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Teachers' digital competency in vocational education: A systematic review

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Abstract With the rapid development of digital technology in the field of education, the digital competency of vocational education teachers has become an important factor affecting the quality of education and learning outcomes. Considering the significance of teachers' digital competency for the digital development of vocational education and the current lack of systematic literature reviews on this topic, this article will provide a systematic review of previous research to report on the existing studies regarding the digital competency of vocational education teachers. This review analyzes 25 studies from 2002 to 2023 sourced from WOS and Scopus, out of an initial 2.757 articles after removing duplicates and irrelevant studies. Findings reveal a lack of comprehensive frameworks for digital competency among vocational education teachers, with their current proficiency being moderate to low. Training programs are frequently suggested as a solution. The research predominantly addresses subjective factors influencing digital competency, with less focus on objective factors. Future research should focus on developing robust digital competency frameworks, assessing teachers' competencies against these frameworks, and creating targeted training measures. Additionally, there is a need to explore objective factors affecting digital competency.

Keywords: competency level, teacher training, competency frameworks, influcing factors, PRISMA

1. Introduction

The rapid advancement of information technology has catalyzed an unprecedented transformation within the field of education. The widespread application of digital technology has introduced entirely new teaching models and tools, significantly enhancing the efficiency and quality of both learning and teaching (Benavides et al., 2020). Educational institutions and educators urgently need to leverage information technology to improve the quality of education and teaching outcomes (Timotheou et al., 2023). Digital transformation has become a crucial direction in contemporary educational reform, with governments and academic institutions worldwide investing substantial resources to promote the development of educational informatization (Akour & Alenezi, 2022). In this context, digital competency, as an essential capability to meet the demands of information education, has garnered significant attention.

With the widespread application of information technology across various industries, vocational education has increasingly focused on digital transformation and the cultivation of practical skills (Zhu et al., 2024). The goal of modern vocational education is to equip students with the abilities and skills required to meet future career development needs, with digital competency being a crucial component that receives significant attention and emphasis (Delcker & Ifenthaler, 2022). Modern vocational education is no longer limited to imparting theoretical knowledge; it places greater importance on developing students' practical skills and innovative thinking, enabling them to succeed and thrive in a digital work environment.

As technology continues to advance, the objectives of vocational education are increasingly aimed at fostering students' comprehensive abilities to cope with a digital work environment (González-Pérez & Ramírez-Montoya, 2022). This includes skills in data analysis, information management, and cybersecurity, among others. In this context, the field of vocational education particularly emphasizes students' digital competency, as the demand for digital skills in the modern job market continues to grow (Goulart et al., 2022). Digital competency encompasses not only basic computer operation skills but also the ability to use digital technology to solve complex problems in work and daily life (Oberländer et al., 2020). Therefore, vocational education teachers need to possess solid digital competency themselves to better guide and train students in meeting future career challenges.

Digital competency encompasses the fundamental skills required for individuals to effectively utilize information and communication technology and digital (Ferriai, 2012), including the ability to access, evaluate, store, create, present, and share information using computers (Ala-Mutka, 2011). Additionally, digital competency encompasses analyzing and critiquing information, communicating and collaborating, sharing, fostering a sense of personal responsibility, and respecting others. Utilizing digital competency increasingly requires individuals to interact with digital technologies and media in ways that are

critical, creative, independent, adaptable, ethical, and reflective (Ferriai, 2012). The definition of digital competency, like competency in general, emphasizes its application across various domains, including work, leisure, and communication (Ala-Mutka, 2011). Ferrari further points out that digital competency is involved in various fields (Ferriai, 2012). According to the European Union (2018), digital competency refers to the self-assured, analytical, and ethical utilization of and interaction with digital tools in education, professional settings, and civic life. It encompasses skills in handling information and data effectively, engaging in online communication and teamwork, understanding media critically, producing digital content (such as coding), ensuring security (including online well-being and cybersecurity-related abilities), addressing issues concerning intellectual property, as well as developing problem-solving skills and logical reasoning.

Teacher digital competency is the essential capability for teachers to carry out professional practices and career development in the digital age (Kelentri et al., 2017). It primarily includes teachers' cognitive, metacognitive, learning strategies, self-efficacy, and teaching methods in a digital environment (Krumsvik, 2014). Additionally, it requires teachers to guide learners in critically and creatively using digital technology (Redecker & Punie, 2017), engage in collaboration and communication, create new content, adhere to ethical requirements in the digital education environment, and possess the ability to assess and solve problems (Spiteri & Rundgren, 2017).

Previous research has examined how vocational education teachers can enhance their digital competency (Burns et al., 2020), what the vocational education teachers' digital competency levels are (Garcia-Delgado et al., 2023), and discussed the factors influencing their digital competency, including school supporting (Cattaneo et al., 2022), previous ICT experiences (Prieto et al., 2020), and personal motivation (Warno, 2020), etc. However, a systematic literature review on the digital competency of vocational education teachers has not yet appeared. In other educational contexts, some systematic literature reviews have already been conducted. For example, there are systematic literature reviews on the digital competency of higher education teachers by Basilotta-Gómez-Pablos et al. (2022) and on the digital competency of K-12 teachers by Yang et al (2023). To better understand the current state of research on vocational education teachers' digital competency and promote its development, conducting a systematic literature review on this topic is necessary.

To achieve this research objective, this article will conduct a systematic literature review on the digital competency of vocational education teachers around the following questions:

RQ1: What are the frameworks for assessing the digital competency of vocational education teachers?
RQ2: What are the research purposes of these studies, and what are the research results?
RQ3: What research designs are presented in the studies, and what are the primary data sources?

With the above research questions as the research objectives, the framework of this review is as follows: first, the research methods and analysis steps used in this review will be explained; next, the selected articles will be analyzed to address the research questions, followed by a discussion of the findings and suggestions for future studies on the digital competency of vocational education teachers.

2. Methodology

To better answer the above research questions, this study will conduct literature screening according to the literature review guidelines of Kitchenham and Charters (Kitchenham et al., 2007), formulate the PRISMA protocol, use PRISMA to identify, screen, and include the literature, and screen out the available literature.

2.1. Search strategies

Articles in this review mainly come from WOS and Scopus. In the database search, the most common keywords used in this research question were used. Therefore, the literature search keywords in the two databases are as following Table 1:

Table 1 Search strings used in the study.

Database	Search strings
WOS	TS= ((teacher* OR lecturer*) AND ("digital competenc*" OR "digital abilit*" OR" digital skill*" OR "digital literacy") AND ("vocational "OR "technical" OR "training"))
Scopus	TITLE-ABS-KEY ((teacher* OR lecturer*) AND ("digital competenc*" OR "digital abilit*" OR" digital skill*" OR "digital literacy") AND ("vocational "OR "technical" OR "training"))

2.2. Selection process

A total of 2.757 articles related to the digital competency of vocational education teachers between 2002 and 2023 were retrieved. This includes 1.460 articles in WOS and 1.297 articles in Scopus.

Inclusion and exclusion criteria (Table 2) were designed around the research questions of this paper. The searched literature will be screened according to the inclusion and exclusion criteria. The selected literature must meet all the inclusion criteria. Literature that does not meet one criterion will be excluded.

Table 2 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Related to teachers' digital competencies.	Not related to teachers' digital competencies.
In the context of vocational education.	Not in the context of vocational education.
Open access.	Not open access.
In English.	In other languages.
Published with a peer review process.	Published without a peer review process.

As shown in Figure 1, before starting the literature screening process, 2.757 articles were identified and 731 duplicates were removed, leaving 2.026 articles. The remaining articles were subsequently evaluated based on the established inclusion and exclusion criteria. Among them, 374 non-English articles were excluded. Based on the titles, abstracts, and keywords, 1.561 articles that were not about teachers' digital competency or did not study vocational education contexts were excluded. Subsequently, 13 articles that were not open-access and 16 that were not peer-reviewed were excluded, leaving 62 articles. Finally, to more comprehensively verify the validity of the remaining articles, a full-text review of the 62 articles was conducted, revealing that 37 of them did not meet the research criteria for the digital competency of teachers in vocational education contexts. Therefore, after the screening process, 25 articles remained, providing research data for the systematic review of the digital competency of vocational education teachers.

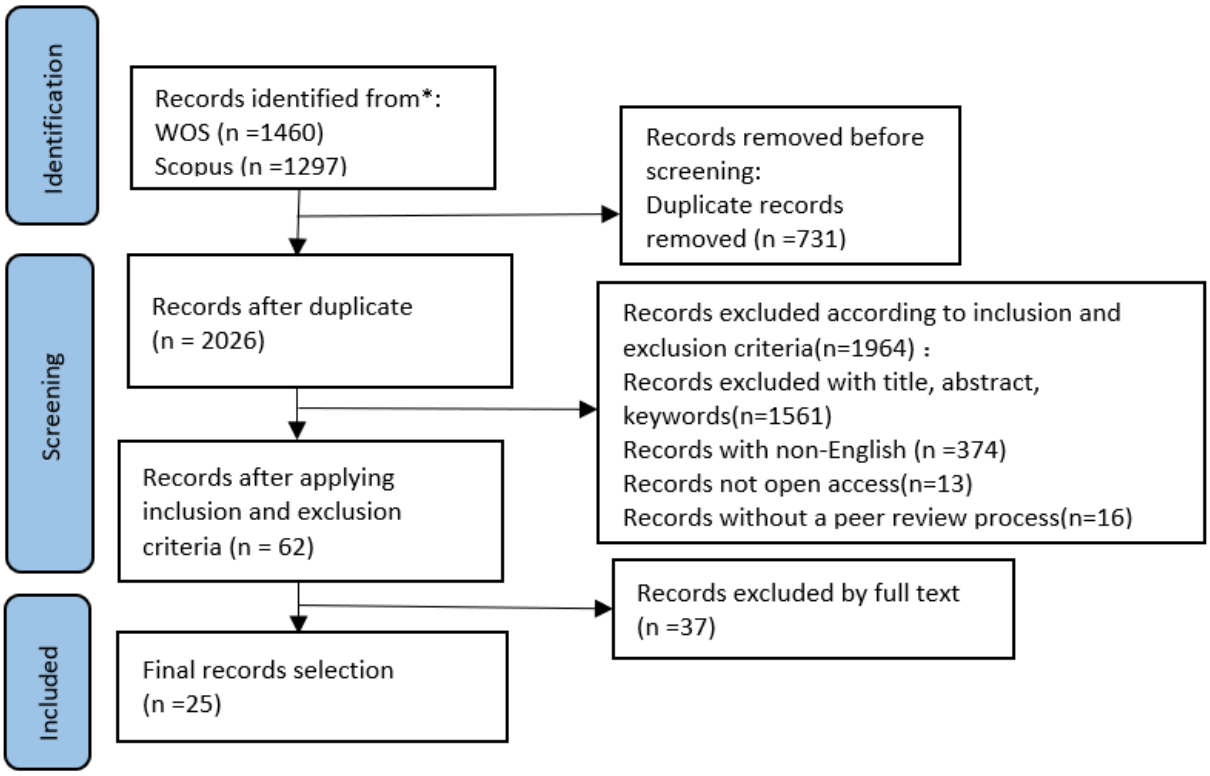

Figure 1 PRISMA flowchart.

3. Results

In this section, we will present the answers to the research questions based on the selected literature and show the results part of this literature review in sequence according to the research questions.

3.1. What are the frameworks for assessing the digital competency of vocational education teachers?

Given the important role of teacher digital competency framework in developing digital competency for vocational education teachers, we first review teachers' digital competency frameworks in the literature. Among the 25 articles reviewed in this study, 14 cited teacher digital competency frameworks. Among them, 7 articles mentioned a single competency framework, and 7 articles mentioned two or more teacher digital competency frameworks.

First, among the seven articles referring to a single competency framework, five were related to current teacher digital competency frameworks. As the most used and well-known teacher digital competency framework, the Digital Competence Framework for Citizens (DigComp) is widely used in assessing teacher competency (Cattaneo et al., 2022). The dimensions of

DigComp mainly include five areas: information, communication, content creation, safety, and problem-solving (Carretero et al., 2017). In the review article, five dimensions of DigComp were directly used to design the questionnaire questions to assess the competency (Rahmawati et al., 2022). Another 2 articles referred to the European Framework for the Digital Competence of Educators (DigCompEdu). DigCompEdu includes six dimensions: professional engagement, empowering learners, assessment, digital resources, facilitating learners' digital competency , and teaching and learning (Redecker & Punie, 2017). At first, only one dimension of the digital resources was referred since the researchers discussed teachers' digital competency in flipped classrooms and they focused on teachers' use of digital technology and digital tools when evaluating teachers' digital competency (Amenduni et al., 2022). Then the whole framework of DigCompEdu was used to design a questionnaire to evaluate teachers' digital competency (Villalba et al., 2018). Also another one article referred to the Common Digital Competence Framework for Teachers (Sanchez-Prieto et al., 2020). The Common Digital Competence Framework for Teachers includes five dimensions: information and data literacy, safety, communication and collaboration, problem-solving, and digital content creation (INTEF, 2017). Besides these, Saripudin et al proposed a framework including three aspects: awareness, praxis, and phronesis, depending on the dimensions of digital literacy proposed by existing researchers. Awareness refers to hearing about new technologies and learning of the capabilities of new technologies; praxis refers to the practice of customary implementation exploring/attempting a variety of applications; phronesis refers to the wise and effective application of technological capabilities, along with the discerning and appropriate use of technologies (Saripudin et al., 2021).

Then, among these 7 articles, another 2 articles proposed a newly established teacher digital competency framework. A Kazakhstan teacher digital competency framework was established, including four dimensions: technical, communication, informational, and epistemological as reference dimensions for evaluating teachers' digital competency (Shagataeva et al., 2021). Through a review of existing competency frameworks, a teacher digital competency framework including three dimensions: technology, teaching, and professional-research development was verified and established by Martínez &Fernández (Martinez & Fernandez, 2015).

In addition, 7 articles cited two or more frameworks in the research. At the very beginning, DigComp and DigCompEdu were both used to study the current status of teachers' digital competency (Burns et al., 2020). Then the Common Digital Competence Framework for Teachers and DigComp were referred to evaluate teachers' digital competency (Sanchez-Prieto et al., 2020). The analysis in the study of Spanish teachers' digital competency is primarily grounded in the Common Digital Competence Framework for Teachers. Additionally, DigCompEdu was consulted to provide a broader perspective for a more comprehensive understanding of teachers' digital competency (Garcia-Delgado et al., 2023) Besides, there are researchers building a six-dimensional digital competency framework based on the five dimensions of DigComp with adding a technical tool dimension (Sánchez-Prieto et al., 2021).

Other research into teacher digital competency has led to the development and refinement of various frameworks aimed at enhancing and assessing technological skills in education. One prominent initiative involves the adaptation of DigCompEdu to the Finnish educational context (Kullaslahti et al., 2019). This localized framework seeks to address the specific needs of Finnish educators by customizing the broad competencies outlined in DigCompEdu. The integration of DigCompEdu with various frameworks such as SELFIE, a Swiss model for basic ICT skills, TET-SAT, the Digital Learning Framework, and evaluations from the Educational Research Center, along with a VET-specific technology integration model, was used to design test questions and establish dimensions for assessing teachers' digital competency (Cattaneo et al., 2022). Additionally, research incorporating DigCompEdu included questions covering three dimensions: professional engagement, facilitating learners' digital competency, and teaching and learning, with particular attention to the characteristics of the vocational context (Antonietti et al., 2022).

3.2. What are the research purposes of these studies, and what are the outcomes?

After the above review of the commonly used frameworks, the following will review the research purposes and outcomes of past studies to clarify the research progress of digital competency of vocational education teachers. There are five research purposes for the digital competency of vocational education teachers. The proportions of these purposes in the literature screened out in this study are shown in Figure 2. Some of the literature has only one research purpose, and other literature has two research purposes.

3.2.1. Outcomes on the current levels of digital competency of vocational education teachers

Firstly, some studies focus exclusively on the level of teachers' digital competency. They found the overall digital competency of vocational education teachers is at a moderate level (Sanchez-Prieto et al., 2020; Sánchez-Prieto et al., 2021; Villalba et al., 2018; Warno, 2020). Nevertheless, some studies indicate that the digital competency level of teachers is at an advanced level (Rahmawati et al., 2022; Mangiri et al., 2019).

Subsequently, other studies have focused on investigating the digital competency levels of teachers with different years of experience. For example, García-Delgado et al. categorize teachers' years of experience into five stages (<5, 6-10, 11-15, 16-20, >20 years) and classify them into basic (Beginner A1 and Explorer A2), intermediate (Integrator B1 and Expert B2), and

advanced (Leader C1 and Pioneer C2) levels (Garcia-Delgado et al., 2023). They find that the digital competency level of teachers with less than 20 years of experience is mostly concentrated at the B1B2 level, indicating a moderate level. However, teachers with over 20 years of experience demonstrate a more evenly distributed competency level across all six levels.

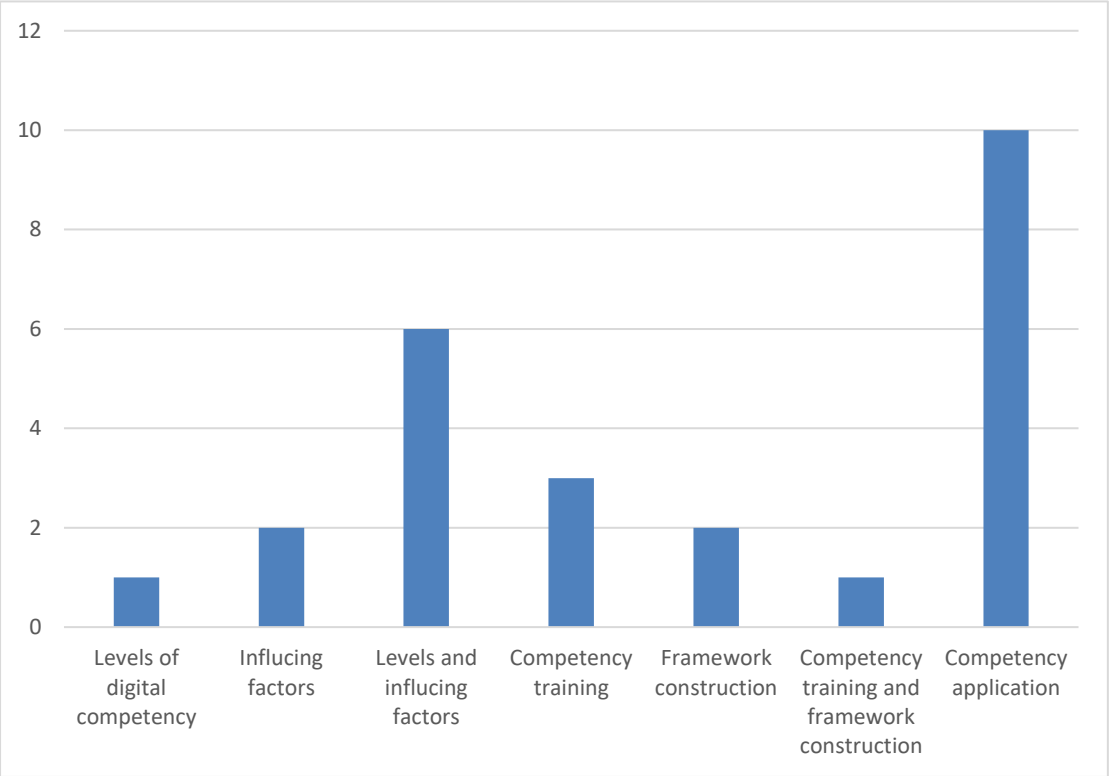

Figure 2 Category results for research purposes. *Source:* Scopus Database and WOS Database

Not all studies investigate digital competency in all domains. Teachers' competency in using digital technology tools and creating learning media resources was an important competency to assess. In the research, this competency was classified as at the third level of the Personal-Capability Maturity Model (P-CMM), indicating a moderately high level (Saripudin et al., 2021). Another six dimensions: professional engagement, digital resources, assessment and feedback, digital pedagogy, facilitating students' digital competency and empowering students were assessed to compares the digital competency of vocational education teachers with that of elementary education teachers and university teachers (Garcia-Delgado et al., 2023). Researchers found that vocational education teachers generally had a lower level of competency, particularly in professional engagement, digital resources, and facilitating students' digital competency.

Furthermore, different teacher groups exhibit varying levels of digital competency. Vocational education teachers were classified into three groups: professional baccalaureate teachers, LGS teachers, and professional subject teachers (Cattaneo et al., 2022). While there are no overall differences in competency levels among these groups, there are variations in specific competencies. For example, LGS teachers exhibit higher competency in technology use and data protection compared to the other two groups, whereas professional baccalaureate teachers score lower in learner capabilities.

3.2.2. Outcomes on influencing factors for digital competency of vocational education teachers

Through a review of existing literature, it has been found that there are multiple factors influencing the digital competency of vocational education teachers, which can be categorized into personal and objective factors.

Personal factors mainly include gender, age, workload, teachers' belonging to professional categories, occupational categories, the student population in the working area, prior levels of education and ICT experience and training, and achievement motivation.

Regarding the influence of gender on teachers' digital competency, two articles suggest that there is generally no significant difference in competency between genders, especially when using digital technology for teaching (Cattaneo et al., 2022; Saripudin et al., 2021). However, some scholars proposed that the gender difference is not significant when advanced digital knowledge is not required (Sanchez-Prieto et al., 2020) and that females tend to outperform males in using technology to facilitate student learning (Cattaneo et al., 2022).

Similarly, literature also suggests that age has an impact on teachers' digital competency (Cattaneo et al., 2022; Prieto et al., 2020; Saripudin et al., 2021; Warno, 2020), especially in problem-solving dimensions (Sanchez-Prieto et al., 2020).

Teachers' digital competency tends to decrease with increasing age (Cattaneo et al., 2022; Saripudin et al., 2021), although Data Protection competency tends to increase with age (Cattaneo et al., 2022). Age also influences teachers' digital competency through the regulation of achievement motivation (Warno, 2020).

Few articles address the influence of workload on years of experience, but some suggest a positive correlation between workload and teachers' digital competency levels—indicating that a higher workload is associated with a greater level of digital competency (Cattaneo et al., 2022).

Vocational education teachers include professional baccalaureate, general education, and professional subject teachers, and the teachers' belonging to professional categories have an influence on their digital competency, among which is the ability to create virtual content (Sanchez-Prieto et al., 2020). Additionally, the digital competency levels of teachers from different professions vary; for instance, teachers from engineering backgrounds tend to have higher digital competency levels compared to those from non-engineering backgrounds (Rahmawati et al., 2022).

Furthermore, the occupational category of vocational education teachers, such as freelancers, employees, temporary employees, civil servants, etc., affects their problem-solving abilities (Sanchez-Prieto et al., 2020; Sánchez-Prieto et al., 2021) and also impacts the dimension of creating digital content (Sánchez-Prieto et al., 2021).

The student population in the working area influences the level of teachers' digital competency, with the most significant impact being on teachers' communication abilities (Sanchez-Prieto et al., 2020) and cooperation skills (Sánchez-Prieto et al., 2021). In areas with fewer students, teachers have more time and energy to communicate with students, leading to higher communication abilities (Sánchez-Prieto et al., 2021).

Teachers' prior levels of education influence their collaboration and communication competencies (Sanchez-Prieto et al., 2020) as well as their safety competencies (Sánchez-Prieto et al., 2021). Lack of understanding and selection ability regarding digital technology and digital learning resources also affects teachers' digital competency levels (Mutohhari et al., 2021).

However, teachers' prior ICT experience does not affect their knowledge and skills in ICT; thus, it does not influence their level of digital competency (Sanchez-Prieto et al., 2020). Still, whether teachers have received ICT-related training does affect their digital competency, especially influencing their competency in digital tools and problem-solving dimensions (Sánchez-Prieto et al., 2021).

Teachers' achievement motivation significantly influences their level of digital competency; the higher the teachers' achievement motivation, the higher their ICT literacy (Warno, 2020). Attitude toward technology and frequency of technology tool usage are also positively correlated with teachers' digital competency levels (Cattaneo et al., 2022). Whether teachers perceive their digital competency as a challenge, or an opportunity also impacts their performance in competency areas. Amenduni et al. proposed that teachers who perceive assessment, autonomous learning and student empowerment as opportunities demonstrate significantly higher levels of digital competency in these areas compared to those who perceive these themes as challenges (Amenduni et al., 2022). Teachers' perception of school support for digital development has a positive impact on the enhancement of their digital competency, such as competency in creating digital resources, assessment, learners' empowerment, etc. (Cattaneo et al., 2022).

Research on the objective factors influencing the digital competency of vocational education teachers mainly focuses on the school's infrastructure, support from the school, geographical location of the school, school quality, and students' use of digital devices.

It is obvious that school's infrastructure is an important factor affecting teachers' digital competency (Mutohhari et al., 2021; Warno, 2020). Furthermore, research found that inadequate school infrastructure hinders the development of teachers' digital competency (Mutohhari et al., 2021). Additionally, support from the school for professional development, school culture supporting digital development, and curriculum support all positively contribute to the teachers' digital competency development (Cattaneo et al., 2022). It can also be said that school policies have a positive impact on teachers' digital competency (Wayan Widana, 2020). However, Cattaneo et al. found that the school's infrastructure does not affect teachers' digital competency (Cattaneo et al., 2022). Meanwhile, some researchers have found through studies that the geographical location and quality of the school also do not affect teachers' digital competency (Rahmawati et al., 2022). Students' use of digital devices also does not impact the teachers' digital competency development (Cattaneo et al., 2022).

3.2.3. Outcomes on training strategies for improving digital competency of vocational education teachers

Developing training courses is a widely used strategy to improve the vocational education teachers' digital competence. This includes creating short-term, competency-based professional development courses (Kovalchuk et al., 2022), designing distance learning courses (Burns et al., 2020), and improving teachers' digital skills through online learning platforms, such as the Moodle platform (Martinez & Fernandez, 2015). Additionally, by analyzing the educational needs and professional development requirements of teachers' digital competency, a teacher digital competency development model can be developed. Based on detailed training concepts and programs, a training model can be designed to improve teachers' digital competency through training in teaching methods and technical skills (Burns et al., 2020). Therefore, information technology training is also an essential measure to enhance teachers' digital competency (Martinez & Fernandez, 2015).

3.2.4. Outcomes on the digital competency framework construction

Through reviewing previous literature on vocational education teachers' digital competency, it is found that most of the frameworks mentioned exist, such as the UNESCO ICT Competency Framework for Teachers and DigCompEdu. Only a few studies mentioned specifically designed frameworks for vocational education teachers' digital competency.

This literature review identifies only three articles that focus on developing a digital competency framework for vocational education teachers, representing just 12% of the total literature reviewed. The methods used for constructing the digital competency framework for vocational education teachers are like those used for other education context teachers, including the Delphi method, structural equation modeling, deductive content analysis, document analysis, and group discussion, among others. The earliest study employed only the deductive content analysis method to analyze and identify the correspondence between the dimensions of Finnish vocational education teachers' digital competency and DigCompEdu (Kullaslahti et al., 2019). It was found that the Finnish vocational education teachers' digital competency framework had a high degree of alignment with DigCompEdu in the areas of digital learning environments and teaching and learning, while the areas of assessment, learner empowerment, and facilitating digital competency showed partial correspondence. Later, another article utilized both document analysis and group discussion to construct a digital competency framework for teachers, including three dimensions: technology, professional-research development, and teaching (Martinez & Fernandez, 2015). In the process of constructing the framework, more than 15 proposals, models, and competence frameworks were reviewed, with 9 texts being analyzed in-depth. Six professors participated in the group discussion stage. The framework provided detailed explanations of the three dimensions and listed specific behaviors at two levels (usage and application-creation) for each dimension. The most recent study used the Delphi method and structural equation modeling to gather students' opinions and collect the digital competencies that students considered important for vocational education teachers. Experts then validated the content validity of these competency dimensions, followed by a survey distributed to master's students in vocational courses to further validate the structural integrity of the model, ultimately identifying the dimensions of the digital competency framework for vocational teachers (Shagataeva et al., 2021).

3.2.5. Outcomes on the application of vocational teachers' digital competency

The digital competency of vocational education teachers is essential for the advancement of other factors in education. The emergence of the pandemic has propelled online teaching to the forefront of education history, as it became necessary to provide remote learning for students unable to attend school physically (Amenduni et al., 2022). To adapt to online teaching, teachers need to possess high levels of digital competency to effectively deliver online courses (Kovalchuk et al., 2022). Some scholars also argue that the advent of remote and blended learning has increased the demand for digital technology, stimulating the development of teachers' digital competency. Therefore, teachers need to have good digital competency to quickly adapt to these new teaching methods and environments (Romanova et al., 2022).

The application of flipped classrooms is becoming increasingly widespread to enhance student engagement in learning activities, and teachers' digital competency is one of the crucial conditions for implementing flipped classroom teaching (Villalba et al., 2018). Teachers' digital competency can enhance the development of their higher-order thinking skills (Wayan Widana, 2020), thereby positively promoting their professional development (Mangiri et al., 2019), especially as the demand for digital technology in remote teaching plays a significant role in the professional development of teachers (Romanova et al., 2022).

Teachers' beliefs in digital competency led them to believe that technology can facilitate teaching and learning, motivating them to incorporate digital tools and software into their teaching practices (Antonietti et al., 2022). Advanced teacher digital competency facilitates teachers' use of ICT tools, aiding in the integration of ICT tools into English teaching (Rodliyah, 2018).

The digital transformation of schools has become a crucial means for schools to adjust to the digital society. Teachers' digital competency occupies an important position in the digital transformation of schools and is a critical influencing factor in school digital transformation (Rauseo et al., 2023).

The goal of teachers' digital competency is to foster the development of students' digital literacy. However, due to various reasons such as teachers' inadequate understanding of digital literacy, the impact of teachers' digital competency on students' digital literacy development is not significant. Nevertheless, teachers' digital readiness, enhanced through online learning, plays a key role in fostering the development of students' digital literacy (Jatmoko et al., 2023).

3.3. What types of research designs are presented in the studies, and what are the primary data sources and who are the research samples or participants?

Mixed research design is widely used, first employing quantitative data analysis and then combining qualitative research for in-depth exploration. The combination of quantitative and qualitative methods facilitates a deeper understanding of the phenomenon under study. As shown in Table 3, six studies adopted a mixed research design in examining teachers' digital

competency. For instance, in research on the role of teachers' digital competency, quantitative data is first collected and analyzed, followed using qualitative data to gain deeper insights into participants' views and attitudes (Villalba et al., 2018). In studies exploring teachers' use of and preparedness for digital technology, researchers often first use quantitative methods to collect data on the difficulties and challenges teachers face when using digital technology. This is followed by informal conversations to further understand teachers' opinions on the effectiveness of digital technology guidelines (Romanova et al., 2022). Similarly, studies investigating teachers' views on using digital technology to assess vocational education talents start with quantitative methods, followed by qualitative research to delve into their personal experiences and perspective (Kulyk et al., 2022). Additionally, researchers (Amenduni et al., 2022)use quantitative methods to collect teachers' views on the relationship between digital competency levels and the challenges and opportunities encountered during remote teaching, then convert the quantitative data into qualitative content analysis for more detailed interpretive analysis (Mayring, 2015). In some studies, quantitative data is first collected on the views of vocational education master's students regarding the teachers' digital competency framework. Subsequently, experts are invited to refine the questionnaire and improve the framework design through qualitative content analysis methods (Shagataeva et al., 2021). Finally, some studies collect teachers' opinions on the integration of new tools into digital competency training courses through quantitative methods, followed by qualitative research to further explore teachers' feedback on their training participation (Martinez & Fernandez, 2015).In these studies, the application of mixed research methods seeks to offer a more thorough understanding of the diverse needs and experiences of teachers in developing digital competency.

Table 3 Research methods.

Research methods	Number of studies
Mixed methods	6
Quantitative	15
Qualitative	4

The most frequently used research method is quantitative, with a total of 15 studies employing this approach. The literature investigating the current situation of teachers' digital competency in vocational education and the influencing factors of teachers' digital competency all use quantitative research methods (Cattaneo et al., 2022; Garcia-Delgado et al., 2023; Mažgon et al., 2015; Rahmawati et al., 2022; Sanchez-Prieto et al., 2020; Sánchez-Prieto et al., 2021; Saripudin et al., 2021; Warno, 2020). In addition, there is also literature using quantitative research methods (Antonietti et al., 2022; Jatmoko et al., 2023; Mangiri et al., 2019; Mutohhari et al., 2021; Rauseo et al., 2023; Widana, 2020) on the application of teachers' digital competency in vocational education to collect opinions on the application environment and role of teachers' digital competency.

In contrast, the number of qualitative research articles is small, with only four articles. Qualitative research methods are used for digital competency training of vocational education teachers (Burns et al., 2020; Kovalchuk et al., 2022), construction of frameworks (Kullaslahti et al., 2019), and the role of digital competency (Rodliyah, 2018). Kovalchuk et al. (2022) mainly analyze the existing legislative documents and research literature to understand the development foundation and main aspects of Ukraine's vocational education and training system. Burns et al. (2020) analyzed existing literature, policies, and reports to improve the content of digital competency training for vocational education teachers. Kullaslahti et al. (2019) developed a digital competency framework for vocational education teachers by referring to the DigCompEdu through deductive content analysis. Through interviews with teachers and classroom observations, the role of digital technology in English classroom teaching practices was obtained (Rodliyah, 2018).

Different research purposes require different instruments. Surveying using questionnaires is the most common data source among quantitative research methods. In qualitative research, the sources of data are mostly interviews, including informal conversation (Romanova et al., 2022) and group discussion (Martinez & Fernandez, 2015). In addition to this, there is also document analysis (such as policy documents, reports, literature, etc.) (Burns et al., 2020; Kovalchuk et al., 2022; Kullaslahti et al., 2019), classroom observation (Rodliyah, 2018), and expert method (Shagataeva et al., 2021).

Among the 25 articles, 16 have vocational schoolteachers as research samples or participants, and some research samples or participants are teachers and students (Jatmoko et al., 2023; Kulyk et al., 2022; Mažgon et al., 2015; Mutohhari et al., 2021; Shagataeva et al., 2021), teachers and school administrators (Rauseo et al., 2023). In the two qualitative studies that analyzed texts, the sample or participant of the study was not mentioned (Kovalchuk et al., 2022; Kullaslahti et al., 2019). Experts participated in the research of Burns et al. (Burns et al., 2020).

4. Discussions and Conclusions

This systematic literature review summarizes the current research on the digital competency of vocational education teachers. It will now examine the gaps in the research, highlighting potential avenues for future studies.

The selected literature indicates an increasingly positive attitude toward the development of digital competency among vocational education teachers, as evidenced by the growing number of articles attempting to clarify the frameworks and

models for enhancing competency development (Ghomi & Redecker, 2019). Digital competency frameworks, which form the basis for developing teachers' digital skills, are valuable for identifying the competencies teachers require to effectively use technology in their educational practices and to support their professional growth (Basilotta-Gómez-Pablos et al., 2022). However, problems still exist. There are only three articles focused on the framework for teachers' digital competency, suggesting that there is still a significant gap in the research on this topic. Most of the current literature utilizes the DigCompEdu and the Common Digital Competence Framework for Teachers. Although this aligns with the findings from reviews of digital competency frameworks for teachers in higher education and primary education (Basilotta-Gómez-Pablos et al., 2022), it also highlights another issue: the lack of digital competency frameworks specifically tailored for vocational education teachers (Redecker, 2017). Vocational education teachers are distinguished by their specialized professions and vocational education has characteristics different from other forms of education (Roll & Ifenthaler, 2021). Therefore, developing a digital competency framework specifically for vocational education teachers would better support their development.

Although there is not yet a fully developed framework for the digital competency of vocational education teachers, there is sufficient research examining their levels of digital competency. These studies focus on both the overall level of digital competency among teachers and the different dimensions of digital competency. However, current studies also reflect certain issues. Among the nine papers that investigate the current level of digital competency among teachers, six indicate that the digital competency of vocational education teachers is currently at a medium to low level. This suggests that it is necessary to enhance training for teachers to improve their digital competency.

Another reason is that the digital revolution necessitates that vocational education adapts to the demands of a digital society. As a crucial component of vocational schools, teachers must face challenges such as social progress, changing students, and updated knowledge (Shokeen & Kaur, 2022). Therefore, it is essential to improve their digital competency.

To enhance teachers' digital competency, training is essential. One approach is to develop training courses, including online professional development courses and distance learning courses for teachers. Additionally, developing training models that analyze the educational needs of teachers in terms of digital competency and their professional development requirements can also improve competency by training teachers in teaching methods and technical skills (Hatlevik & Hatlevik, 2018; Instefjord & Munthe, 2017). Whether it is the development of courses or training models, the approach is consistent with that for teachers' digital competency in other types of education. As described in this literature review, the absence of a digital competency model for vocational education teachers makes it challenging to implement these training measures. Therefore, developing a digital competency model for vocational education teachers is a significant gap identified in this literature review.

Analyzing the factors that influence the development of digital competency among vocational education teachers is crucial. As highlighted in the literature, the factors influencing the development of digital competency among vocational education teachers are diverse and can be divided into personal and objective factors. However, the review reveals that more research has been conducted on personal factors than on objective factors (Cattaneo et al., 2022). This indicates that the development of teachers' digital competency tends to focus more on the teachers themselves, emphasizing the influence of subjective factors. Conversely, the research on the impact of objective factors on vocational education teachers' digital competency is insufficient and needs further exploration. This is another gap identified in this literature review.

Objective factors, acting as external influences on the development of digital competency among vocational education teachers, are essential and can significantly affect the impact of personal factors. By researching objective factors, we can further clarify the environmental conditions necessary for the development of teachers' digital competency, guiding schools, society, and governments to create better environments for digital competency development. This can also help teachers better leverage personal factors to enhance their digital competency.

This literature review identifies several gaps in the research on digital competency among vocational education teachers. However, it also has certain limitations. The limitations of this review are mainly as follows: first, the study primarily screened literature from the WOS and Scopus databases. Although these are large and comprehensive databases, this screening range does not include all the currently published literature on the digital competency of vocational education teachers (Gusenbauer & Haddaway, 2020). Second, the literature search for this review was limited to English, excluding literature in other languages on the digital competency of vocational education teachers (Newman & Gough, 2020). This may affect the results of the review analysis.

Ethical Considerations

Not applicable.

Conflict of Interest

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