VTE VOCATION, TECHNOLOGY & EDUCATION

THEMATIC PAPER: APPRENTICESHIP

Next-Gen learning: The role of advanced technologies in preparing technical vocational education and training engineering educators

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ABSTRACT

This study explores the role of advanced technologies—virtual laboratories, simulations, and virtual reality (VR)/augmented reality (AR)—in online training for technical vocational education and training (TVET) engineering educators. Using an exploratory sequential mixed-methods approach, the research combines qualitative interviews (N = 11) and a quantitative survey (N = 237) to assess the effectiveness of these tools. Findings indicate that most educators recognize the benefits of integrating advanced technologies, improving engagement and skill development. However, excessive reliance on technology without interpersonal interaction may negatively impact learning outcomes. Data privacy and security concerns also emerged as critical issues. The study highlights the need for a balanced approach, ensuring practical applicability and alignment with course objectives. Future research should examine the long-term impact of these technologies on professional development and their role in fostering collaborative learning within digital educational environments.

Key words: online learning, adult education, course design, educational technology

INTRODUCTION

The professional education system is rapidly evolving under the influence of new technologies (Ghosh & Ravichandran, 2024; Goertz *et al.*, 2021). Virtual laboratories, simulators, and virtual reality (VR)/augmented reality (AR) are transforming not only the learning process (Abdul Razak *et al.*, 2022) but also how knowledge is delivered from instructors to learners (Diao & Qu, 2024). Engineering disciplines, among the first to adopt these innovations, still face challenges in bridging the gap between theory and practice (Alekseeva & Solomonova, 2020; Bilenko *et al.*, 2020; Buzaubakova *et al.*, 2023).

Despite ongoing global discussions, the effectiveness of these technologies in Technical Vocational Education and Training (TVET) remains underexplored, particularly from the perspective of educators (Egunjobi & Adeyeye, 2024; UNESCO-UNEVOC, 2019, 2022). This article, part of a doctoral study, examines the role of advanced technologies in TVET teacher training through online learning, focusing on the Russian Federation. Given its diverse socio-economic and technological landscape, regional differences in digital access make this study relevant for other countries with similar educational and economic conditions.

The training of TVET engineering educators in Russia is evolving through online and in-person courses offered by universities and private institutions. Typically, it builds on prior engineering education while enhancing pedagogical and applied skills. Professional development programs are often conducted in collaboration with the Ministry of Education and industry partners. Given the diverse backgrounds of TVET educators, understanding

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how advanced technologies can be effectively integrated into online training is essential.

METHODS AND RESEARCH DESIGN

This study is based on data collected as part of a doctoral research project. It represents the findings of an exploratory sequential mixed-methods design (Creswell & Plano Clark, 2017), combining both qualitative and quantitative research techniques (Spöhring, 1989). The primary research question is: Are advanced technologies—such as virtual laboratories, simulations, and VR/AR—effective in the online training of TVET engineering educators? Data collection was carried out in two phases to address this question.

The first phase involved 11 in-depth interviews with instructors responsible for training TVET engineering educators online. Participants were selected from eight federal districts of Russia to ensure regional representation considering variations in digital infrastructure and economic development (the Russian Federation consists of eight federal districts, administrative divisions that encompass multiple regions—from 6 to 18 regions inside each federal district—with varying levels of digital infrastructure and economic development). The primary objective of this phase was to explore educators' perspectives on the effectiveness of advanced technologies in TVET training. The interview protocols were developed based on the theoretical portion of the study, which included an analysis of the existing online training system for TVET engineering educators in Russia, classical learning theories, and key principles of digital didactics. Thematic analysis of the interview data allowed for the formulation of a hypothesis regarding the role of modern technologies in improving training outcomes.

Based on thematic analysis, the study formulated the following hypothesis: "Integrating modern technologies (virtual laboratories, simulators, and VR/AR) enhances TVET engineering educators' professional skills and improves training effectiveness".

The second phase tested the hypothesis through a survey of 237 TVET engineering educators from five federal districts in Russia. The survey aimed to validate the findings from the qualitative phase by assessing educators' perceptions of advanced digital tools in online training. To achieve broader generalizability, participants were selected from regions with different levels of technological advancement. However, this study does not specifically analyze regional differences in perception of technology.

Findings from the qualitative phase directly influenced the development of the questionnaire, ensuring a structured alignment between qualitative insights and quantitative validation. This mixed-methods approach strengthened the study's methodological coherence, allowing for an in-depth exploration of key factors influencing the effectiveness of online training for TVET engineering educators.

RESULTS

The findings confirm that advanced technologies contribute to the effectiveness of online training for TVET engineering educators. Respondents rated the use of interactive learning platforms, virtual laboratories, and simulators as significantly beneficial ($P < 0.001$), indicating confidence in employing these advanced technologies. Additionally, their responses highlighted the role of digital tools in bridging the gap between theory and practice. Their willingness to integrate these tools suggests that virtual laboratories, simulators, and other interactive resources can improve educational outcomes.

When asked about supplementary resources to enhance online learning, respondents highlighted virtual laboratories and interactive textbooks as key missing elements in the digital learning environment. Wilcoxon test results demonstrated that these resources were evaluated as statistically significant improvements ($P < 0.001$).

The perceived importance of VR/AR and interactive simulators was also statistically confirmed ($P < 0.001$), reinforcing the need for their inclusion in educational programs. However, when considering tools for deeper engagement, 35.44% of respondents rated simulators and laboratories as highly effective, while 40.50% expressed a preference for interactive discussions and live Q&A sessions (44.7%). This suggests that while technology facilitates content acquisition, deeper immersion requires interpersonal interaction and collaborative learning.

Notably, 75.53% of respondents supported the integration of advanced technologies ($\chi^2 = 61.776$, $P < 0.001$), highlighting their potential to enhance TVET training. Despite this, concerns about data privacy (39.20%) and security (60.80%) were prevalent, underscoring the need for robust cybersecurity measures in digital learning environments.

An important finding is that 29% of educators emphasized the necessity of aligning technology use with practical applicability ($\chi^2 = 139.41$, $P < 0.001$), highlighting the importance of ensuring that digital tools are relevant and beneficial for real-world teaching practice.

These results indicate that while advanced technologies are generally perceived as enhancing online training effectiveness, their implementation must be carefully structured. A technology-driven approach alone is insufficient; meaningful pedagogical integration is essential. Blind adoption of VR/AR simulators, virtual laboratories, and other tools without pedagogical alignment may not yield the desired educational outcomes and could even hinder learning. Effective technology integration requires verifying its relevance to specific educational programs and balancing technological solutions with human interaction. Additionally, addressing security and data confidentiality concerns is crucial when designing digital learning environments.

CONCLUSION

The study's findings confirm the transformative potential of advanced technologies in the online training of TVET engineering educators. Most respondents acknowledged that virtual laboratories, simulators, and AR/VR technologies enhance learning outcomes and engagement. However, excessive reliance on technology at the expense of traditional pedagogical methods, such as group discussions and interpersonal interaction, may negatively impact learning effectiveness. The choice of technological tools should align with course objectives, balancing innovation with practical application. For instance, while VR is highly effective for practicing engineering design, its benefits should be assessed within a broader pedagogical framework (Pan & Filippova, 2024).

Concerns regarding data security highlight the need for educational and platform developers to implement data protection policies and establish clear standards for safe digital learning environments. Additionally, increasing educators' digital literacy and providing methodological guidelines for integrating advanced technologies into online courses are essential for optimizing their use.

To maximize the effectiveness of online training, educators should integrate interactive digital tools and prioritize practice-oriented content delivery. Short, modular learning units have been shown to increase engagement, making them a promising approach for future course design. Institutional support, such as structured professional development programs and access to digital infrastructure, is essential to enhance educators' digital competence (Neuweg, 2018; Wahl, 2023).

A promising direction for future research is the long-term impact of advanced technologies on TVET engineering educators' professional development and their role in preparing professionals for vocational education and training institutions. Further exploration of online interaction mechanisms and the role of digital platforms in fostering professional communities among educators is also warranted.

In conclusion, while modern technologies offer significant advantages for online training, their implementation must be supported by thorough pedagogical planning to maintain an effective balance between digital tools and traditional teaching methods.

DECLARATIONS

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Author contributions
Dolgova N: Conceptualization, Data curation, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing—Original draft, Writing—Review and Editing, Visualization, Project administration. The author has read and approved the final version of the manuscript.

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Ethical approval
Not applicable.

Informed consent
Qualitative stage: The participants were informed that the interview data were only used for research purposes, and their information would be anonymized when presenting the research results. Moreover, they were allowed to stop the recording at any moment during the interview and could refuse to respond to any question asked.

Quantitative stage: The participants in the survey took part anonymously, with no personal data collected. Only aggregated information and responses to the survey questions were gathered. The participants were informed that their survey data would be anonymized and used

solely for research purposes. They were also informed that they could choose to stop the survey at any time and were not obligated to respond to any question.

Conflict of interest

The author has no conflicts of interest to declare.

Data availability statement

Data used to support the findings of this study are available from the corresponding author upon request.

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