywords in 21st-century learning skills and teacher competencies highlights a strong emphasis on core competencies such as "critical thinking," "collaboration," and "creativity." These terms underscore a widespread focus on equipping students with skills essential for navigating complex, dynamic environments. Digital integration is also prominent, with keywords like "digital literacy," "computational thinking," and "educational technology" reflecting the increasing incorporation of technology in education. The appearance of terms like "STEM" and "e-learning" aligns with a shift toward digital and blended learning environments, a trend accelerated by global challenges like the COVID-19 pandemic. The frequent mention of "teacher education" and "professional development" further points to a concerted effort to prepare teachers for these evolving educational demands, equipping them with skills to foster both cognitive and digital competencies in students.

In terms of international collaboration, the United States and the United Kingdom lead in research output and citations, reflecting their prominent roles in the field. These countries not only contribute significant publications but also show high co-authorship counts, indicating active collaboration with global research communities. Emerging contributions from Asian countries, particularly Indonesia, China, and Singapore, highlight regional investments in education reform, especially around technology integration. European nations such as Germany, the Netherlands, and Spain also demonstrate strong, regionally influential research, while smaller countries like Finland and Ireland make impactful contributions despite fewer publications. The data reveals a complex global research network, with established leaders and emerging hubs contributing diverse perspectives shaped by regional educational policies, funding, and collaborative efforts.

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