INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 13, Issue 4, (2024) E-ISSN: 2226-6348

Status, Trends and Challenges of TVET Teacher ICT Competencies: Insights from Bibliometric and Thematic Analysis

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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v13-i4/23822 DOI:10.6007/IJARPED/v13-i4/23822

Published Online: 30 November 2024

Abstract

This study reveals the current status, future trends and challenges of technical and vocational education and training (TVET) teacher information and communications technology (ICT) competencies driven by the COVID-19 pandemic and the fourth industrial revolution technologies through bibliometric and thematic analyses of 67 papers since 1960. Despite progress, the field still lacks core productivity and international cooperation. The study shows that while educational interventions have improved TVET teachers' ICT competencies, the effect is not always ideal due to multiple factors. Insufficient attention to TVET teachers needs to be guarded against in the post-pandemic era, and future research will require interdisciplinary collaboration to further improve the TVET teacher ICT competencies framework and continuous development system in order to cope with changing educational needs and technological advances.

Keywords: Status, Trends and Challenges, TVET Teacher, ICT Competencies, Bibliometric, Thematic Analysis

Introduction

Citing Bill Gates, UNESCO emphasizes the need for technical and vocational education and training (TVET) teachers to seamlessly integrate technology into their curricula (UNESCO-UNEVOC, n.d.). To achieve this, teachers must possess information and communications technology (ICT) competencies to prepare learners for the current and future world of work. Teacher ICT competencies are considered to significantly overlap with digital competencies, referring to the confident, critical, and creative use of ICT to achieve broad life goals (European Commission, n.d.; Fernández-Batanero et al., 2022).

Scholars worldwide have reviewed this topic from various perspectives. Tinmaz et al. (2022) systematically reviewed the four key concepts of digital literacy, digital competencies, digital skills, and digital thinking. Nguyen & Habók (2023), systematically synthesized

assessment tools for teacher digital literacy from four perspectives: main content, tool type, reliability and validity reports, and frameworks or models. Revuelta-Domínguez et al. (2022) examined the development of the concept of digital teaching competence, how its dimensions are defined, and how models for educational development and teacher digital teaching competence assessment are constructed. Hernadez et al. (2022), wrote a literature review about digital competencies at both international and national levels papers, aiming to uncover the challenges faced by teachers. In a comprehensive review of the literature on digital competences and teacher professional development, Fernández-Batanero et al. (2022) identified research trends and potential future directions in this field.

To reveal the complexity and diversity of ICT competencies among teachers at various stages of education, scholars have conducted more detailed analyses. Rakisheva & Witt (2023) introduced digital competence frameworks available to educators based on the needs of pre-service teacher training. Masoumi & Noroozi, (2023), systematically reviewed the approaches and facilitating factors for developing professional digital competence in novice teachers. Avci & Pedersen (2023) synthesized existing research on in-service teacher digital competence in K-12 educational contexts over the past decade, focusing on the definition of "digital competence" and its overlap with similar terms. In higher education context, research on teacher ICT competencies covers multiple aspects, including teacher attitudes (Bachalapur & S, 2022); definitions of ICT competencies (Zhao et al., 2021); assessment criteria, processes, and methods (Sillat et al., 2021), as well as training needs and techniques (Basantes-Andrade et al., 2022).

Lahn & Berntsen (2023), questioned to what extent the leading digital competencies conceptual frameworks serve as effective templates for researching such competencies in the context of TVET teacher professional development, and what alternative conceptual models might be suitable for this professional field. However, considering TVET as a critical pathway for personal development and social progress, focusing solely on this aspect of TVET teacher ICT competencies is clearly insufficient. Where is the core productivity in this research field currently centered? What research angles are scholars focusing on regarding TVET teacher ICT competencies? What are the developmental trajectories and future research directions in this research field? To address these research gaps, this study aims to explore the status, trends, and challenges of TVET teacher ICT competencies through bibliometric and thematic analysis.

Methodology

In this study, we employ bibliometric analysis and thematic analysis to gain a comprehensive understanding of the status, trends and challenges in the research field of TVET teacher ICT competencies. Computer software tools, including VOSviewer, CiteSpace, Excel, and NVivo, are employed to assist in the analysis.

Data Sources and Cleaning

This study employed the Web of Science (Core Collection) and Scopus databases to ensure that the data were drawn from a more extensive range of high-quality peer-reviewed journals (Birkle et al., 2020; Mahdi et al., 2024). To ensure comprehensiveness and accuracy of the data, an advanced search was conducted using multiple keywords in the "topic", without limiting publication dates. Following the manual screening of the search results, a total of 67

valid papers were identified. The complete data search and cleaning process is depicted in Figure 1.

Research Methods

Bibliometric analysis is a quantitative method that objectively maps the development of academic research. It permits the extraction and quantification of information such as authors, publication years, keywords, journals, regions, and references from existing literature. These external characteristics and relationships in the literature are subjected to mathematical and statistical tests (Donthu et al., 2021 ; Linnenluecke et al., 2020). Computer software, such as Excel, VOSviewer, and CiteSpace, is employed to visualize the information, thereby creating maps that intuitively display the knowledge structure of the research field of TVET teacher ICT competencies. It helps us quickly grasp the current research status and hotspots, as well as predict its trends and tendencies (Chen, 2018; Eck & Waltman, 2009).

Thematic analysis is a qualitative research method that reveals deeper meanings by identifying, analyzing, and reporting patterns or themes within data. It can be outlined as a six-step process of familiarizing with data, generating initial codes, searching for themes, reviewing themes, defining themes, and producing a report (Braun & Clarke, 2006). Using coding and querying function by NVivo, key concepts in literature can be systematically tagged and categorized, allowing for tracking theme evolution and identifying relationships between themes (Allsop et al., 2022). Additionally, NVivo's visualization tools construct thematic networks that intuitively display the complexity and diversity of the research field of TVET teacher ICT competencies, aiding in understanding current research dynamics and potential challenges.

Bibliometric Analysis

This study included 67 papers published between 1960 and June 16, 2024, sourced from the Web of Science (Core Collection) and Scopus databases. According to VOSviewer statistics, these papers originated from 24 countries/regions and were authored by 220 authors affiliated with 105 organizations. They were published in 56 different journals. The primary languages of the papers were English (54 papers) and Spanish (8 papers). The total number of references across these papers was 1948, drawn from 1638 journals.

Trends in the Publications

Researchers used data from Citespace's log to plot the publication trends, as shown in Figure 2 created using Excel. Research papers on TVET teacher ICT competencies first appeared in 2005. The goodness of fit for the second-order polynomial monitoring results was $R^2 = 0.9766$, which is close to 1, indicating that the model effectively explains the data's variability. Publications exhibited nonlinear growth: before 2020, the accumulated papers were relatively low, but from 2020 onwards, there was a significant increase. After peaking in 2021, the number of annual publications stabilized at over ten papers per year. Due to incomplete data for the year 2024, detailed discussion is not feasible at this time. However, based on current trends, it is anticipated that the number of publications in 2024 will exceed ten.

This trend of publication occurred concurrently with the broader historical context. The outbreak of the COVID-19 pandemic in 2020 prompted a rapid global shift towards online

and blended learning modes in the education system, necessitating TVET teachers to rapidly enhance their ICT competencies to adapt to remote and digital educational environments (ILO-UNESCO, 2020; UNESCO, 2020). Subsequently, with the advancement of the fourth industrial revolution, various emerging technologies such as artificial intelligence (AI), internet of things (IoT), and big data continue to emerge. Governments and international organizations are increasingly emphasizing and supporting ICT competencies through policy measures (UNESCO International Centre for Technical and Vocational Education and Training, 2022).

Co-occurrence Analysis

Authors

Using VOSviewer, a co-authorship network was constructed for 220 authors divided into 54 clusters. According to Price's Law, a core author group forms when the publications of core authors constitute 50% of the total publications (Price, 1963). The formula is $N = 0.749 (Nmax)^{1/2}$, where Nmax represents the number of publications by the most prolific author during the period. Upon calculation, Nmax=5 and N=1.674. Therefore, authors who have published more than two papers are considered core authors in this field (Table 1). There are a total of seven core authors, with a combined publication count of 24 papers, accounting for 35.8% of the total publications. Hence, the core author group in this field has not yet fully formed

Among the core authors, two stable collaborative groups can be identified. Antonietti Chiara, Cattaneo Alberto, Rauseo Martina, and Amenduni Francesca are all affiliated with the Swiss Federal University for Vocational Education and Training. They have been actively publishing research papers on the influencing factors and impacts of vocational teacher digital competence, as well as their effects on school digital transformation, during the period from 2021 to 2023 (Amenduni et al., 2022; Cattaneo et al., 2021, 2022; Rauseo et al., 2023). The team from Universidad de Granada in Spain, consisting of Lopez-Belmonte Jesus, Pozo-Sanchez Santiago, and Moreno-Guerrero Antonio-Jose, focuses more on the impact of vocational training teacher digital teaching competence on the practice of blended learning. They published several related papers in 2020 (Lopez-belmonte et al., 2020; Lopez-Belmonte, Jose Moreno-Guerrero, et al., 2020; Lopez-Belmonte, Moreno-Guerrero, et al., 2020).

Organizations and Countries

VOSviewer divided 105 organizations into 51 clusters. The organization with the highest number of publications is the Universidad de Granada in Spain, with a total of six papers and 33 citations. Following this is the Swiss Federal University for Vocational Education and Training from Switzerland, with five papers and 103 citations (ranked first). Notably, Kazan Federal University in Russia has only two publications, but its average citation count is exceptionally high at 49.5.

Further analysis of the co-occurrence map of countries reveals no international collaborative research in this field. Spain ranks first with 20 publications, followed by Ukraine and Russia with eight and seven publications, respectively. Switzerland is the most influential country, with 103 citations, followed by Spain and Ukraine with 76 and 36 citations, respectively.

Journals

According to VOSviewer statistics, the 67 papers were published across 56 journals. Most of these journals belong to the fields of educational technology, computer education, and engineering technology. Table 2 presents the top three journals in terms of papers published and citations. None of the three most published journals have an average citation of more than five, while the three most cited journals all published only one paper. This indicates that the impact of papers in this field is not journal-related.

Additionally, Bradford's law states that in a specific research field, journals can be divided into three groups such that each group contains approximately the same number of papers, but the ratio of the number of journals in each group increases exponentially (Bradford, 1934). However, when dividing the 56 journals into three groups, with each group approximately containing 22 papers, the resulting ratio is 18:22:22, which does not follow the exponential increase pattern. Therefore, this field has not yet formed a stable core group of journals.

Keyword Analysis

Cluster

22 keywords with a frequency greater than three were selected, and a co-occurrence map was generated by Citespace, as shown in Figure 3. The larger the radial nodes and font size, the higher the frequency of the keywords, and the thicker the connecting lines, the stronger the co-occurrence relationships between the keywords. The color of the radial nodes and connecting lines represents the years in which the keywords appeared, following the legend in the lower-left corner, with colors ranging from lower to higher years incrementally.

"Digital Competence" (15 times), "Vocational Training" (9 times), "Vocational Education" (9 times), "Vocational Education and Training" (9 times), "Education" (5 times), "Teacher Training" (5 times), "E Learning" (5 times), and "Blended Learning" (5 times) are the representative terms in this field, given their frequency of occurrence greater than five. "E Learning" and "Blended Learning" reflect the research context of TVET teacher ICT competencies, while the other keywords are descriptive terms for this field.

Further utilizing Citespace's "all in one" function to cluster keywords, eight clusters with a size greater than ten were identified (Table 3).

#0 Digital Teaching Competence and #2 Educational Process both focus on the preparation and enhancement of TVET teacher ICT competencies. The former emphasizes blended learning methods and their impact on student motivation (Artemov et al., 2023; Dziabenko et al., 2012a; Lopez-belmonte et al., 2020), while the latter pays more attention to changes and demands in the educational environment (Golovina & Shcherbakova, 2021; Romanova et al., 2022; Svoboda, 2022; Zabolotska et al., 2021).

#1 Digital Health and #5 Vocational Education concentrate on specific populations such as individuals with cognitive impairments and particular fields like healthcare and agriculture (Houwink et al., 2020; Kovalchuk & Zaika, 2021; Kulju et al., 2024), emphasizing the practical application and effectiveness of ICT competencies (Batz et al., 2021; Guillen-Gamez et al., 2023; Riviou et al., 2014).

#3 Information Technology and #6 Digital Transformation emphasize the application of ICT tools in education and highlight their importance in enhancing teacher ICT competencies. The former focuses on tools like AR and new media (Lopez-Belmonte, Moreno-Guerrero, et al., 2020; Totter et al., 2005), while the latter explores e-learning systems, hermeneutic model and skill enhancement courses (Del Prete, 2017; Neupokoeva & Chapaev, 2021; Zwart et al., 2017).

#4 Digital Competence expands the research subjects to pre-service teachers, focusing on improving teacher ICT competencies through appropriate training and model development. It emphasizes the significant impact of ICT competencies development on educational outcomes and teaching methods (Lopez-Belmonte, Jose Moreno-Guerrero, et al., 2020; Misnevs et al., 2021; Moreno Guerrero et al., 2019).

#7 Educational Technology focuses on the digital demands and challenges in the context of the COVID-19 pandemic, emphasizing the critical role of educational institutions in advancing the digitalization process and the skills and support needed by teachers in this process (Cattaneo et al., 2021; Kovalchuk et al., 2022; Muktiarni et al., 2023; Rauseo et al., 2023).

All clusters emphasize the importance of TVET teachers' ICT competencies and how they can be enhanced through various methods such as training and technology. Most clusters also discuss the application and effectiveness of different educational technologies in TVET teaching and the impact of digital transformation on the education system and teachers. Together, these clusters provide a comprehensive view of the enhancement of TVET teacher ICT competencies.

Timeline

Citespace's Timeline View provides a clear visualization of the development trends in this field. Figure 4 displays eight clusters, arranged from top to bottom according to their size. The horizontal axis represents time, spanning from 2005 to 2024. Keywords with a frequency greater than three are shown on the horizontal axis, with their positions indicating the time of their first appearance. The meaning of radial nodes is the same as its meaning in the co-occurrence mapping. The solid lines on the horizontal time axis represent the lifecycle length of each cluster, while the dashed lines indicate the periods when the clusters were inactive.

The research in this field can be roughly divided into three stages. The clusters #0 Digital Teaching Competence and #2 Educational Process have the longest time spans, covering nearly the entire timeline of the study. The clusters #1 Digital Health, #3 Information Technology, and #4 Digital Competence began to attract researchers' attention around 2012-2013. The clusters #5 Vocational Education, #6 Digital Transformation, and #7 Educational Technology emerged predominantly in the period leading up to the outbreak of the COVID-19 pandemic in 2018. All clusters showed increased activity during the pandemic years of 2019-2022.

When time-slicing for 2022-2024 separately, it is observed that, except for #0 Digital Teaching Competence and #3 Information Technology, other clusters continued to receive varying degrees of attention. Further monitoring for bursts using Citespace, no bursts were

observed with a strength greater than three, which indicating that there were no significant research hotspots.

Co-citation Analysis

References

Setting the threshold for the minimum number of citations of a cited reference to three, the reference co-citation mapping by VOSviewer contains 23 references. As shown in Figure 5, the co-citation network is divided into three major clusters represented by different colors. The green cluster primarily comprises research literature on the European Union's *Digital competence of educators* (DigComEdu) and TPACK theory. The red cluster focuses on research by Spanish scholars on teachers' digital teaching competence. The blue cluster predominantly includes literature on surveys and analysis of ICT competencies among TVET teachers and pre-service teachers. Most highly cited references were published after 2017, with earlier publications on TPACK theory providing theoretical support to the research (Mishra & Koehler, 2006).

Journals

In Table 4, among the top five journals by co-citations, all except Pixel-Bit- Revista De Medios Y Educacion (Q2) are categorized as Q1 in their respective JCR categories. The top two journals are interdisciplinary journals bridging computer science with education and computer science with psychology. The remaining journals are all within the field of educational research. Both Comunicar and Pixel-Bit- Revista De Medios Y Educacion are Spanish-language journals.

Authors

Based on further analysis using VOSviewer to construct the co-authorship network with a minimum threshold of five citations per cited author, we identified 26 authors for co-authorship analysis. The highly co-cited authors are grouped into four major clusters, each centered around one or two key authors. Yellow cluster centered around Christine Redecker, author of DigComEdu (Redecker & Punie, 2017). Alberto A. P. Cattaneo in red cluster, who leads the Swiss Federal Institute for Vocational Education and Training, specializing in TVET, teacher education, and educational technology. Julio Cabero Almenara is the center of blue cluster, who is a professor at Universidad de Sevilla in Spain, focusing on ICT applications in education and involved in the Spanish adaptation of Digital competence of educators (Cabero-Almenara & Palacios-Rodríguez, 2020). The green cluster encompassing UNESCO's ICT Competency Framework for Teachers (ICT CFT) and Punya Mishra's TPACK theory (Mishra & Koehler, 2006; UNESCO, 2018).

Thematic Analysis

In this study, with the help of NVivo, 67 papers were analyzed by themes to get 251 reference points. These reference points were categorized and coded into two primary codes: "Trends" and "Challenges." The code "Trends" was further divided into five secondary codes and six tertiary codes (as shown in Figure 6). Similarly, the code "Challenges" was divided into four secondary codes and 16 tertiary codes (as shown in Figure 7).

Trend Analysis

Digitalization is currently regarded as the most significant and urgent mega-trend shaping the evolution of TVET systems. The level of ICT application in educational processes influences

educational quality and fosters the development of students' ICT competencies (Cattaneo et al., 2021; Kravchynska et al., 2021). TVET institutions are widely adopting various educational technologies, compelling teachers to adapt to new educational environments (Burns et al., 2020).

Therefore, TVET teacher ICT competencies have become crucial. They are expected to possess comprehensive capabilities in integrating technology, information, values, teaching, and communication(Garcia-Delgado et al., 2023; Moreno Guerrero et al., 2019). TVET teachers need to continually enhance their professional skills, effectively integrating the advantages of educational technologies into teaching practices, and even driving the digital transformation of TVET institutions in reverse (Cattaneo et al., 2021). Their roles are being redefined from mere knowledge transmitters to builders, facilitators, coaches, and content creators (Burns et al., 2020; Golovina & Shcherbakova, 2021).

There is growing awareness of the continual development and implementation of educational intervention methods contributing to enhancing TVET teacher ICT competencies (Kulju et al., 2024; Mercader & Gairin, 2021). The Russian education sector reports that over 80% of teachers have undergone further education or professional retraining in the past three years (Burns et al., 2020). Research by Wannapiroon et al., (2022) indicates that 93.19% of trained TVET teachers have passed assessments in ICT competencies. The Ministry of Education and Science of Ukraine has conducted a series of effective studies in the field of vocational education, yielding significant results (Lazarenko et al., 2023). Kovalchuk & Zaika (2021) identified multiple indicators for TVET teacher ICT competencies. Ukrainian higher education institutions have introduced professionally oriented software, providing practical opportunities for ICT competencies development among pre-service teachers and vocational education specialists (Yezhova et al., 2019). Shcherbyna (2021) discusses an open professional development system for teachers combining informal and formal education, corporate training, and workplace learning. Additionally, an agricultural university has developed psychological and educational support programs based on the absorption level of teaching content and subject matrices (Zakharov et al., 2021).

Fortunately, the enhancement of teachers' ICT competencies is becoming a noticeable trend, as they gradually adopt and apply ICT. Golovina & Shcherbakova (2021) highlight that 31% of teachers improve their ICT competencies through community support, while 41% use online platforms for professional development. Pre-service teachers in Kazakhstan demonstrate a certain level of awareness regarding ICT competencies (Shagataeva et al., 2021). Students in Galicia specializing in vocational training generally hold a positive attitude towards ICT, viewing its use as a preventive measure against obsolescence and a facilitator for improving teaching practices (Kravchynska et al., 2021). Zakharov et al. (2021) point out that teachers commonly express interest in tools such as video conferencing, interactive content, and oral response modules.

Challenges Analysis

TVET teachers have not yet reached the optimal level of ICT competencies required by current teaching environments. TVET teacher ICT competencies are fragmented, with different scholars not reaching a unified conclusion. The ICT competencies level of Swiss TVET teachers is considered capable of addressing common cognitive challenges (Amenduni et al., 2022),

while pre-service TVET teachers in Kazakhstan demonstrate a moderate level of ICT competencies (Bitemirova et al., 2023). Kravchynska et al. (2021) note that teachers exhibit high levels of information literacy and communication skills. However, some scholars argue that teachers perform well in the storage and retrieval of information, data and digital content but overlook the development of information literacy and media literacy (Moreno-Guerrero et al., 2020). Other scholars point out that the rapid evolution of educational technology has created a noticeable gap in technological applications between teachers and students (Batz et al., 2021; Kovalchuk et al., 2022; Lopez-Belmonte, Moreno-Guerrero, et al., 2020).

On the other hand, there are significant gaps and challenges among teachers in their ability and methods to integrate ICT into teaching practices. Some teachers struggle to translate their ICT competencies from training into actual work scenarios. Research by Batz et al. (2021) indicates that fewer than half of teachers use computers in their daily or weekly lesson preparations. Variations in digital competencies among students at different educational levels also confuse teachers when designing standardized learning strategies and teaching methods (Moreno Guerrero et al., 2019). Integrating emerging technologies such as augmented reality (AR) into teaching practices poses a challenge for teachers in ICT application, while optimizing data to provide students with the best feedback presents another challenge (Garcia-Delgado et al., 2023; Lopez-Belmonte, Moreno-Guerrero, et al., 2020). Furthermore, scholars point out that the complexity of TVET spanning different locations (schools and workplaces) adds to the difficulties teachers face in integrating technology (Antonietti et al., 2022; Cattaneo et al., 2022; Wannapiroon et al., 2022)

The formation of ICT competencies among TVET teachers is influenced by various personal factors, which exhibit significant points of differentiation. The impact of educational background on teacher ICT competencies is reflected in their level of education (Zakharov et al., 2021), type of education received (Garcia-Delgado et al., 2023; Mercader & Gairin, 2021), era of education (Kovalchuk & Zaika, 2021), and practical industry experience (Mulyanti et al., 2024). Across different subjects and fields, the demand for ICT competencies among teachers varies, influencing their effectiveness (Moreno Guerrero et al., 2019; Shcherbyna, 2021; Zabolotska et al., 2021). There are also gender differences in self-assessment of ICT competencies and computer self-efficacy, influenced by types of digital skills considered (Cattaneo et al., 2022). Personal interest and aspirations for self-development are key motivators for teachers to use ICT, influenced by cognitive levels (Rauseo et al., 2023; Riviou et al., 2014; Shagataeva et al., 2021), emotional fatigue and occupational burnout(Del Prete, 2017; Golovina & Shcherbakova, 2021; Riviou et al., 2014), and time constraints (Cattaneo et al., 2022; Dziabenko et al., 2012b; Vilppola et al., 2022; Zwart et al., 2017).

External factors also significantly interfere with and impede the improvement of TVET teacher ICT competencies. Many studies point out that hardware and technological barriers are major obstacles (Dziabenko et al., 2012a; Kulyk et al., 2022; Lopez-Belmonte, Moreno-Guerrero, et al., 2020; Mariño-Fernández et al., 2021; Mažgon et al., 2015), although not all countries or regions face the same issues (Amenduni et al., 2022). The majority of TVET teachers express a desire for more training opportunities and digital resources (Antonietti et al., 2022; Kovalevskaya et al., 2021; Lopez-Belmonte, Moreno-Guerrero, et al., 2020; Lucia de Vega-Martin et al., 2022; Sanchez-Prieto et al., 2021; Yezhova et al., 2019). There is a lack of support from relevant institutions in organizing training for TVET teachers and driving school

reforms (Cattaneo et al., 2022), and legal and policy aspects should further address issues such as occupational burnout among TVET teachers(Golovina & Shcherbakova, 2021), research pressures (Golovina & Shcherbakova, 2021), and performance standards (Mulyanti et al., 2024). Additionally, teachers' salary levels and external funding support will impact their motivation and training opportunities (Dziabenko et al., 2012b; Kulju et al., 2024).

Finally, there is a low level of academic attention on the TVET teacher ICT competencies, and the scarcity of research may hinder their development and progress (Antonietti et al., 2022; Bitemirova et al., 2023; Casal Otero et al., 2021; Cattaneo et al., 2022; Krasavina et al., 2018). Existing discussions mainly focus on teachers' perceptions of ICT and their minimum technical proficiency requirements (Cattaneo et al., 2021; Lopez-belmonte et al., 2020), lacking in-depth exploration of assessment tools and standards (Guillen-Gamez et al., 2023; Kulyk et al., 2022), collaborative action policies and development plans (Guillen-Gamez et al., 2023; Kovalchuk & Zaika, 2021), sustainable monitoring and labor market demands (Kravchuk et al., 2023), as well as specific needs across different countries and fields (Burns et al., 2020; Kravchynska et al., 2021). Continuing professional development courses for teachers are noted to not sufficiently meet individual teachers' needs (Cattaneo et al., 2022; Riviou et al., 2014; Romanova et al., 2022; Shcherbyna, 2021; Vilppola et al., 2022; Wannapiroon et al., 2022). This may require further expansion of research to clarify contradictions, involving managers (Rauseo et al., 2023), students (Amenduni et al., 2022), and even the teachers themselves (Sanchez-Prieto et al., 2020). Some scholars also point out cognitive misconceptions, such as excessive focus on tools rather than the overall teaching experience of TVET teachers (Riviou et al., 2014), and underestimation of teachers' collaborative and self-directed learning abilities (Garcia-Delgado et al., 2023).

Conclusions

The TVET teacher ICT competencies have emerged as a research field only in the past 20 years, driven by the COVID-19 pandemic's push for online education and policy support for the technological advancements of the Fourth Industrial Revolution. Although some core authors have emerged in specific regions like Switzerland and Spain, this field has yet to establish a stable core group of contributors or foster international collaborations. Additionally, Ukraine and Russia are another two notable countries. Most papers in this field are published in journals related to educational technology, computer education, and engineering technology, with no dedicated core group of journals. The impact of individual papers is not significantly influenced by the journal, organization, or country/region.

Keyword and co-citation analysis indicate that research on the TVET teacher ICT competencies occurs within the broader contexts of e learning and blended learning. The TPACK framework, the EU's DigCompEdu, and UNESCO's ICT CFT provide the main theoretical support for this research field. Currently, almost all studies emphasize the importance of TVET teacher ICT competencies and the research perspectives have evolved from a single standardized approach to a broader and deeper exploration over time. Specific fields (such as agriculture and healthcare), specific populations (such as individuals with cognitive impairments), and the application of specific ICT tools (such as AR and new media) have gradually gained scholars' attention. These studies explore methods and strategies to enhance TVET teacher ICT competencies from multiple angles. However, despite all clusters

being active during the COVID-19 pandemic and a peak in publications in 2021, no significant research hotspots have emerged in this field.

Digitalization has become an irreversible key trend in the evolution of the TVET system. The transformation of the role of TVET teachers and the importance of their ICT competencies to the quality of education have gained global consensus. Through educational interventions and professional training, the TVET teacher ICT competencies have shown a significant upward trend, with an increasing number of TVET teachers beginning to accept and apply ICT. Despite this, TVET teacher ICT competencies remain fragmented and difficult to integrate into practice, which didn't reach optimal levels in the current educational environment. Variations in student ICT competencies, insufficient information and media literacy, the rapid development of emerging technologies, challenges in data literacy, and the complexity of teaching locations all pose significant obstacles for TVET teachers in enhancing their ICT competencies.

Although educational interventions are effective measures to enhance TVET teacher ICT competencies, the outcomes of these interventions are not always ideal. Factors such as educational background, disciplinary field, gender, personal interests, and self-development aspirations exacerbate the disparities in ICT competencies levels among TVET teachers, complicating the design of training and courses. Additionally, external factors such as hardware and technological barriers, lack of training opportunities and digital resources, inadequate laws and policies, and funding shortages also affect the implementation of educational interventions to varying degrees. Currently, there are significant research gaps ranging from macro-level development to labor market needs, from assessment tools to sustainable monitoring. Even the overall direction of ICT competencies training for TVET teachers requires further discussion.

In conclusion, despite scholars recognizing the importance of teacher ICT competencies, the TVET teacher group still receives insufficient attention. This study systematically reviews the development trajectory and research challenges in this field, aiming to alert scholars to the post-pandemic relaxation observed in this area. The issue of the continuous development of professional ICT competencies for TVET teachers has not yet been fully explored. This study suggests adopting interdisciplinary and coherence principles, starting with the construction of a framework for TVET teacher ICT competencies, to further improve the system for the ongoing development of TVET teacher ICT competencies.

Acknowledgements
Funding details
The study received no funding.
Disclosure statement
The authors report there are no competing interests to declare.

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Table 1
Core authors of the TVET teacher ICT competencies research field

Authors	Papers	Citations	Average citation
Cattaneo Alberto	5	103	20.6
Antonietti Chiara	3	99	33
Rauseo Martina	4	53	13.25
Amenduni Francesca	2	50	25
Lopez-Belmonte Jesus	3	18	6
Pozo-Sanchez Santiago	3	18	6
Moreno-Guerrero Antonio-Jose	4	15	3.75

Table 2
Top three journals of the TVET teacher ICT competencies research field

Top Three	Journals	Papers	Citations	Average citation
Papers	Information Technologies and Learning Tools	4	13	3.25
	Obrazovanie I Nauka-Education and Science	2	3	1.5
	Red-Revista De Educacion A Distancia	2	7	3.5
Citations	Computers in Human Behavior	1	50	50
	Computers & Education	1	49	49
	Journal of Optimization in Industrial Engineering	1	22	22

Table 3
Keyword clustering information of the TVET teacher ICT competencies research field

Clusters	Top Terms (Latent Semantic Indexing)	Size
#0 Digital Teaching Competence	ICT Building Competency; Secondary School; Remote Experiments; Vocational Training; Distance Learning; Professional Training; Blended Learning; Digital Teaching Competence	33
#1 Digital Health	Digital Health; Professional Competence; Healthcare Professional; Nursing Informatics; Primary Care Education; Continuing Professional Development; Vocational Training	27
#2 Educational Process	Educational Process; Professional Education; Information Environment; Communication Technologies; Educational Innovation; Teacher Education; Educational Technology; Vocational Training; Teachers Characteristics	20
#3 Information Technology	Information Technology; Blended Learning; Educational Innovations; Digital Competence; Teacher Qualifications; Green; Use Case; Skills; Competence; Digitization	18
#4 Digital Competence	Digital Competence; Structural Equations; Vocational Teachers; Online Mentoring; Professional Digital Competence; Vocational Education; Digital Learning; Digital Readiness; Enhanced Learning	17
#5 Vocational	Vocational Education; Workplace Learning; Digital Learning	17

Education	Material; Collaborative Learning; Hermeneutic Circle; Cognitive Psychology; Digital Didactics; Didactic; Teaching Didactic Communications	
#6 Digital Transformation	Digital Transformation; School Improvement; School Management; Vocational Education; Key Competencies; Digital Technologies; Vocational Training; Distance Learning	17
#7 Educational Technology	Educational Innovation; Educational Technology; Vocational Training; Teacher Education; Digital Competences; Technical-Professional Education; Teacher Training; Curriculum Development	14

Table 4

Top five co-cited journals of the TVET teacher ICT competencies research field

Journals	Citations
Computers & Education	32
Computers in Human Behavior	21
Education and Information Technologies	14
Comunicar	14
Pixel-Bit- Revista De Medios Y Educacion	13

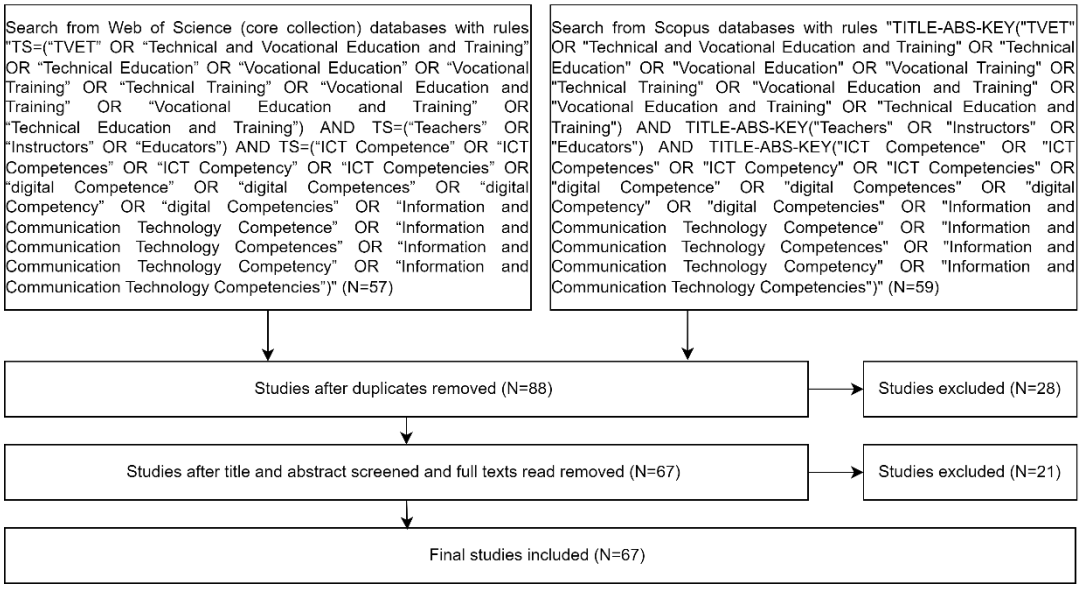

Figure 1 The data search and cleaning process of this study

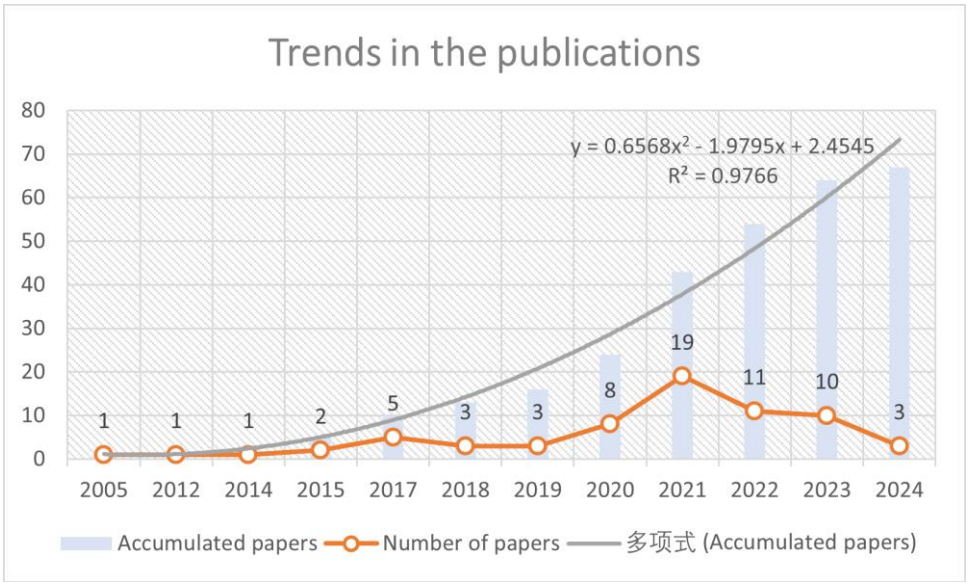

Figure 2 Trends in the publications of the TVET teacher ICT competencies research field

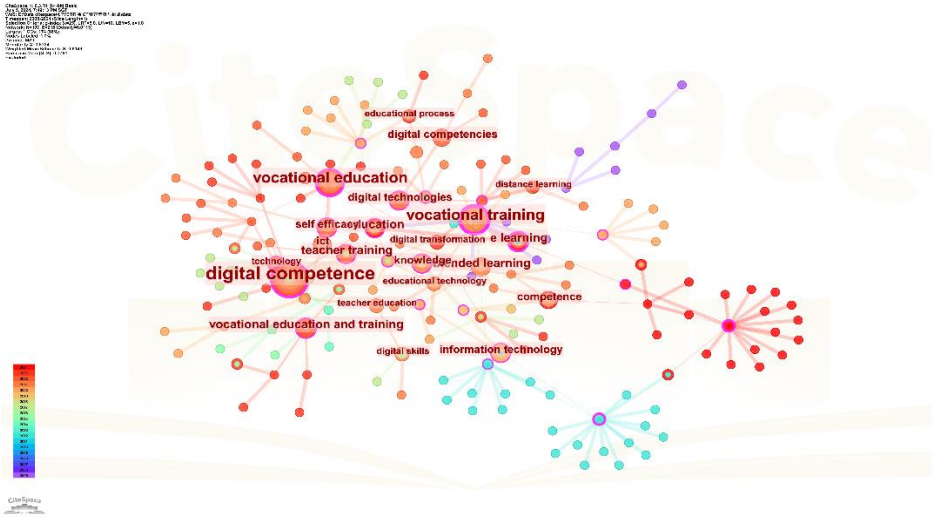

Figure 3 Keyword co-occurrence mapping of the TVET teacher ICT competencies research field

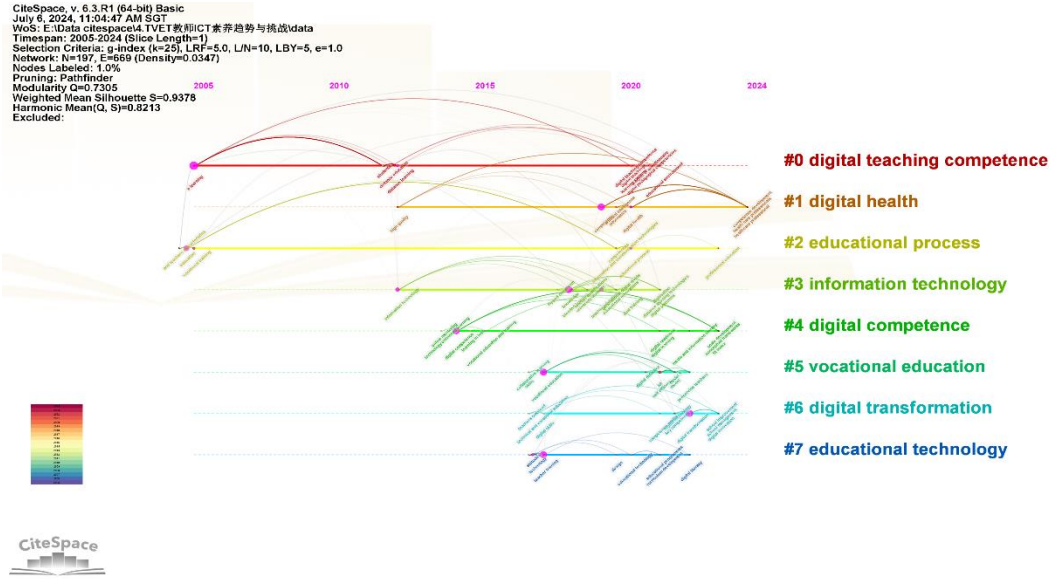

Figure 4 Keyword timeline view of the TVET teacher ICT competencies research field

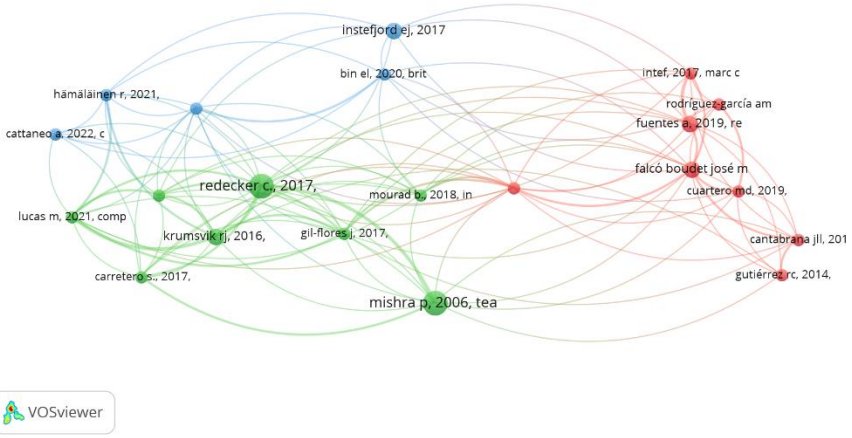

Figure 5 Reference co-citation mapping of the TVET teacher ICT competencies research field

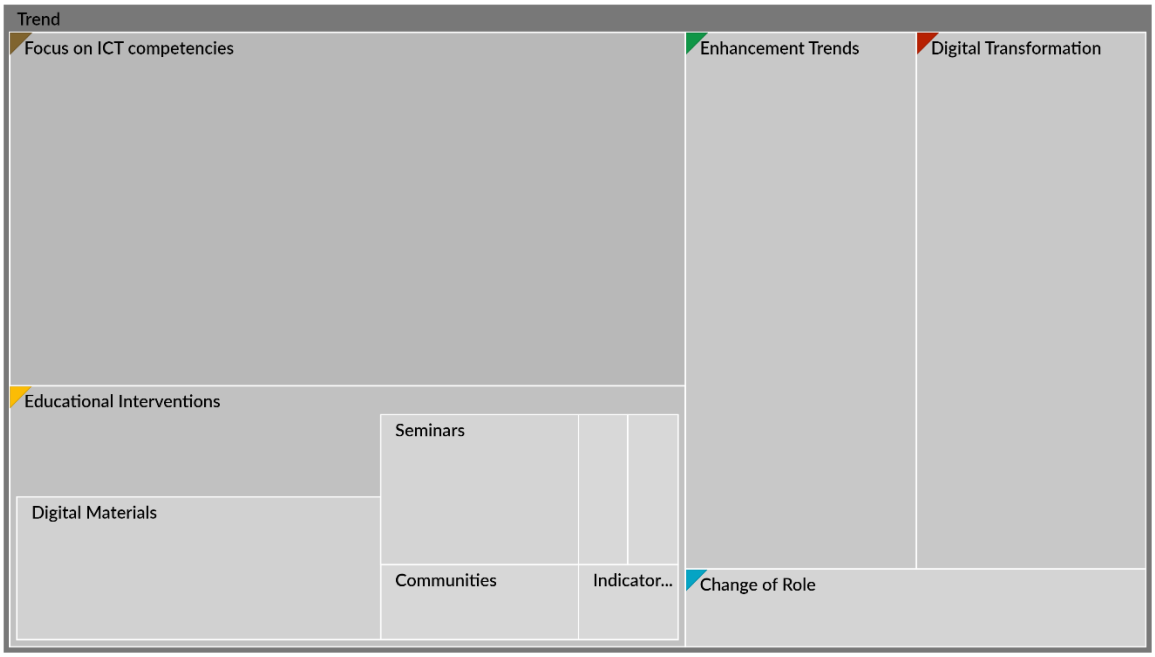

Figure 6 Hierarchy charts for trend analysis based on the number of reference points by NVivo

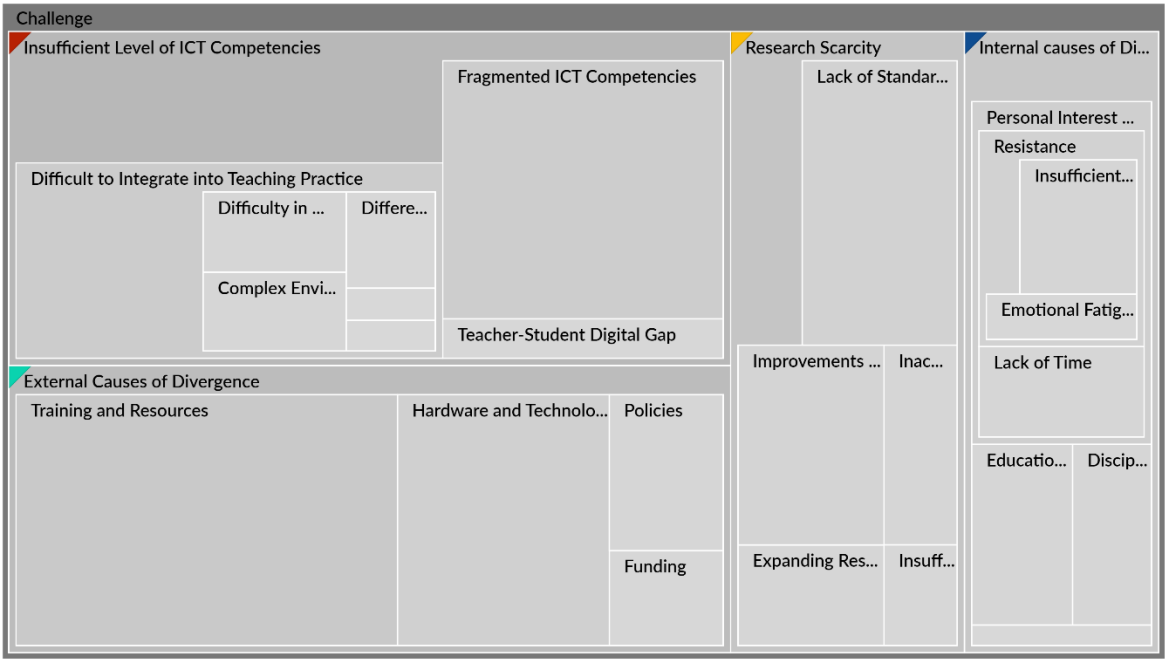

Figure 7 Hierarchy charts for challenges analysis based on the number of reference points by NVivo

(1) Figure 1 The data search and cleaning process of this study
(2) Figure 2 Trends in the publications of the TVET teacher ICT competencies research field
(3) Figure 3 Keyword co-occurrence mapping of the TVET teacher ICT competencies research field
(4) Figure 4 Keyword timeline view of the TVET teacher ICT competencies research field
(5) Figure 5 Reference co-citation mapping of the TVET teacher ICT competencies research field
(6) Figure 6 Hierarchy charts for trend analysis based on the number of reference points by NVivo
(7) Figure 7 Hierarchy charts for challenges analysis based on the number of reference points by NVivo