



Digital Transformation of Assessment in the Evaluation of Vocational Education Competencies: A Literature Review (2021–2026)

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ABSTRACT

Digital transformation has brought significant changes to competency assessment systems in vocational education. Technological advancements such as e-assessment, learning analytics, Artificial Intelligence (AI), Generative AI, computer-based assessment, and virtual simulation are driving the creation of more effective, adaptive, and data-driven assessment systems. This project will examine the evolution of research on digital transformation in competence assessment in vocational education between 2021-2026. The approach employed is a Literature Review using the PRISMA phases, which comprise identification, screening, eligibility evaluation, and the inclusion of publications. The ScienceDirect database was used for the literature search, which included terms such as digital assessment, competency assessment, and vocational education. The screening method produced 23 papers that matched the inclusion criteria for analysis. The findings show that research trends have evolved from a focus on digital abilities and user perceptions to the use of AI, Generative AI, learning analytics, and intelligent algorithms in competence evaluation. The implementation of digital assessment has proven to enhance efficiency, objectivity, and the accuracy of evaluations, as well as the ability to provide real-time feedback. However, challenges such as educators' digital competencies, technological infrastructure, and data security remain major concerns. Therefore, strengthening digital competencies, developing infrastructure, and integrating intelligent technologies are crucial strategies for optimizing the implementation of digital assessment in vocational education.

1. Introduction

Digital revolution has affected many parts of education, including mechanisms for analysing and assessing learning outcomes. Technological breakthroughs such as Learning Management Systems (LMS), learning analytics, artificial intelligence (AI), computer-based assessment, and e-assessment are pushing a paradigm change from traditional assessment to digital assessment that is more flexible, authentic, and data-driven (Jurāne-Brēmāne, 2023);(Caspari-Sadeghi, 2023). This shift is consistent with the demands of the Fourth Industrial Revolution and Society 5.0, which emphasise the need of using technology to improve the quality of learning and educational decision-making (Bygstad et al., 2022). In this context, assessment no longer serves merely as a

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tool for measuring learning outcomes, but also as a means of continuously monitoring students' competency development in real time through the use of learning data and integrated analytics systems (Ifenthaler et al., 2023). Research shows that the digitization of assessments can improve the efficiency of the evaluation process, provide faster feedback, and support personalized learning through more in-depth data analysis (A. A. P. Cattaneo et al., 2022).

Technical and Vocational Education and Training (TVET) is an educational field that depends largely on competence evaluation since it focuses on the development of vocational skills that match industry demands (Roll & Ifenthaler, 2021). Unlike general education, which focuses more on academics, vocational education challenges students to exhibit practical skills, problem-solving ability, and the application of skills in real-world job circumstances (A. A. P. Cattaneo et al., 2022). Therefore, the assessment system used must be capable of measuring competencies authentically and objectively. However, various studies indicate that competency evaluation systems in many vocational education institutions are still dominated by conventional approaches that are insufficiently capable of comprehensively capturing practical skills and work performance. In accordance with the progress of digital transformation, various innovations such as e-portfolios, simulation-based assessments, performance assessments, and learning analytics are being developed to support competency evaluations that are more authentic, sustainable, and aligned with the characteristics of vocational education (Sun & Tian, 2026);(Kumarawel & Yusop, 2022).

Although digital transformation in assessment offers numerous benefits, its implementation still faces a number of challenges. One of the primary concerns is instructors' lack of digital competence in planning and implementing technology-based examinations. According to research, teachers' digital competences play an important role in influencing the success of technology integration in the learning and evaluation processes. In the context of vocational education, teachers' digital skills are impacted by personal variables, teaching experience, workload, and institutional support; hence, considerable variances in their capacity to use technology for digital assessment and learning (A. A. P. Cattaneo et al., 2022);(Antonietti et al., 2022);(A. A. P. Cattaneo et al., 2025). In addition, limited digital infrastructure, uneven internet access, and a lack of professional training are common obstacles encountered in the implementation of digital assessments at various vocational education institutions (Habibi et al., 2023);(Amenduni et al., 2022);(Tzafilkou et al., 2023). These conditions have led to inefficient digital assessment implementation, which may have an impact on the accuracy of student competency measurements as well as the efficacy of the learning evaluation process.

During recent years, advances in artificial intelligence (AI), learning analytics, and simulation technologies have prompted a number of changes in the evaluation of vocational education skills. AI-based assessment systems enable the evaluation process to be conducted automatically, objectively, and continuously through the analysis of student performance data, thereby improving the accuracy and efficiency of learning assessments (Tlili et al., 2023); (Crompton & Burke, 2023);(Sun & Tian, 2026). In addition, the use of virtual simulations, computer vision, and learning behavior analysis provides a more comprehensive picture of students' skills compared to traditional assessment methods, as it allows for the measurement of competencies in an environment that closely resembles real-world work conditions (Silva et al., 2023);(Sun & Tian, 2026). According to a recent systematic analysis, AI-based evaluations improve skill-based learning outcomes by providing timely, accurate feedback targeted to students' unique requirements (Sun & Tian, 2026). However, the adoption of this technology brings additional issues surrounding the validity of evaluations, algorithm openness, data protection, the ethical use of AI, and the preparedness of human resources to properly employ the technology in vocational education (Holmes & Tuomi, 2022).

Although research on digital assessment in vocational education continues to grow, the findings remain scattered across various topics such as teachers' digital competencies, artificial intelligence (AI)-based assessment, learning analytics, e-assessment, and simulation-based evaluation. Most studies focus on the deployment of certain technologies or situations, thus they have not yet presented a complete picture of the evolution of digital assessment transformation in the evaluation of vocational education abilities (A. A. P. Cattaneo et al., 2022);(Sene, 2023). Furthermore, the fast technology improvements throughout the 2021-2026 timeframe have fuelled the birth of many digital assessment technologies, such as AI-assisted assessment, adaptive assessment, and learning analytics, which necessitate a literature review to identify research trends, the technologies employed, the benefits gained, and the challenges of implementation (Kandul et al., 2023). Therefore, a literature review is needed to systematically examine the digital transformation of assessment in the evaluation of vocational education competencies during the 2021–2026 period, as a basis for developing an assessment system that is more effective, adaptive, and relevant to the needs of the future workforce (Alfredo et al., 2024);(Sun & Tian, 2026).

Given the background that emphasizes the development of digital assessment technologies, competency evaluation, teachers' digital competencies, AI, learning analytics, e-assessment, and the challenges of implementing these in vocational education, the research questions (RQs) must be able to guide a systematic literature synthesis, including:

1. RQ1. What are the trends in research on the digital transformation of assessment in the evaluation of vocational education abilities between 2021 and 2026?
2. RQ2. What digital assessment technologies are used in the evaluation of vocational education competencies?
3. RQ3. What are the advantages of using digital assessment to evaluate student abilities in vocational education?
4. RQ4. What are the challenges and obstacles in implementing digital assessment in vocational education?
5. RQ5. What strategies are recommended in the literature to optimize the implementation of digital assessment in vocational education?

2. Methodology

The major research approach used in this study is a literature review. The literature review was conducted by examining various facts, data, and information obtained from scientific sources, such as articles and relevant research journals (Akbar et al., 2026). This study is classified as a literature review, as it was conducted using a complete and systematic literature search. The research was conducted according to the methodological procedures provided by (Dybå, T., & Dingsøyr, 2008). These steps are as follows: (1) draft and review the research protocol, (2) establish inclusion and exclusion criteria, (3) conduct a literature search and apply exclusion criteria, (4) identify relevant studies, (5) assess study quality, (6) extract data from selected studies, and (7) synthesise research findings. Furthermore, the synthesis results are presented narratively, utilising a theme analysis technique to reveal patterns and interrelationships across study findings. This study did not make literature quality assessment a fundamental aspect of the review process, as indicated by (Grant et al., 2009).

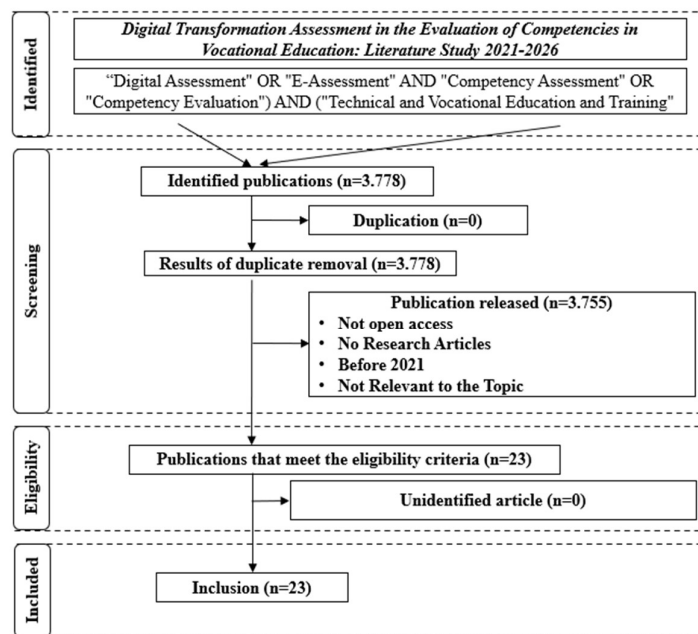


Fig.1. Prism method for article search

The graphic depicts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach used to select articles for the study "Digital Transformation Assessment in the Evaluation of Competencies in Vocational Education: Literature Review 2021-2026". The process began with the identification stage, which involved searching databases using keywords related to digital assessment, e-assessment, competency assessment, competency evaluation, and TVET. The initial search found 3,778 papers that might be relevant to the study subject.

During the screening step, all articles were reviewed to exclude those that did not meet the study criteria. No duplicate articles were found, so the total number of publications remained at 3,778. 3,755 papers were then removed because they did not match the inclusion criteria, such as being empirical research articles, not being available in full text (open access), written before 2021, or being inappropriate to the study's subject. Following the screening procedure, 23 articles remained that satisfied the initial criteria.

The eligibility phase involved a more in-depth examination of the articles' alignment with the research objectives. The evaluation results showed that all remaining articles met the eligibility criteria, and no articles were excluded at this stage. Therefore, in the inclusion phase, 23 articles were selected as the final sample for analysis and synthesis. Overall, the PRISMA diagram demonstrates that the selection process was conducted systematically, transparently, and in a structured manner, ensuring that the articles used are truly relevant to examining the development, implementation, benefits, and challenges of digital assessment in evaluating vocational education competencies during the 2021–2026 period.

3. Results

Based on the authors' research, using the keywords "Digital Assessment" OR "E-Assessment" AND "Competency Assessment" OR "Competency Evaluation" AND "Technical and Vocational Education and Training," a comprehensive search in databases such as ScienceDirect yielded 3,778 articles relevant to the keywords used, based on abstracts and titles that met our specific criteria. A total of 23 papers were chosen for this systematic review based on all inclusion criteria, which were classified as follows: articles published within the previous 6 years, open-access articles,

research articles, and articles related to the topic and area of vocational technology education. All papers that did not fulfil these criteria were removed and did not go on to the next round of examination. Table 1 shows the list of articles that have been approved for the next stage.

Table 1. Synthesis Summary of Articles received from 2021-2026

No	Author	Year	Country	Context
1	Herbert Thomann, Jan Zimmermann , Viola Deutscher. (Thomann et al., 2024).	2024	Germany	Advances in Immersive Virtual Reality (IVR) technology have opened up new opportunities in vocational education and training (VET).
2	Cristobal Romero, Sebastian Ventura. (Romero & Ventura, 2020).	2020	Spain	This is situated against the backdrop of fast advances in Educational Data Mining (EDM) and Learning Analytics (LA), which are increasingly being used.
3	Muhammad Zaheer Asghar, Amir Narimani, Elena Barbera, Javed Iqbal, Ercan Akpinar.(Asghar et al., 2026)	2025	Finland	In strengthening teachers' digital competencies in implementing digital assessment in the era of educational transformation.
4	Nur Kholifah, Muhammad Nurtanto, Valiant Lukad Perdana Sutrisno, Nuur Wachid Abdul Majid, Hani Subakti, Rihab Wit Daryono, Achmadi Achmadi. (Kholifah et al., 2025).	2025	Indonesia	This research is motivated by the increasing demands for workplace skills in the Industry 4.0 era and digital transformation, which necessitate graduates of vocational education.
5	Xia Sun And Haoeng Tian. (Sun & Tian, 2026).	2026	China	The advent of artificial intelligence (AI) has brought substantial improvements to vocational education and entrepreneurship through the use of learning analytics, virtual simulations, and generative AI.
6	Usani Joseph Ofem, Eme Orok Iban Amanso, Ene I. Ene c, Eno Ndaraka Asuqu. (Ofem et al., 2024).	2024	Nigeria	The significance of implementing inclusive assessment in ensuring a fair and equal learning environment for all students.
7	Anton Subarno. (Subarno, 2026)	2026	Indonesia	To meet the objectives of Industry 4.0, Vocational Education and Training (VET) teachers must have relevant digital capabilities.
8	Michael J. J. Roll and Dirk Ifenthaler.(Roll & Ifenthaler, 2021).	2021	Germany	The increasing demands of Industry 4.0, which require prospective vocational education teachers to possess multidisciplinary digital competencies.
9	Hong Li. (Li, 2025).	2025	China	To fulfil the increasingly complicated labour demands, vocational institutions in China must increase the quality of education and vocational literacy among students.
10	Khalid Alalawi, Rukshan Athauda, Raymond Chiong.(Alalawi et al., 2025)	2025	Australia	The use of learning analytics and machine learning in education to predict student performance through the analysis of learning data.
11	Sherly Rahmawati, Sarah Prestridge, Ade Gafar Abdullah, Isma Widiaty. (Rahmawati et al., 2025).	2025	Indonesia	The fast progress of digital technology has modified the skill requirements for the workforce in a variety of industrial sectors.
12	Akhmad Habibi, Sofyan, Amirul Mukminin. (Habibi et al., 2023a).	2023	Indonesia	In this era of digital transformation, the use of digital technology into vocational education has become critical to facilitating efficient learning processes.

No	Author	Year	Country	Context
13	Alberto A.P. Cattaneo, Chiara Antonietti, Martina Rauseo.(A. A. P. Cattaneo et al., 2022).	2022	Switzerland	Teachers' Digital Competence (TDC) in effectively supporting technology integration
14	S M Hizam, H Akter, I Sentosa and W Ahmed.(Hizam et al., 2021).	2021	Malaysia	The use of Learning Management Systems (LMS), primarily Moodle, to facilitate learning in higher education.
15	Wenshuang Luo, Lijing Zang, Weihao Liang, Qianhui Ma & Jiankun Chu. (Luo et al., 2026).	2026	China	The growing role of vocational education in China's education system alongside ongoing educational reforms.
16	Alberto Cattaneo, Maria-Luisa Schmitz, Philipp Gonon, Chiara Antonietti, Tessa Consoli, Dominik Petko. (A. Cattaneo et al., 2025)	2025	Switzerland	Investigating the impact of personal characteristics, such as instructors' ideas about technology, technological understanding, and Technological Pedagogical Content understanding (TPACK).
17	Valle N, Antonenko P, Valle D, Dawson K, Huggins-Manley A, Baiser B. (Valle et al., 2021)	2021	United States	Learning Analytics Dashboards (LADs) are increasingly being used as a tool to provide feedback to students in online learning.
18	Wild S, Schulze Heuling L. (Wild & Schulze Heuling, 2021)	2021	Germany	The growth of digital transformation in education and the workplace necessitates the use of legitimate and reliable tools to assess individual digital skills.
19	Daniela Luengo-Aravena, Patricio Cabello, Beatriz Rodriguez-Milhomens Bachino. (Luengo-Aravena et al., 2024)	2024	Chile	Increasing demand for digital skills and collaborative problem-solving (CPS) abilities
20	Lucas M, Bem-Haja P, Siddiq F, Moreira A, Redecker C. (Lucas et al., 2021).	2021	Portugal	Teachers' digital abilities are critical in handling digital change in the education sector.
21	Tanja Held, Mathias Mejeh. (Held & Mejeh, 2024).	2024	United kingdom	Motivation is a critical aspect in the success of the learning process and lifelong learning.
22	Xia Wang , Zhu Tian , Jian Zhang. (Wang et al., 2026).	2026	China	The development of Artificial Intelligence (AI) has brought significant changes to vocational education, particularly in the fields of innovation and entrepreneurship
23	Xiangyu Wang, Kang Cao. (Wang & Cao, 2025).	2025	China	The advancement of artificial intelligence (AI) has accelerated revolution in vocational education, notably in the areas of innovation and entrepreneurship.

An analysis of keyword co-occurrence using VOSviewer shows that digital assessment, e-assessment, learning analytics, artificial intelligence, digital competence, competency assessment, and TVET are dominant themes in research from 2021 to 2026. The relationships between keywords indicate an increasing integration of digital technology into the evaluation of vocational education competencies. Additionally, there is a movement in study focus from digital competences and e-assessment to the use of learning analytics, artificial intelligence, and data-driven assessment systems. These findings imply that transforming digital assessment is a crucial problem for improving the quality of competence evaluation and graduates' readiness to fulfil the expectations of the digital sector. The results of this keyword mapping are shown in Figure 2.

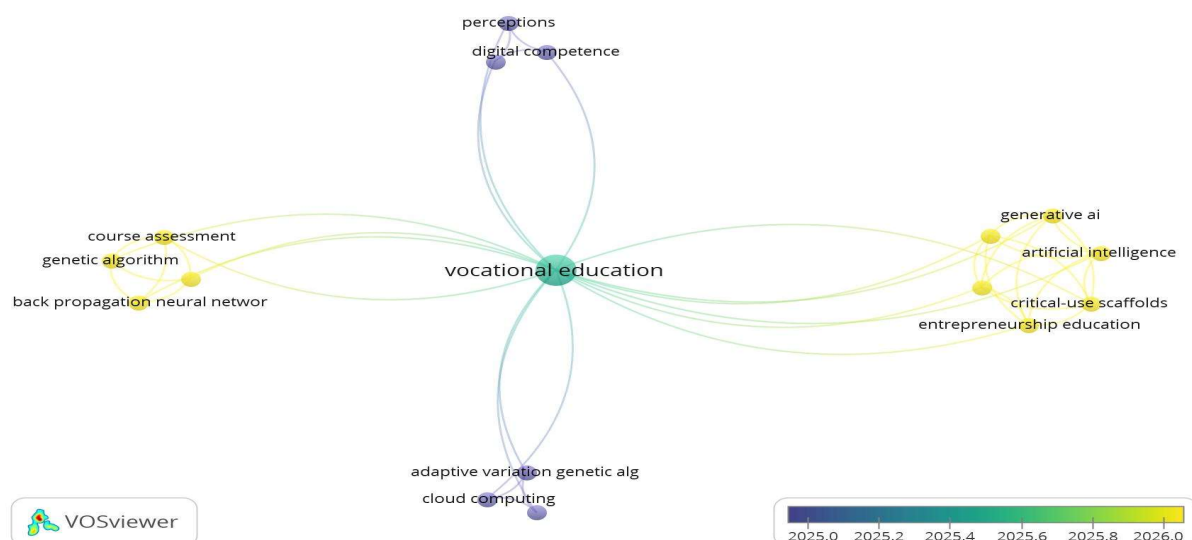


Fig.2. Bibliography based on vosviewer

Based on the results of the VOSviewer overlay visualization, The research on the digital revolution of assessment in vocational education throughout the 2025-2026 era focused on the phrase "vocational education," which had the highest frequency of occurrence and served as a link between various research themes. Co-occurrence analysis indicates that in the early phase of the research, the focus was on "digital competence" and "perceptions," reflecting attention to digital competencies as well as the perceptions of educators and students regarding the adoption of technology for learning and assessment. Additionally, the emergence of the keywords "cloud computing" and "adaptive genetic algorithm" indicates the utilization of computing technologies and intelligent algorithms to support the learning evaluation process.

Recent research developments are marked by increasing attention to artificial intelligence, generative AI, critical-use scaffolds, and entrepreneurship education. These findings imply a trend away from developing digital competences and toward the use of artificial intelligence and generative technologies to improve assessment quality, personalise learning, and create 21st-century abilities. Additionally, the emergence of keywords such as course assessment, genetic algorithm, and backpropagation neural network indicates the development of intelligent computation-based evaluation models aimed at improving the accuracy and effectiveness of competency assessment. Overall, the visualisation findings reveal that the digital transformation of assessment in vocational education is shifting toward the use of AI and cognitive analytics as the key means of enabling a more adaptable, objective, and data-driven evaluation system.

- 1) **RQ1.** What are the research trends for the digital transformation of assessment in the evaluation of vocational education abilities from 2021 to 2026?

According to an analysis of the selected papers, research on the digital transformation of assessment in the evaluation of vocational education abilities increased significantly between 2021 and 2026. In the initial term (2021-2022), research concentrated largely on the development of teachers' digital competences, the preparation of educational institutions, and the adoption of e-assessment and computer-based assessment as means of digitising the learning evaluation process (A. A. P. Cattaneo et al., 2022);(Wild & Schulze Heuling, 2021). As we begin the 2023-2024 academic year, research is expanding in the use of learning analytics, data-driven assessment

systems, and digital platforms to better monitor students' competency growth (Valle et al., 2021);(Kandul et al., 2023).

Furthermore, between 2025 and 2026, there appears to be a movement in research focus toward the application of Artificial Intelligence (AI), Generative AI, machine learning, and adaptive assessment systems capable of giving students with automatic and personalised feedback. VOSviewer visualizations also indicate that keywords such as artificial intelligence, generative AI, and digital competence are becoming increasingly dominant themes in recent research. These findings suggest that the transformation of digital assessment has evolved from the mere digitization of assessment tools toward intelligent, adaptive, and analytics-based competency evaluation systems designed to support 21st-century skill requirements and the demands of the digital workplace. (Sun & Tian, 2026); (Alfredo et al., 2024b).

2) **RQ2.** What digital assessment technologies are used in the evaluation of vocational education competencies?

Based on an examination of 23 papers that matched the inclusion requirements, it was discovered that the digital transformation of assessment in vocational education is aided by different technologies utilised to improve the efficacy of student competence assessments. The most extensively utilised technologies are E-Assessment and Computer-Based Assessment (CBA), which enable the assessment process to be completed digitally, effectively, and offer students with immediate feedback (A. A. P. Cattaneo et al., 2025). Furthermore, learning analytics are frequently utilised to gather and analyse data on learning activities, allowing educators to monitor students' development in a continuous and evidence-based way (Valle et al., 2021).

Recent technical breakthroughs have resulted in an increased usage of Artificial Intelligence (AI) and Generative AI in evaluation procedures. These technologies are used to carry out automated assessments, anticipate learning success, and deliver more personalised and adaptive feedback (Alalawi et al., 2025). In addition, several studies have also utilized Virtual Reality (VR) and Virtual Simulation Assessment to evaluate practical skills that are difficult to measure through conventional tests (Thomann et al., 2024). Other technologies identified include e-portfolios, digital rubrics, cloud computing, and algorithms based on machine learning and neural networks to improve the accuracy of competency assessments. These findings indicate that competency assessment in vocational education has evolved toward a more automated, adaptive, authentic, and data-driven assessment system to support the skills needs of the 21st century and the digital workplace.

3) **RQ3.** What are the advantages of digital assessment revolution in evaluating student skills in vocational education?

A review of the literature indicates that digital assessment transformation offers various significant benefits for evaluating student competencies in vocational education. One of the primary benefits is greater assessment efficiency and objectivity, since digital technology allows for the automated and more accurate collecting, processing, and analysis of learning outcome data than traditional approaches. Additionally, digital assessment can provide rapid, real-time feedback, allowing students to immediately understand their competency levels and make continuous improvements (A. Cattaneo et al., 2025); (Wild & Schulze Heuling, 2021).

The utilisation of technologies like e-assessment, learning analytics, and artificial intelligence (AI) allows for more authentic, performance-based competence assessments. Educators may test students' talents more fully using digital simulations, e-portfolios, and learning activity analysis, including the technical skills, problem-solving abilities, and critical thinking skills necessary in the

job (Valle et al., 2021);(Thomann et al., 2024). Furthermore, using learning analytics allows for continuous monitoring of students' competency improvement and better informed instructional decision-making.

- 4) **RQ4.** What are the problems and constraints to integrating digital assessments in vocational education?

According to a study of the literature, there are still technological, pedagogical, and organisational barriers to using digital evaluation in vocational education. One of the key challenges is the low degree of digital competence among educators in building, maintaining, and using technology-based assessment systems. Many vocational teachers still struggle to integrate digital technology into the competency evaluation process due to limited knowledge and experience in using digital assessment platforms (A. A. P. Cattaneo et al., 2025). Furthermore, constraints in technological infrastructure, such as uneven internet access, limited availability of digital devices, and poor technical assistance, pose hurdles to the implementation of digital evaluations, particularly in developing countries (Habibi et al., 2023).

Another problem is the validity and effectiveness of digital assessments in assessing practical skills, which are an important aspect of vocational education. Although technologies such as e-assessment, learning analytics, and artificial intelligence can improve the efficiency of assessment, there are still concerns regarding the accuracy of evaluation results, data security, and the transparency of the algorithms used in automated assessment systems (Alfredo et al., 2024); (Sun & Tian, 2026). Therefore, the successful implementation of digital assessment requires improving teachers' digital competencies, strengthening technological infrastructure, and developing assessment systems that are valid, secure, and aligned with the competency requirements of the modern workplace.

- 5) **RQ5.** What strategies does the literature recommend for optimizing the implementation of digital assessment in vocational education?

The findings of the literature research show that optimising the application of digital assessment in vocational education necessitates a multifaceted strategy that includes technological, human resource, and institutional policy considerations. The most frequently recommended strategy is to enhance teachers' digital competencies through ongoing training so that educators can effectively design, administer, and evaluate technology-based assessments. Strong digital capabilities have shown to be a critical aspect in the successful incorporation of technology into the learning evaluation process (A. A. P. Cattaneo et al., 2025);(Lucas et al., 2021).

Furthermore, the literature emphasises the significance of improving digital infrastructure, such as device availability, reliable internet connections, and user-friendly and secure assessment platforms. Adequate infrastructure support enables the consistent and sustainable implementation of digital assessments (Habibi et al., 2023). Recent study also supports the use of Artificial Intelligence (AI), learning analytics, and data-driven evaluation systems to increase the objectivity of exams, give real-time feedback, and assist instructors in precisely identifying students' learning requirements (Alalawi et al., 2025);(Sun & Tian, 2026).

Furthermore, collaboration between educational institutions, industry, and technology developers needs to be strengthened to ensure that the assessment systems developed align with the competency needs of the workforce. The integration of authentic project-based assessments, simulations, and e-portfolios is also recommended to ensure that competency evaluations reflect the actual skills required in modern work environments (Thomann et al., 2024).

4. Conclusions

According to the results of a literature study of 23 papers that matched the inclusion criteria, the digital transformation of assessment in vocational education has witnessed substantial progress throughout the 2021-2026 timeframe. This development is marked by the increasing use of technologies such as e-assessment, computer-based assessment, learning analytics, artificial intelligence (AI), virtual simulation, and e-portfolios in the process of evaluating students' competencies. These technologies have proven capable of enhancing efficiency, objectivity, and the accuracy of assessments, as well as providing faster and continuous feedback.

Nevertheless, the implementation of digital assessment still faces various challenges, particularly regarding educators' digital competencies, limitations in technological infrastructure, internet access, as well as ethical and data security issues. Therefore, the successful implementation of digital assessment requires support for digital competency training for teachers, strengthening of infrastructure, integration of AI and learning analytics technologies, and collaboration between educational institutions and the industry. Overall, the digital transformation of assessment has become an important component in assessing vocational education abilities because it facilitates the evaluation of skills that are more genuine, flexible, and linked with the demands of the 21st-century workforce. These findings suggest that the development of technology-based evaluation systems must continue to improve in order to generate competent vocational education graduates who are job-ready and capable of responding to future technological advances.

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