Key Factors of Online Course Perceived Effectiveness for Preparing TVET Engineering Teachers in Russia

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CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 Introduction

Currently, the teacher training system, including in the field of engineering and pedagogical education, is facing significant challenges related to technological transformation and the need for rapid adaptation to changing conditions. Global trends, such as digitalisation, automation, population ageing, and environmental and social challenges, necessitate a reevaluation of the goals and content of educational programs, as well as the models of teaching practice in vocational education and training (OECD, 2025; UNESCO, 2024; WEF, 2025).

According to the Trends Shaping Education 2025 report, education has to become a factor of resilience in times of uncertainty and play a key role in shaping a future-oriented toward adaptability, solidarity, and technological thinking (OECD, 2025). At the same time, The Future of Jobs Report 2025 emphasises that by 2030, approximately 39% of professional skills will transform, requiring reskilling and a revision of vocational training models (WEF, 2025).

The development of technical and vocational education and training (TVET) systems is particularly relevant when it leads to a system that can simultaneously meet the needs for digital and environmental competencies, provide flexibility in educational pathways and guarantee inclusiveness (UNESCO-UNEVOC, 2024). In this context, the role of engineering teachers is gaining importance as agents of innovation and change in vocational education—professionals who are capable of integrating modern technologies, educational innovations, and labour market demands.

Over the past decades, the system of teacher training for TVET organisations in Russia has undergone transformations driven by both socio-economic and political changes. Researchers note that the collapse of the USSR, the transition to a market economy, and the globalisation of educational standards required a transformation of the goals, content and forms of teacher training (Kubrushko, 2002b; Romanov, 2008). Today, the Russian vocational education system is undergoing a process of modernisation. According to OECD reports, the growing shortage of qualified teaching staff, outdated curricula, and the need for digital and soft skills point to the urgency of reforming both the content and the organisational models of teacher education (OECD, 2021; Cedefop, 2025). Increasing demands for the quality of vocational education have drawn attention to teacher qualifications—particularly in the field of engineering pedagogy, where training requires a combination of professional expertise, methodological competence, and digital literacy (Maiburov, 2019; Vorobyeva, 2022; Gadzhikurbanova, 2023). The availability of these competencies in teachers is particularly relevant in the context of implementing the digital transformation strategy in education and transitioning to a model of lifelong learning.

Existing research on vocational teacher training has focused on several key aspects, including the content of pedagogical training (Kubrushko, 2002b), the historical development of engineering pedagogy as a field (Tenchurina, 1998), and the use of contemporary educational technologies in adult learning (Lebedeva, 2011). However, the integration of theoretical, methodological, and practical components within modern engineering pedagogical education models remains insufficiently explored. Moreover, a significant gap persists between the current practices of teacher preparation and the actual professional demands faced by teachers in the context of digital transformation (Grinshkun & Suvorova, 2024).

The theoretical foundation of this study consists of both classical educational theories—such as humanistic (Maslow, 1968), behaviorism (Corr & Perkins, 2006; Thorndike, 1898), cognitive

(Piaget, 1952; 1962; 1971; 1974; 1985; 2013), constructivist (Vygotsky, 1926; 1978; 1984; 1986; 1987; 1987a; 1987b; 1997; 1999; 2005; 2010), and Albert Bandura's social learning theory (Bandura, 1977; 1986; 2014)—and contemporary approaches that reflect the specifics of adult and digital education. These include andragogy (Knowles, 1973; 1980; 1984), digital didactics (Bilenko et al., 2020), heutagogy (Hase & Kenyon, 2001), and Diethelm Wahl's "Pädagogischer Doppeldecker" model (Wahl et al., 2020). A comprehensive analysis of pedagogical theories relevant to the training of TVET engineering teachers provides a deeper understanding of how teachers perceive and acquire both professional and pedagogical competencies. It also forms a conceptual basis for the effective design of educational programs aimed at preparing future professionals. Thus, the study integrates theoretical depth with strong practical relevance, focusing on the development of digital training formats for TVET engineering teachers.

This study presents a systematisation and analysis of factors influencing the perceived effectiveness of engineering educator training in the context of digital education technologies. The research aim is to identify key components of successful online training courses.

1.2 Background and Problem Statement

The system of teacher education for vocational education and training (TVET) in Russia has historically developed unevenly, undergoing numerous institutional changes and regulatory transformations. In the early 2000s, the academic program "Vocational Education" was removed from the bachelor's and master's degree structures and replaced by the unified program "Technological Education." This shift marked a return to the engineering-pedagogical training model typical of the mid-20th century. This solution levelled out the sectoral specificity of teacher training, excluded the possibility of integrating the industrial-technological component with the psychological-pedagogical one, and did not provide for prospective and cross-sectoral training of specialists (Romantsev et al., 2011).

Despite isolated efforts at institutional reform, including the creation of academic-methodological associations and the development of professional standards, the shortage of professionally trained teaching staff persisted for two decades. According to the Ministry of Labour of the Russian Federation, the projected staffing needs for teachers by 2030 amount to 96,000 specialists, including 40,000 school teachers. Additionally, according to a monitoring report by the People's Front, 34% of Russian TVET and VET institutions report a shortage of qualified personnel ("A Century of Learning", 2024). An excessive bureaucratic workload and unattractive employment conditions—such as heavy teaching loads and low salaries—significantly contribute to the worsening staff shortage. Researchers note that the workload on remaining teachers has increased considerably, negatively affecting the quality of education and limiting opportunities for professional development and instructional renewal (Osipova et al., 2019; Serkina, 2025).

The COVID-19 pandemic posed an additional challenge by revealing the low level of digital readiness among TVET teacher trainers. At the onset of the crisis, institutional systems and resources were unprepared for the transition to online formats, as only 10% of programs had digital support, and many teachers and trainers struggled to use digital didactic tools effectively (Agranovich et al., 2020). At the same time, there was growing interest in using online courses and modular learning as tools for the training and retraining of teachers in contexts where face-to-face formats were inaccessible. Despite the rapid expansion of online education, systematic research into its effectiveness in the context of engineering pedagogical training remains largely absent. These circumstances highlight a critical need to develop new approaches to teacher education that are grounded in digital didactics, hybrid and networked learning formats, and the principles of project-based and personalised pedagogy (Dubitsky, 2023). At the same time, it remains unclear how future TVET engineering teachers perceive the effectiveness of online

learning within their training programs, which elements of digital courses they find meaningful, and to what extent these formats contribute to the development of professional and pedagogical competencies.

Among recent key initiatives is the launch of the “Professionalitet” project (2025), which aims to establish sustainable cluster-based partnerships between educational institutions and industry, as well as the creation of federal-level vocational education technoparks and advanced teacher training centres. However, for their successful implementation, it is necessary to develop integrated training models that combine sector-specific content with pedagogical and psychological components grounded in competency-based and anticipatory learning approaches (Chuhina, 2015; Dubitsky, 2023).

Despite a high level of regulatory and managerial activity, questions concerning the methodological, curricular, and digital transformation of TVET teacher competence development remain insufficiently explored. The lack of comprehensive research is particularly noticeable in the field of engineering-pedagogical education, which remains underrepresented in both Russian and international scholarly literature. Little attention has been paid to the integration of professional and pedagogical training in the context of digitalisation and emerging industrial demands, particularly as they relate to the training of TVET engineering teachers. There is also a significant gap in research exploring learners' subjective experiences—such as motivation, professional identity, and self-assessment of their learning in digital environments. This lack of insight creates significant difficulties in understanding the mechanisms of professional competencies formation in engineering and pedagogical directions through digital educational technologies. Moreover, a persistent disconnect remains between academic training programs and the actual demands of the modern industrial and educational landscape.

In the context of digitalisation in vocational education, there is an increasing need for evidence-based approaches to the training of engineering teachers within the TVET system. Despite the active implementation of online courses and digital professional development formats, the question remains: What factors determine the effectiveness of such programs from the perspectives of the key stakeholders—teachers and learners? This study gains further relevance in light of the ongoing shortage of technical teaching staff and the growing demands of the digital economy and Industry 4.0.

Against the background of the challenges of technological transformation, the shortage of personnel, and increasing requirements for the quality of specialists' training, there is a need for a scientific understanding and design of an effective model for TVET engineering teachers' training. In the context of educational digitalisation, scholars and practitioners increasingly recognise the potential of online courses as purposeful instruments for the professional development of TVET engineering teachers. Accordingly, the core research problem addressed in this study lies in the insufficient empirical investigation of the factors that determine the perceived effectiveness of online courses in TVET engineering teachers training, as well as the lack of comprehensive analysis of the perspectives of both learners and teacher trainers involved in digital TVET teacher preparation. Moreover, it is essential to consider the opinions of TVET engineering teacher trainers, which enables the formation of a holistic view of an effective architecture for digital educational programs tailored to the modern requirements of the TVET system.

This research aims to address the identified scholarly and methodological gap by proposing and modelling an effective system for the online training of TVET engineering teachers. The proposed system aims to meet the demands of the digital economy and the contemporary labour market while aligning with current educational priorities at both national and international levels.

1.3 Purpose of the Study

This study aims to identify the key factors that determine the perceived effectiveness of online courses in the training of TVET engineering teachers within the technical and vocational education and training (TVET) system. To achieve this aim, a mixed-method research approach is applied—an exploratory sequential design in which each stage yielded specific results.

The target sample includes two participant groups: (1) teacher trainers who deliver online courses for TVET engineering teachers and (2) TVET engineering teachers who have completed professional development or retraining through online learning.

The study begins with the application of a qualitative method, namely standardised in-depth interviews with teacher trainers, to identify the key factors they associate with online course effectiveness. The data collected in this phase inform the development of a hypothetical model, which forms the basis for the questionnaire design.

The second phase involved conducting a quantitative study using a mass survey of TVET engineering teachers to identify statistically significant factors influencing the perceived effectiveness of online courses.

Each of the steps yielded its own results, which necessitated the inclusion of an additional step, data triangulation. Using data triangulation, it was possible to identify both similar factors and unanticipated research findings.

The study aims to address the theoretical and empirical gap in the field of digital training for TVET engineering teachers while also developing and validating an instrument to evaluate the effectiveness of online learning. The findings will provide a deeper understanding of how key components of digital educational programs are perceived and will offer practical recommendations for their design in alignment with the objectives of the TVET system.

1.4 Methodology and Research Design Overview

The study employs an exploratory sequential mixed-methods research design, aligning with contemporary research practices (Creswell & Plano Clark, 2018), and utilises purposeful sampling to accurately represent the perspectives of teacher trainers and TVET engineering teachers. The study adopts this approach as the most appropriate for addressing the research gap, given the scarcity of prior research on the topic. It also enables the development of a valid data analysis system to identify the factors influencing the perceived effectiveness of online learning among TVET engineering teachers (Creswell et al., 2004; Creswell, J. W., & Creswell, J. D., 2018). The objective of using a mixed-methods design is to combine an in-depth understanding of an underexplored phenomenon (through interviews) with subsequent empirical testing of the identified factors on a representative sample (through a survey), thus enhancing the validity and reliability of the empirical findings (Diekmann, 2020). The research first analyses teacher trainers' perceptions (qualitative phase), followed by the views of TVET engineering teachers (quantitative phase). This combination captures both individual meaning-making and generalised patterns of perception regarding online courses. Between-method triangulation is applied to compare data from both phases, thereby confirming the hypotheses and reinforcing the reliability of the findings (Denzin, 2017).

The study consists of four sequential phases. The study comprises four sequential phases. In the first phase, standardised in-person, open-ended, in-depth interviews were conducted with teacher trainers delivering online courses for TVET engineering teachers (N = 11), providing the initial

qualitative data (Patton, 2014; Johnson, 2014). This format ensures the consistency and comparability of data while maintaining flexibility, variability, and the depth of respondents' answers. It is crucial to note that this approach keeps the influence of the interviewer on the survey results to a minimum (Hyman,1954). The main aim of this stage is to identify the key factors that influence the effectiveness of online educational programmes for TVET engineering teachers. To dig deeper into the obtained texts, the study employed a six-step content analysis method (Mühlfeld et al., 1981) to identify key categories and construct data-based hypotheses. The resulting textual findings from the interviews were manually coded and then cross-checked using ATLAS.ti software. This approach ensures the accuracy and relevance of the findings and levels out the omissions in the manual coding process of essential data for research work.

The qualitative analysis informed the development of a questionnaire designed to test the hypotheses. The structure of the questionnaire items reflected the categories identified during the interviews. The questionnaire underwent pilot testing and expert review for content validity, involving five experts in online education for TVET engineering teachers and five TVET engineering teachers who had completed such courses (Can, 2011).

The quantitative phase involved surveying TVET engineering teachers with experience in online learning as part of their professional development or retraining programs (N = 237). This phase aimed to test the hypotheses, identify the significance of factors influencing the perceived effectiveness of online courses, and validate the theoretical model developed in the qualitative phase. For processing and analysing the quantitative data, QCAmap and the RStudio software environment (version 4.4.3) with the R programming language were used (Wickham et al., 2023). The study adhered to ethical standards, ensuring that participation was voluntary, confidentiality was guaranteed, and participants were allowed to withdraw at any stage.

The interpretation of results draws on a comprehensive set of theories, including humanistic (Maslow), behaviorist (Pavlov, Thorndike), cognitive (Vygotsky, Piaget), constructivist (Dewey, Vygotsky), andragogy (Knowles), heutagogy (Hase & Kenyon), digital didactics (Bilenko), the Pedagogical Double-Decker (Wahl), and social learning theory (Bandura). This theoretical foundation provides a robust conceptual framework for interpreting the findings and aligning the empirical data with theoretical models of TVET teacher preparation in the context of digital transformation.

Figure 1.1 illustrates the sequential stages of the study, including qualitative data collection and thematic analysis, the development and validation of the quantitative instrument, quantitative data collection and hypothesis testing, and the final integration of results.

Each phase builds upon the previous one and contributes to the primary goal of the research — to identify key factors that determine the perceived effectiveness of online courses for TVET engineering teachers. Moreover, each phase follows specific methodological research questions, which are presented and discussed in detail in the next section. These questions reflect the sequential exploratory nature of the research work, combining the exploratory design of the qualitative phase, which contributes to the purpose of the quantitative phase and allows the integrative function of the data triangulation phase to unfold. This approach helps to ensure the validity of the data as well as consistency between the research design and its key purpose.

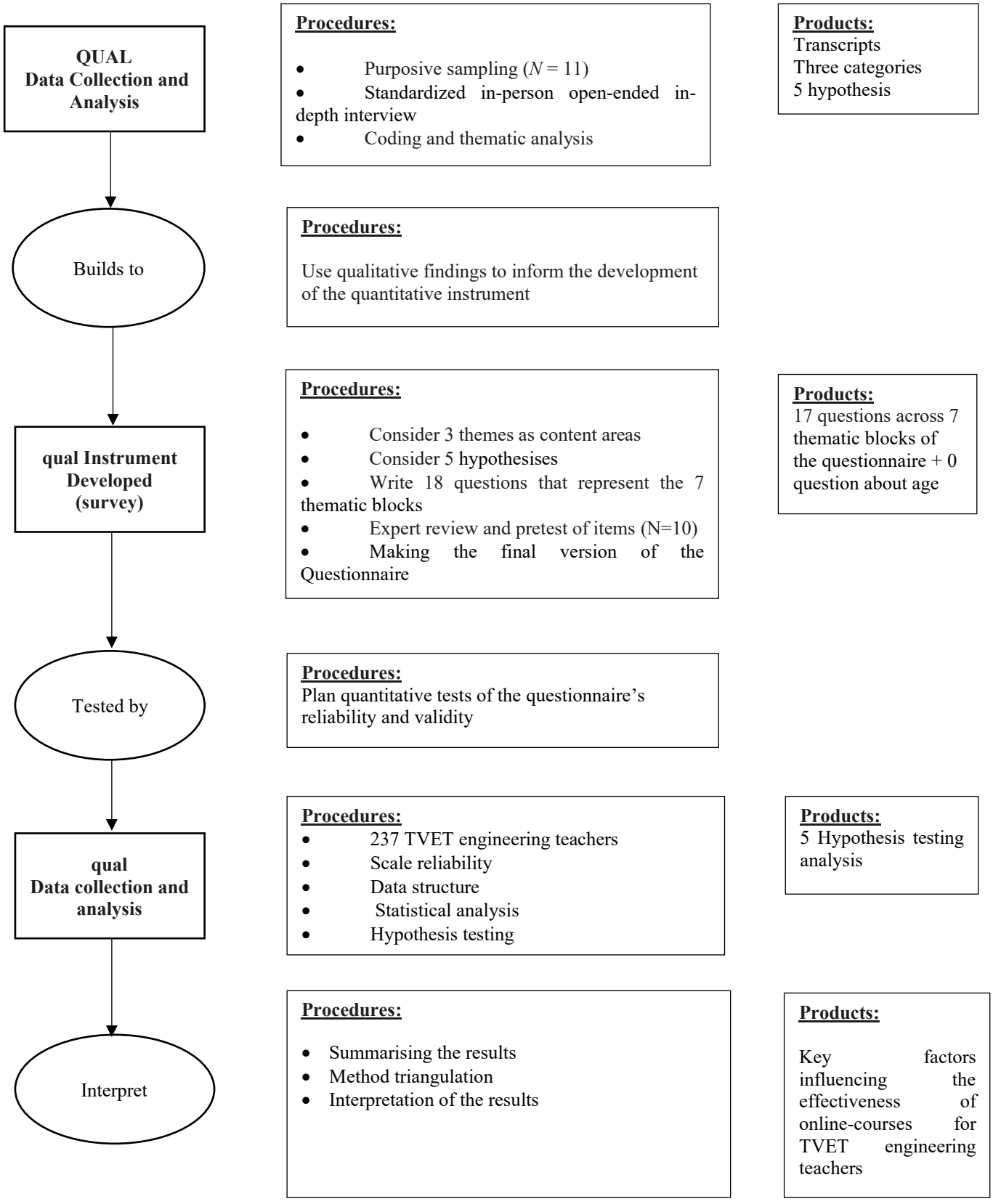

Figure 1.1 *Graphic Presentation of Exploratory Mixed Methods Research Design (based on Craswell & Plano Clark, 2017, p.66-67)*

1.5 Research Questions

This study focuses on examining the factors that determine the perceived effectiveness of online courses in the training of TVET engineering teachers. The research draws on the perspectives of two key groups— teacher trainers who design and deliver online courses and TVET engineering teachers who participate in training in digital formats. The research questions were formulated by the logic of the exploratory sequential mixed-methods design and aimed to identify significant connections between participant perceptions and the structural features of online courses.

Thus, the Primary Research Question is formulated as follows:

What are the key factors that determine the perceived effectiveness of online courses for preparing TVET engineering teachers in the professional education system, as perceived by both course teacher trainers and participating trainees within the TVET engineering teacher programs?

In line with the exploratory sequential design, a set of Procedure-Guided Research Questions was formulated to guide each phase of the study. In the qualitative phase, the research question aimed to explore the perspectives of teacher trainers delivering online courses. It was formulated as follows: What key factors influence the perceived effectiveness of online courses for training TVET engineering teachers in the professional education system, according to the teacher trainers who deliver these courses? In the connecting phase, based on insights from the qualitative data, the following mixed methods question was addressed: How can the results of in-depth interviews with teacher trainers be used to develop a questionnaire to investigate the views of TVET engineering teachers and validate factors of effectiveness of online courses? During the quantitative phase, the study focused on how participants in online courses assess the importance of different factors. The related research question was: How do TVET engineering teachers taking online courses assess the impact of various factors on the perceived effectiveness of these courses? Finally, in the integration phase, the study examined the alignment between qualitative and quantitative findings. The design-specific question was: How do the results of the large-scale survey of TVET engineering teachers align with the opinions of online course teacher trainers regarding the factors that determine the perceived effectiveness of online learning in the context of TVET teacher preparation?

1.6 Theoretical Framework

The theoretical framework of this study is informed not only by pedagogical theories and didactic models but also by a broader contextual analysis of the development of technical and vocational education in Russia. It includes three foundational areas: the historical evolution of technical and vocational education and training (TVET), the historical development of teacher training within the TVET system, and the classification, didactic characteristics, and practical implications of distance and e-learning formats currently applied in TVET educator training. These contextual dimensions serve as a macro-level foundation that situates the research problem within national educational policy, institutional structures, and the digital transformation of teacher preparation. Building on this foundation, the theoretical model outlines four interrelated levels that guide the analysis of perceived effectiveness in online learning environments:

1. Basic Level: Fundamental Learning Theories

The theoretical model builds on classical learning theories, which represent the basic ideas that form the foundation for understanding the key factors of the perceived effectiveness of online courses. These theories help to develop online courses for TVET engineering teachers, provide a

deeper understanding of how educational processes work, and highlight key didactic principles for practice-oriented online courses.

2. Central Level: Contemporary Learning Theories

The core of the theoretical framework draws on contemporary educational theories, such as digital didactics, that articulate the key didactic and conceptual foundations for designing digital learning courses. These include, for example, the theory of digital didactics. Such theories not only facilitate the analysis of learning processes and content but also support the development of flexible learning pathways, the visualisation of educational experiences, and a more nuanced focus on modes of interaction within the implementation of educational programs.

3. System Level: Pedagogical theories of adult learning

This level incorporates frameworks such as andragogy (Knowles, 1973), which reflects the principles of adult learning and is especially relevant in the context of professional development for TVET engineering teachers. Additionally, heutagogy (Hase & Kenyon, 2000, 2003) emphasises self-determination and learner-directed educational processes, which are critical in online learning environments. Both of these theories relate to digital didactics and require a balanced application of their key postulates for effective implementation.

4. Meta-Level: Applied Didactic Models

This level incorporates applied didactic solutions designed to support the development of educational courses aligned with current requirements for TVET engineering teacher training through online courses. This level consists of:

- Wahl's Pädagogischer Doppeldecker (Wahl, 2023), which proposes the integration of professional and pedagogical "cores" in specialist training, applies to the design of TVET educational programs.
- The Three-Layer Model of Vocational Didactics (Deutsches Didaktisches Dreieck, Schröder, 2015; Bönsch, 2006), which structures vocational education into operational, methodological, and content levels.
- HyFlex (Atkinson, 2023) provides an additional perspective on considering the flexibility of learning formats as a factor influencing perceived effectiveness.

Thus, the proposed theoretical model provides an interpretation of the research results, accounting for various levels of pedagogical interaction — from theoretical foundations to applied didactic solutions. Historical and structural analyses help explain why particular pedagogical theories and digital formats are relevant in the Russian TVET context, supporting the interpretation of empirical findings in light of educational policy and practice. This dual focus ensures both conceptual depth and contextual validity in the examination of perceived effectiveness in online professional development for TVET engineering teachers.

Thus, the proposed theoretical model provides a comprehensive and theoretically grounded basis for interpreting the research findings across different levels of pedagogical interaction—from foundational theory to applied didactic strategies. It also serves as an analytical foundation for formulating questionnaire categories, processing interview data, and justifying research hypotheses. The multi-level theoretical structure ensures methodological rigour, supports coherent analysis, and strengthens the alignment between conceptual models, research tools, and empirical conclusions.

1.7 Advancing Scientific Knowledge and Significance of the Study

This study contributes to the advancement of scholarly knowledge both within the framework of the international research agenda on the training of TVET engineering teachers and in the broader

context of research on the professionalisation of teaching personnel. In the context of rapid digitalisation in education and the transformation of pedagogical requirements, the system for preparing TVET engineering teachers faces the pressing need to adapt didactic models, teaching methods, and assessment tools (Amrenova, 2024). Despite growing interest in online learning within teacher education, the academic literature continues to lack research focused on analysing the factors influencing the perceived effectiveness of online courses from both sides of the learning process—teachers, trainers, and learners.

This study presents a context-specific analytical framework and an advanced empirical model that identifies the key factors influencing the perceived effectiveness of online learning in training TVET engineering teachers. Through the application of an exploratory sequential mixed-methods design, the study not only uncovers participants' subjective views on the effective elements of digital learning but also develops a tool for large-scale quantitative validation of factors relevant to vocational education. Unlike most studies, which focus on a single group (most often learners), this research captures the perspectives of both teacher trainers and TVET engineering teachers engaged in online learning, thus enabling the construction of a more comprehensive and valid model of effectiveness factors.

The study demonstrates how professionals with technical backgrounds can acquire pedagogical competencies through digital formats aligned with the demands of digital transformation and the expectations of high-tech industries. The findings are, therefore, adaptable and applicable across a wide range of international contexts, opening new avenues for interdisciplinary and transnational dialogue in the field of TVET teacher training.

This study aims to fill an important gap in research on understanding the key factors of effectiveness in online training for TVET engineering teachers by presenting a comprehensive empirical model. This model presents the opinions of teacher trainers and TVET engineering teachers, providing a comprehensive view of the factors influencing perceived effectiveness from different perspectives. Within the domain of Russian TVET research, this study offers a rare example of a fully realised exploratory sequential mixed methods design tailored to the specific challenges of engineering teacher preparation. It has resulted in a theoretically and empirically grounded model that is relevant both nationally and internationally in the context of the digital transformation of TVET While international literature includes studies on digital learning in vocational education (for example, in the context of STEM teacher development), to date, no studies have compared the perceptions of course effectiveness held by teacher trainers and learners within the training of TVET engineering teachers. This study addresses that gap and adapts methodological approaches to the training of TVET engineering teachers through online courses.

The scientific novelty of this study lies in its systematic analysis of diverse stakeholder perspectives on the perceived factors of online learning effectiveness—drawing on data from teacher trainers (as course designers and facilitators), TVET engineering teachers, and course participants. This triangulated approach enabled the identification of both converging expectations and assessments, as well as significant discrepancies in perceived effectiveness factors of digital educational programs. The analysis enabled the formulation and substantiation of key determinants that shape the perceived effectiveness of training for TVET engineering teachers. These factors include format flexibility, practice-oriented content, the use of AR/VR in online courses, and the crucial roles of feedback and motivation in achieving successful learning outcomes.

Furthermore, the identified factors of perceived online course effectiveness in the context of engineering-pedagogical education illustrate the interrelation between course structure, digital environments, and the subjective appraisal of professional utility. The study also presents refined

definitions of the concepts "Perceived Effectiveness of Online Courses," "Active Learning," and "Convenience" as applied to professional online teacher training within the context of digitalisation and industrial transformation. These conceptual clarifications demonstrate their significance in the context of course design and implementation. Moreover, the study presents an expanded definition of the term "TVET Engineering Teacher," supplemented with a description of the varied roles of teachers in engineering disciplines within the framework of the vocational education and training system, as well as their new role in a digital society.

The analysis led to the development of a multi-level theoretical and didactic model for online training of engineering discipline teachers in the TVET system. (Appendix A). This model synthesises foundational learning theories—including behaviorist and humanistic perspectives—with contemporary concepts in digital didactics and adult learning frameworks, such as andragogy and heutagogy. In addition, it incorporates applied instructional designs, including Wahl's Pedagogical Biplane and the Dreidecker three-tier model of professional didactics. The HyFlex approach defines the outer structure of the model. It allows for flexible formats, supports personalised learning paths, and helps adapt content to individual learner needs. This structure illustrates the transfer from theoretical frames to practice-oriented strategies of digital courses specifically tailored to the context of engineering pedagogical education. It helps to develop online courses, which could lead to fostering core professional pedagogical competencies among specialists with technical backgrounds. This model provides opportunities for personalisation, reflection, and adaptation of content to meet learners' actual needs.

From a theoretical perspective, the study refines the methodological and didactic foundations for integrating classical and contemporary pedagogical theories with applied didactic models, thereby facilitating the analysis of digital educational practices within the TVET system. The theoretical framework, which combines traditional and modern educational paradigms, supports data interpretation in an interdisciplinary and transnational context, incorporating social learning theory alongside current digital learning modalities.

This research contributes to the expansion of interdisciplinary knowledge at the intersection of digital pedagogy and engineering education. By synthesising pedagogical theories and practical didactic strategies for online instruction, the study lays the groundwork for both conceptual and empirical tools. It may support the development of designing and evaluating systems for online continuous professional development courses in TVET engineering for teachers. Moreover, it introduces Russian empirical data into a broader international discourse on hybrid and online teacher education, offering context-sensitive conclusions of relevance to comparative educational research in the TVET sector, as well as for the development of practical resources and strategies applicable across diverse educational settings.

The practical significance of the research findings is threefold. First, curriculum designers and course developers can utilise the recommendations derived from empirical data on critical factors in creating flexible and effective digital learning environments tailored to the needs of TVET engineering teachers within the TVET system. Second, policymakers and institutional leaders receive actionable guidance to support the professional development of TVET engineering teachers through scalable, accessible, and efficient formats. Last but not least, researchers in the fields of teacher education and digital didactics are offered a foundation for further inquiry and the investigation of similar issues in other national or sectoral contexts. Additionally, the study provides insights into how digital platforms and online tools can effectively structure the design of international upskilling programs.

The findings of this study are highly relevant not only in the context of the Russian system for training TVET engineering teachers but also from an international perspective. The shortage of

teaching staff in technical and vocational education—particularly in the context of digital transformation and the shift toward Industry 4.0 and AI-driven industrial development—is a common challenge in many countries (Wang et al., 2024; Ahmad, 2024). Moreover, the high heterogeneity of teacher training systems across European and non-European countries highlights the importance of approaches based on digital tools and flexible training models (CEDEFOP, 2022; Mizova et al., 2023). These conditions create opportunities to adapt the study's findings to international and transnational contexts, for example:

- in the framework of international projects such as those by UNESCO-UNEVOC, OECD, CEDEFOP, etc.;
- in cross-cultural comparisons (e.g., between countries in Eastern Europe, Latin America, and Southeast Asia);
- in corporate training systems for mentors and trainers (e.g., using the Kirkpatrick/Desimone model).

Thus, this study helps to identify scientific and methodological gaps in the field of digital training for TVET engineering teachers and demonstrates its potential for transnational application. The proposed theoretical and empirical model may serve as a foundation for developing flexible, adaptive, and pedagogically grounded training programs in the context of digitalisation and industrial transformation. The results contribute to strengthening both the academic and practical foundations of TVET and open new directions for international academic and professional dialogue. The study offers a new perspective on designing digital programs in TVET by combining the pedagogical reflections of teacher trainers with the perceptions of end users—TVET engineering teachers—thereby shifting from intuitive solutions to evidence-based practices. Moreover, the study proposes a new paradigm for analysing the effectiveness of online learning in TVET by offering a valid and adaptable model that integrates the perspectives of both teacher trainers and TVET engineering teachers, aligns with theory, and is grounded in empirical verification. This model could be a foundation for future research, course development, upskilling strategies, and policy-making in the field of digital teacher education.

1.8 Description of Terms

- Theoretical and Pedagogical Approaches

The terms presented below outline learning concepts that form the foundation for the educational models designed in this study.

Andragogy is an educational approach centred on adult learners, emphasising self-directed learning, the practical application of knowledge, and the relevance of learners' life experiences.
The term andragogy was first coined by Alexander Kapp in 1833, in a book on Plato’s philosophy of education, where he included a dedicated section on adult education and called it Andragogik (Kapp, 1833; Loeng, 2017; 2018). However, the concept gained broader theoretical and practical significance only much later—primarily through the work of Malcolm Knowles (1973), who viewed the adult learner as an intrinsically motivated, self-directed individual oriented toward solving real-life tasks. Key principles of andragogy include learner participation in planning, reliance on practical experience, solving relevant professional problems, outcome-oriented learning, and the development of autonomy (Knowles, 1973; Jarvis, 2001; Merriam & Bierema, 2014; Guirguis, 2020).

Heutagogy is a pedagogical concept that focuses on self-determined learning, where learners decide what, how, why, and for what purpose they study. Initially described by S. Hase and C. Kenyon (Hase & Kenyon, 2011), heutagogy is seen as a logical extension of andragogy and is

grounded in humanistic pedagogy, constructivism, transformational learning, and action learning. It is particularly relevant in digital learning environments, where learners design their learning paths, participate in setting goals and assessment methods, and actively engage in reflection and feedback. In the context of TVET teacher training, heutagogy fosters independence, metacognitive skills, and adaptive professional behaviour.

Behaviorism is a theory that views learning as the formation of stable behavioral responses to external stimuli. The environment shapes learner behavior by reinforcing actions through rewards or punishments. Key proponents include E. Thorndike (1898), I. Pavlov (1925), and B.F. Skinner (1961). Teachers use behaviorism in educational practice to develop skills through repetition, reinforcement, and monitoring of outcomes. However, critics often highlight that this approach neglects internal cognitive processes and the learner's active role in constructing knowledge. It is suitable for structured learning environments with clear external motivation (Thorndike, 1898; Skinner, 1965).

Constructivism is a learning theory that views learners as active participants who do not receive knowledge in a ready-made form but rather construct it themselves through personal experience, interaction with the environment, and reflection. Major theorists include J. Piaget, L.S. Vygotsky, J. Bruner, and J. Dewey. In constructivist learning, students are engaged in goal setting, content exploration, and knowledge construction based on existing cognitive frameworks. The learning process centres on problem-based tasks, group work, reflection, and contextual application of knowledge. The theory underpins modern pedagogical models such as experiential learning, project-based learning, and active digital environments (Dewey, 1938; Piaget, 1971; Vygotsky, 1978; Bruner, 1997).

Pedagogy is the science and practice of teaching, encompassing both practical instructional methods and theoretical foundations of learning. It includes issues related to methodology, curriculum content, educational goals, and teacher-learner interaction. The term is traditionally associated with teaching children and youth, in contrast to andragogy (adult learning) and heutagogy (self-determined learning) (Wallace, 2009).

Digital Didactics is a structured area of pedagogy focused on the development and application of didactic strategies, tools, and teaching methods in digital learning environments. It emphasises the organisation of learning processes, the selection of digital resources, and the design of digital assignments (Bilenko et al., 2020).

Digital Pedagogy, unlike digital didactics, is a broader concept encompassing the philosophical, critical, and social aspects of teaching with digital technologies. It focuses not only on "how" to teach but also on "why," "what," and "under what conditions" teaching should occur in the digital age (Jisc, 2020; Huang et al., 2024).

- Digital Educational Technologies and Environments

The following terms describe the environment and tools used in the learning process.

Distance Educational Technologies (DET) refer to a set of digital tools that support the delivery of educational processes via information and telecommunication networks (primarily the Internet), enabling instructor–learner interaction at a distance in synchronous or asynchronous modes. DET includes digital resources (platforms, services, tasks, and video lectures), remote teaching methodologies, and feedback and support mechanisms. According to Article 16 of Federal Law No. 273-FL "On Education in the Russian Federation" (2012), DET is a legitimate method for delivering electronic educational programs. Russian literature identifies four generations of DET: case-based, Internet-based, networked, and those based on information-educational environments

(Blinov et al., 2020). The term "technology" is understood here as the application of theory into practice (De Bono, 1993), as adapted by the author based on Federal Law No. 273 (De Bono, 1993; Blinov et al., 2020).

Digital Educational Environment is an integrated system of digital platforms, services, and resources that supports the organisation, implementation, and management of the educational process, including communication, assessment, content access, and learner support. It includes elements such as learning management systems (LMS), virtual classrooms, knowledge bases, and digital libraries (Ministry of Science and Higher Education, 2020; Bilenko et al., 2020).

E-learning refers to a form of education that delivers learning content using digital technologies, encompassing both online (internet-enabled) and offline formats (COL, 2023; OECD, 2021). It encompasses both synchronous and asynchronous interactions and may include LMS-based courses, video lectures, digital simulators, and other forms of media. In Russian practice, official regulations define e-learning as instruction that uses information technologies, databases, and internet resources (FL No. 273-FL "On Education," 2013, Art. 16).

Online Learning is a form of e-learning that requires access to a digital network (typically the Internet) for materials, communication, and interaction with teacher trainers and peers (COL, 2023; UNESCO-UNEVOC, 2025).

VR/AR in Education refers to the use of virtual (VR) and augmented reality (AR) technologies to simulate educational and professional scenarios, enhancing engagement, visualisation, and the development of practical skills (Radianti et al., 2020; UNESCO-UNEVOC, 2024).

Flexible Learning refers to educational formats that allow learners to choose the time, place, pace, and mode of learning. It includes various forms—from online and distance learning to in-person and blended learning—tailored to individual needs and learner capabilities (COL, 2023; Naidu & Frazer, 2024; EALG, 2008).

- Learning Models and Formats

These terms describe instructional forms and flexible models for delivering educational content.

Blended Learning is a pedagogical approach that combines in-person and online instruction to increase flexibility in time, pace, learning paths, and location. International experts recognise it as a formal model where part of the content is delivered online and part in person (Graham & Halverson, 2020; INEE, 2021). In the Russian context, experts define it as a combination of networked and in-person or autonomous learning (Isakovich, 2021).

Hybrid-Flexible Learning (HyFlex) is a model that integrates in-person, online, and asynchronous formats, allowing learners to choose their mode of participation without compromising educational quality (Beatty, 2019; Atkinson, 2022). In the context of training TVET engineering teachers, the model provides didactic flexibility, learning equity, and digital environment support.

Diethelm Wahl's Pedagogical Double-Decker is a didactic approach that combines theory and practice through the simultaneous demonstration and explanation of educational content. It assumes that the teacher demonstrates theoretical principles through their behavior, allowing learners not only to understand the content but to experience it in action. This model is especially relevant for TVET teacher training, where the principle of "learning by teaching" is applied (Wahl, 2013).

- Professional Development and Teacher Training

This section defines concepts related to the development and preparation of teaching staff in the TVET system.

TVET (Technical and Vocational Education and Training) refers to a system of education and training designed to develop technical, applied, and interdisciplinary skills for qualified work across various economic sectors. It encompasses formal and informal education at the vocational and higher education levels, as well as continuing professional development and workforce training programs (UNESCO, 2015; TVET Journal, 2021).

TVET Engineering Teacher is a professional who combines technical expertise and pedagogical competencies to provide both theoretical instruction and practical training in technical and vocational education. These teachers support skill development in line with labour market demands and digital transformation, often functioning as both teachers and trainers (UNESCO, 2015; OECD, 2021; Hofmeyr & Vally, 2022; Cedefop, 2022).

Professional Development (PD) is a strategically organised and continuous process aimed at enhancing teachers' professional competencies, including knowledge, skills, attitudes, and readiness to meet evolving educational demands. In the context of digitalisation, PD encompasses both in-person and online formats and requires active cognitive, behavioral, and emotional engagement from participants (Salas et al., 2012; Desimone, 2009; Fütterer et al., 2024).

Vocational Teacher/Trainer is a specialist in vocational education who provides both theoretical instruction and practical training. Internationally, vocational teachers typically deliver theoretical content, while vocational trainers focus on skill development. In the context of TVET engineering education, teachers often combine these roles, demonstrating both subject-specific expertise and methodological and pedagogical competence (MacKenzie & Povere, 2009; OECD, 2010).

- Key Components and Indicators of Learning Effectiveness

The following definitions relate to the assessment, outcomes, and perception of learning.

Perceived effectiveness of online courses refers to learners' (in this study, TVET engineering teachers') subjective evaluation of how well the content, structure, and format of an online course align with their professional expectations, goals, and needs and how effectively the course contributes to the development of relevant competencies. Educational evaluation approaches form the basis for this concept (Kirkpatrick & Kirkpatrick, 2012; Sun et al., 2008).

Active Learning is a pedagogical approach that involves learners directly in the learning process through discussions, problem-solving, case analysis, role-playing, and other practice-oriented methods that promote meaningful participation and reflection (Bonwell & Eison, 1991; Prince, 2004; Desimone, 2009).

Feedback refers to purposeful pedagogical interaction in which learners receive information about the extent to which their performance meets educational objectives and success criteria. In online learning, the feedback includes both personalised comments from teacher trainers and automated feedback systems (AFS) that provide immediate and adaptive responses. Effective feedback enhances metacognitive skills, self-regulation, and learning outcomes (Hattie & Timperley, 2007; Shute, 2008; Steinert et al., 2025).

CHAPTER 2: THEORETICAL RESEARCH FOUNDATIONS OF TVET TEACHER TRAINING

2.1 Historical Development of Technical and Vocational Education in Russia

This chapter provides a historical overview of the development of technical and vocational education and training, as well as teacher training for the TVET system in Russia, from the state's inception to the present. It defines vocational education as the training provided in vocational institutions (colleges and technical schools) that award qualifications to skilled workers. The study excludes an analysis of educational organisations based in industries and corporations that also prepare skilled workers. The research focuses on the role of the teacher-engineer in vocational education, emphasising innovative and engineering-oriented specialities while excluding narrowly focused fields, such as medicine and veterinary science.

2.1.1 Pre-Professional Foundations (Before 14th Century)

The development of vocational education in Russia underwent significant changes over many centuries. The era of educational inception in Rus' began after the Christianization of Rus' in 988, by which time the East Slavs already possessed reading and writing skills (Kolpakova, 2022). The Christianization of the Slavic tribes began in the 9th century, but it encountered significant linguistic and cultural challenges. In the second half of the 9th century, Cyril and Methodius translated sacred texts from Greek into the Slavic language. They established the first school in 863, where they conducted instruction in a language accessible to the local population (Dzhurinskii, 2003). Education included literacy, singing, and reading based on Orthodox texts (Grigor'ev, 1900, pp. 3-5). Supported by grand princes and the higher estates, schools were private and church-funded, educating children in literacy, including serfs and enslaved people (Grigor'ev, 1900, p. 11). The first schools aimed to prepare clergy and disseminate knowledge while also welcoming adults who aspired to become teachers or pursue ordination (Kolpakova, 2022, p. 4).

From 1240, a "dark time" began for Russia with the arrival of the Mongol-Tatar yoke, halting educational development for nearly three centuries (Grigor'ev, 1900, p. 20). Chroniclers regarded the princes as "unbookish and illiterate" and noted their disregard for public education (Grigor'ev, 1900, p. 21). Monasteries remained the last bastion of literacy, but by the end of the 15th century, the clergy also included illiterate individuals (Kolpakova, 2022, p. 5).

2.1.2 Proto-Vocational Training and Craft Transmission (VI-XIII Centuries)

The history of professional education dates back to the 6th century. Archaeological findings have indicated the existence of artisans with specialised technical knowledge (Zhurakovskii, 1978). For a long period (6th–17th centuries), craft training served as the primary method of transmitting professional knowledge. Practical skills were passed down from master to apprentice through domestic training (Igtisamova, 2012, pp. 131-132). E.E. Deev, in his works, considers the emergence of the professional education system in the context of state formation and leans towards the view that professional education itself only appeared in the 19th century (Deev, 2004, pp. 28-34).

From the 9th century onwards, foreign specialists, particularly master teachers from Byzantium, significantly developed public forms of craft training and initiated the earliest instances of professional retraining for Russian artisans (Igtisamova, 2012, p. 132).

2.1.3 Emergence of Guild-Based Vocational Instruction (XIV - XVI centuries)

The emergence of workshops marked the period from the 14th to the 16th century, each led by a master who operated their school, where apprentices and journeymen acquired professional knowledge and skills. An expanded process of craft training supplanted the previously established system of knowledge transfer from parents to children. However, the transfer of technological techniques and knowledge from teacher to student during work remained an unchanged component. This period is characterised by narrow specialisation, indicating the increasing complexity of production technologies and a broad system of knowledge. The content of vocational education included knowledge that aided in work, such as record-keeping, calculations, and drafting. Teachers closely linked general education to craftsmanship (Igtisamova, 2012, p. 133). During Boris Godunov's reign (1598–1605), state officials developed plans to establish the first schools for studying foreign languages and training not only clergy but also civil servants. However, a political upheaval thwarted these plans (Kolpakova, 2022, p. 6).

2.1.4 Institutional Roots and State Involvement (XVII - XVIII centuries)

From the 9th to the 17th century, monastic instructors primarily conducted craft training in monasteries, teaching skills essential for monastic life—such as carpentry, book copying, and icon painting—while primarily instructing women in sewing (Bogdanov, 1964). However, women's craft courses did not become widespread, despite their existence until 1917. Graduates applied their skills in everyday life or in church workshops to make religious garments (Igtisamova, 2012, p. 134). The first Greek printing press (1679) and the Slavo-Greco-Latin Academy (1686) laid the groundwork for professional education (Kolpakova, 2022, p. 7).

The division of Rus' into northeastern and southwestern regions, along with the Mongol-Tatar yoke, significantly hindered educational progress, preserving only elementary schools with a low level of education until the 17th century (Grigor'ev, 1900, p. 59). The same schools that later employed them also trained teachers, which led to high competition and contributed to a decline in the quality of education (Grigor'ev, 1900, p. 66).

By the 18th century, education shifted from preparing for sacred service to military service or teaching, leading to the degradation of parish education and a decrease in respect for the profession of teacher-master. Under Peter I, national education, including spiritual and secular schools, was one of the key postulates of his reforms (Vakhterov, 1897, pp. 3-5), preparing specialists for state service modelled on the Kyiv-Mohyla Academy and adopting Western European features (Grigor'ev, 1900, p. 137). This period saw the separation of theoretical training from practical activity (Igtisamova, 2012, p. 134), laying the foundations for the concept of professional schools as entities independent of production activities, which marked the beginning of state-secular professional schools in Russia (Myasnikov & Naidenova, 2006; Osovskii, 1984). The integration of specialised theoretical knowledge with practical production, reminiscent of modern dual education, characterises this era.

2.1.5 Formation of State-Structures Vocational Education (XVIII - XX centuries)

In the second half of the 17th century, Russia saw the development of its professional education system, transitioning from individual and small group forms to collective ones (Igtisamova, 2012, p. 135). During this period, state professional educational organisations emerged, combining general and vocational training (Babich, 2003, p.62) and a regulatory base for the education system was established (RAE, 2003, p. 106). This period saw the founding of important state vocational-practical schools, such as the Embassy School and the Medical School (Igtisamova, 2012, pp. 136-137).

By the 18th century, Russian teachers began introducing practical components and professional pedagogy into vocational education (Tolstoy, 1885, p. 17; Piskunov, 2001, pp. 212-215). The latter half of the 19th century, influenced by the abolition of serfdom and an increase in literacy (Vakhterov, 1897, p. 11; Education in Russia, pp. 2022), saw the emergence of zemstvo schools, classical and real gymnasia, and vocational schools providing primary and vocational education (Zhurakovskii, 1978; Kamenskii, 1999; Knyaz'kov & Serbov, 1910; Igtisamova, 2012, p. 138). By the beginning of the 20th century, the theory of vocational education had become a significant component of Russian pedagogical thought, emphasising vocational training in various formats, including apprenticeships and vocational school programs (Piskunov, 2001, pp. 212-215).

Transformational changes reshaped Russia's vocational education system in the late 19th and early 20th centuries (Materials on the history of the Prokhorov manufactory and the commercial and industrial activities of the Prokhorov family, 1916, p. 26; Igtisamova, 2012, pp. 163-164). D.K. Sovetkin played a key role in formulating the theory of production training based on a detailed analysis of the labour process (Shabalov, 1950, pp. 45-46). This period laid the foundation for technical schools, which began to offer an education level surpassing that of intermediate technical schools, thereby preparing engineering assistants (Igtisamova, 2012, pp. 230-231).

The Ministry of Education addressed problems related to the shortage of qualified teachers and limited access to teaching materials in the 1892 "Rules for Teachers of Special Subjects and Leaders of Practical Sessions in Middle and Lower Technical Schools" (Zhurakovskii, 2000, p. 82), which established criteria for teachers and practical training supervisors (Igtisamova, 2012, p. 231).

Trends in Russian pedagogical thought closely shaped the development of vocational education theory (Lebedev, 1990). Significant contributions to the teaching methodologies of special subjects were made by scholars such as I.A. Stebut (1898, 1909) and S.A. Vladimirskii (1895, pp. 1, 65), marking the formation of professional pedagogy as an independent field of knowledge in the early 20th century.

2.1.6 Professional Pedagogy and System Expansion (XIX century – 1990)

At the turn of the 19th and 20th centuries, the Russian Ministry of Public Education initiated a discussion about upcoming reforms in the vocational education and training system, during which participants acknowledged the need to adapt it to the real needs of society and the economy. External events, including the war with Japan and revolutionary upheavals, hindered attempts at reform (Voitekhovskaya, 2013, pp.125-126).

Following the 1917 Revolution, significant changes occurred in Russia. All private schools were closed, and the go persecuted religious educational organisations (Kolpakova, 2022, p. 13). The principles of unity, universal free education, and accessible vocational training replace all types of paid education. After Lenin's 1918 decree, the centralisation of educational administration began, with an emphasis on a labour-oriented approach and polytechnic training (Igtisamova, 2012, p. 281).

The creation of vocational schools and educational institutions—such as schools for peasant youth, the Central Institute of Labour, and A.K. Gastev's schools for working youth (Moiseev, 1931) — reflected a drive to integrate education with production and the socialisation of young people. However, the early Soviet years revealed inadequacies in the vocational education system and inconsistencies in the implementation of general education policy (Federal Law, 2005).

By the 1930s, despite various reform efforts, the vocational education system remained fragmented and often disorganised, featuring diverse training forms—such as brigade and individual apprenticeships (Igtisamova, 2012, pp. 297-298) and club schools (Igtisamova, 2012, p. 295) —that did not always include general education in the curriculum, (Igtisamova, 2012, p. 304) with training carried out directly by enterprise employees.

Between 1921 and 1929, the need for professional pedagogical staff led to the emergence of Russian vocational pedagogy as a distinct scientific discipline (Ovchinnikov et al., 2000, pp. 69-70).

In the following decades, attempts to unify and improve the vocational education and training system led to the formation of an extensive network of educational institutions, including vocational and technical schools (Prokhorovich & Kovalenko, 1975, p. 41), as well as schools for working youth. These changes necessitated the continuous improvement of teachers' qualifications and the adoption of new technologies in the educational process (Igtisamova, 2012, p. 323). Starting in the 1980s, vocational-technical schools began to actively cooperate with enterprises to prepare personnel (Igtisamova, 2012, p. 338), and vocational education institutions became self-sustaining, developing multiple forms of enterprise collaboration (Nuretdinov, 2021).

Since 1991, the education system has faced a crisis driven by economic and social transitions, prompting further reforms and regulatory measures (Khudolii, 1998, pp. 21-22).

2.1.7 System Transformation and Deregulation (1990 – 2000)

In 1992, a new stage in the history of education began in Russia, with the goal of education becoming the development of the individual and society (Vyazemskii, 2013). The Federal Law "On Education" (Federal Law, 2005), adopted in 1992, established the foundations of the education system and the rights associated with it, including mandatory basic education and the freedom to choose the type of educational institution. A classification of educational institutions emerged, encompassing state, municipal, and private institutions, with types of education defined as preschool, general, secondary, higher professional, special, and additional education (The Federal Law "On Education" №3266/1, 1992). The 1990s were also a period of emergence for new types of educational institutions with unique educational programs, leading to inconsistency and the development of state standards regulating the activities of educational organisations (Sitarov, 2019).

However, with the appearance of private educational institutions, a problem arose in ensuring the quality of education (Il'inskii, 2004). A complex socio-economic situation during this period led to the cancellation of employment guarantees for graduates of professional educational organisations and caused a rise in unemployment (Dneprov, 2011, p. 18).

2.1.8 Modernisation and Global Integration (2000 – 2020)

Since the beginning of the 21st century, Russia has initiated a comprehensive reform of its educational system. This reform included the creation of the Russian Public Council for Education Development and the introduction of the Unified State Exam (USE) in 2007, aimed at standardising higher education admissions (Fifteen years of the Unified State Exam in operation, 2016). Russia joined the Bologna Process in 2003, transitioning to a two-tier education system comprising bachelor's degrees (4 years) and master's degrees (2 years), marking a shift towards digital learning (Sitarov, 2019).

In 2008, two types of secondary vocational education institutions were distinguished: technical schools and colleges. Colleges offer four-year advanced programs, often integrated into higher education structures, unlike technical schools, which focus on training skilled workers (On the approval of the standard regulations on educational institutions of secondary vocational education (Resolution No. 543), 2008). The introduction of new educational standards has reduced the differences between these institutions.

Between 2000 and 2002, secondary vocational education institutions became multidisciplinary and multifunctional by expanding the range of educational products they offered (Kirillov, 2006, p. 227). Over the next two years, the government transferred control from the federal to regional authorities and placed these institutions under their supervision. However, the legislative documents were not formalised until 2012, a full decade later (Federal Law No. 273-FZ, 2012; Dudyrev et al., 2019, p. 52). The 2005 federal program, which aimed at specialised training and the integration of IT into the educational process (Igtisamova, 2012, p. 417), had a greater impact on higher education. This approach marginalised secondary vocational education, and the 2006 reforms—which eliminated one of its levels, basic vocational education—caused an oversupply of university graduates and a shortage of skilled labour (Igtisamova, 2012, pp. 419-420).

In response, new educational programs closely tied to economic needs were developed between 2007 and 2010, including efforts to introduce applied bachelor's degrees. After regional authorities took control of vocational education in 2011–2012, the government discontinued this program (Government of the Russian Federation, 2007; Dudyrev et al., 2019, pp. 198-200). The development of a cluster model for secondary vocational education from 2011 to 2015 (Dudyrev et al., 2019, pp. 201-205), along with the implementation of pilot dual education projects from 2013, were notable developments (Dudyrev et al., 2018, p. 2). In 2012, Russia joined WorldSkills International (WSI) (Russia has officially become the 60th member of WorldSkills International., 2012), contributing to the creation of a comprehensive ecosystem involving various educational and professional communities (Dudyrev et al., 2019, pp. 215-219, 221), as well as the development of a new pedagogical framework (Presidential instructions Pr-2582, para. 2a and 2b, 2016) and mentorship by 2019 (Order No. R-145, 2019).

The Education Law of 2012 unified the systems of initial and secondary vocational education (Il'inskii, 2012). Since 2015, vocational institutions have assumed the functions of senior schools (Dudyrev et al., 2022, pp. 24-25), aligning workforce training with the needs of the labour market and the broader economy, including the digital sector (Dudyrev et al., 2022).

2.1.9 Digitalisation and Practice-Oriented Reform (2020 – present)

Between 2000 and 2022, Russia's higher education system expanded its range of educational services and transitioned to a multi-level model of instruction. In 2022, Russia withdrew from the Bologna Process (Russian universities excluded from Bologna Process, 2022) and began developing its education system (The Bologna education system, 2022). The COVID-19 pandemic in 2020 highlighted issues in the accessibility of distance learning and paved the way for further development of digital technologies in education (Dudyrev et al., 2022, p. 31; Dudyrev et al., 2020).

In response to these challenges, the Ministry of Education adopted strategies for the development of vocational education through 2030 and launched the "Professionalitet" project to train qualified skilled workers (Decree No. 387, 2022). The next step in development was the emergence of educational production clusters and the development of new educational standards aimed at improving the quality and accessibility of education. In December 2021, a new qualification for

teachers in the system of secondary vocational education, "master-teacher," was developed, specifically prepared for the "Professionalism" project based on two-state educational organisations (Master-teachers will appear under the "Professionalitet" project, 2024).

Furthermore, educational authorities introduced the practice of demonstration exams, strengthened partnerships with employers, and began implementing the cluster model of education. A key milestone was Russia's participation in the WorldSkills International movement until 2022, after which national organisers developed the country's championship movement ("Professionals", 2023).

Reforms in 2023 aimed to create conditions for individualising the educational process and strengthening a practice-oriented approach. As of September 1, 2023, teachers in the vocational education system must hold a higher professional education in their relevant speciality and have at least three years of work experience (INEE, 2024). In 2023, the Ministry of Education established Russia's first Federal Technopark of Vocational Education to train teachers and master industrial trainers for the secondary vocational education system (Creation of Training Centers for Vocational Education Staff—Federal Technoparks, 2023). Currently, the system of secondary vocational education serves as a viable alternative to higher education, attracting a significant number of students from diverse social backgrounds ("Blue collars" are turning white, 2023).

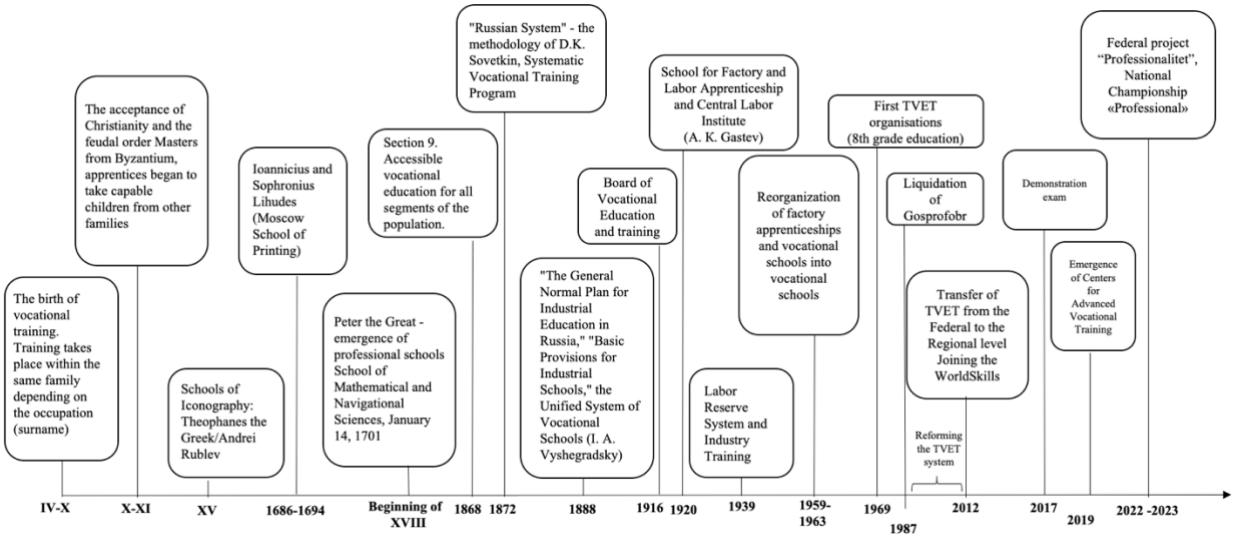

Figure 2.1 *Chronology of TVET development stages (own representation)*

Despite years of development, the Russian vocational education and training system continues to undergo changes that respond to economic, social, and political challenges. The primary objective of retrospective analysis is to provide a comprehensive overview of the workforce training system's development and the consequences that each situation led to. Such a holistic view is necessary for a deep understanding of the modern Russian vocational education and training system.

The Russian education system is categorised into general, vocational, supplementary, and professional training, promoting lifelong learning opportunities (Federal Law No. 273, Art. 10, Cl. 2, 2012/2023) (Figure 2.2).

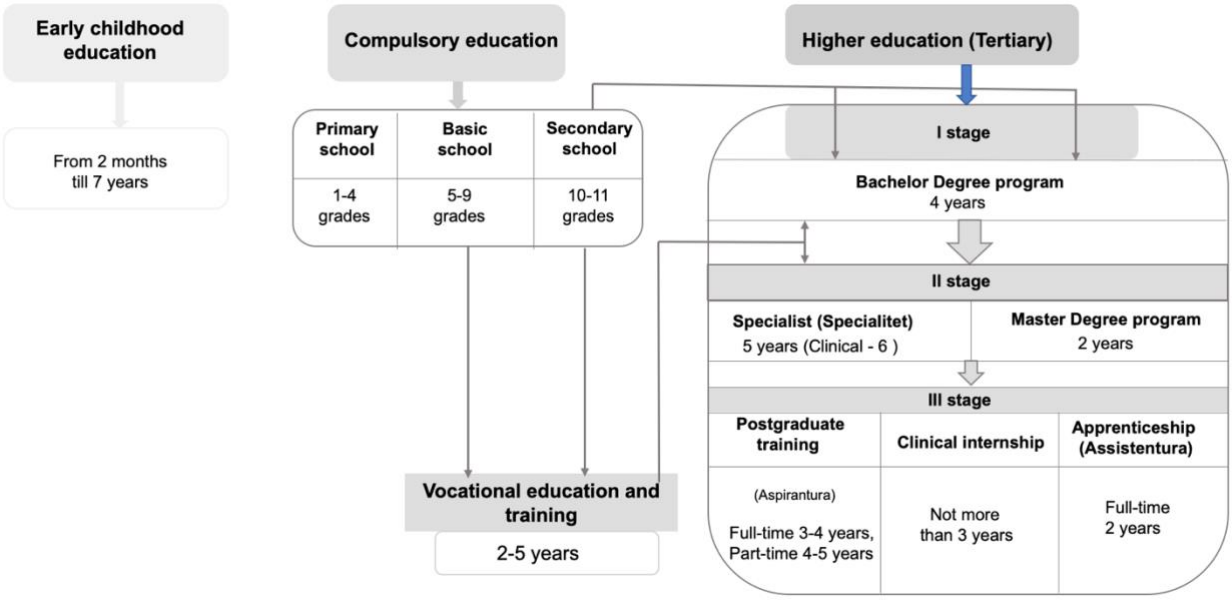

Figure 2.2 *The educational system of the Russian Federation (own presentation)*

Pre-primary education is offered by nurseries and other institutions, ensuring comprehensive development and preparation for school, available for children from two months to seven years, with options for care until eight years. Compulsory education spans from primary (grades 1-4, ages 6-11) to basic (grades 5-9, ages 9-16) and secondary education (grades 10-11, ages 14-18), delivered in schools, lyceums, or gymnasiums with varying durations based on federal standards and learning formats.

Primary education focuses on basic literacy, numeracy, and cultural behaviours. In contrast, basic education develops moral values and scientific fundamentals, preparing students for the OGE (Official Graduate Examination) required for obtaining a basic education certificate. Success in these exams enables progression to secondary or vocational education, with vocational institutions admitting students based on their middle school grades rather than OGE scores. Secondary education further aims to provide individualised study and professional orientation, culminating in the unified state exam (EGE) for university admission eligibility (Federal Law No. 273, Art. 68, Cl. 1, 2012/2023).

Vocational education prepares skilled workers and mid-level specialists across various fields, contingent upon completing basic or secondary education, with durations varying by profession and including options for expedited programs after grades 10 or 11 (Federal Law No. 273, Art. 68, Cl. 1, 2012/2023; Dolgova, 2022).

Higher education aims to train highly qualified professionals and facilitate intellectual and moral development across bachelor's, specialist, and master's levels, with options for accelerated programs for those with vocational diplomas (Federal Law No. 273, Art. 68, Cl. 1, 2012/2023) (Table 2.1).

Table 2.1 *Levels of higher professional education (1st and 2d stages)*

Type of education	Bachelor's degree	Specialist	Master's Degree
Educational qualifications for admission	General secondary education or its equivalent	General secondary education or its equivalent	Bachelor's or Specialist Degree
Terms of study (full-time form)	4 years	At least 5 years	2 years

Type of education	Bachelor's degree	Specialist	Master's Degree
Education document to be received	Bachelor's Degree	Specialist diploma	Master's Diploma
Acquired qualification (degree)	Bachelor	Specialist	Master
Description of education	General fundamental training in a particular field of study without specialization	Focused on practical work in the chosen specialty	In-depth mastering of theoretical aspects, focused on research activities
Form of Final State Attestation	Passing the state examinations, preparation and defense of the bachelor's graduation qualification work	Passing the state examinations and defending the graduation thesis (project)	Passing the State examinations and defending the Master's Thesis
Further Education	Master's degree	Undergraduate or postgraduate	Postgraduate educaiton

Scientific and pedagogical training forms part of higher education and is available to graduates for further specialisation in academia, medicine, or arts (Table 2.2) (Federal Law No. 273, Art. 69, Cl. 4, 2012/2023).

Table 2.2 *Types of Postgraduate training*

Type of education	Postgraduate	Clinical internship	Apprenticeship
Educational qualifications for admission	Master's or specialist degree	Graduate degree in medicine or pharmacy	Master's or specialized degree in culture
Terms of study	3-4 years (full-time), 4-5 years (part-time)	Not more than 3 years	2 years (full-time form only)
Education document to be received	Conclusion on the compliance of the thesis for the degree of Candidate of Science with the established criteria	Diploma of Completion of Residency	Diploma of Completion of Postgraduate Diploma
Acquired qualification (degree)	Degree of Candidate of Science (only after defending a dissertation) or Postgraduate Diploma	Physician in a particular specialty	Specialist of the highest qualification, teacher in a higher school
Description of education	Scientific-research work under the supervision of the supervisor	In-depth study of methodological, clinical and medico-social fundamentals of medical sciences; formation of skills and abilities of independent professional activity during practice in a medical institution	Individual study plan under supervision of supervisor and head of department of higher education institution
Form of Final State Attestation	Consideration of the thesis for the degree of Candidate of Sciences	Accreditation of a specialist	Graduate work in the creative and performing specialty

Type of education	Postgraduate	Clinical internship	Apprenticeship
			(performance, recital, performance, exhibition or film)
Further training	Doctoral dissertation	Postgraduate education	Postgraduate education

Summary
The development of the vocational education and training system in Russia originates in craft families and undergoes significant changes only after a decade of development. The Russian Emperor Peter I (Peter the Great) was the first leader to pay attention to vocational education and implement reforms that served as a starting point for the institutionalisation of the VET system. In the second half of the 19th and early 20th centuries, educational policy began to focus more on practice-oriented training, laying the foundations for the establishment of a system of technical schools and the development of a domestic pedagogy of vocational education.

During the Soviet period, the TVET system expanded access to education but faced challenges related to teacher qualifications and systemic rigidity. Post-Soviet reforms introduced decentralisation, standardisation, and international alignment (e.g., the Bologna Process), yet also triggered concerns about excessive academisation and weakened links to practical training.

Since 2020, accelerated by the COVID-19 pandemic and national strategic initiatives, Russia has shifted towards digitalisation and practice-oriented models, exemplified by the federal programme "Professionalitet". As of 2025, the TVET system remains in transition, with ongoing regulatory reforms aimed at aligning vocational training with the evolving demands of the digital economy.
These historical developments contextualise the present study, which addresses the need for effective models of training TVET engineering teachers through flexible digital formats.

2.2 Historical Development of Teacher Training for TVET in Russia

The evolution of teacher training, initially linked to the development of vocational education systems, began with literacy and numeracy instruction under the guidance of the clergy until the early 18th century, when formalised initiatives for teacher training emerged, notably with the establishment of a School of Mathematical and Navigational Sciences in 1701. The establishment of this school marked the beginning of teacher education, which expanded by 1800 with the introduction of teacher training in secondary schools (Kubrushko, 2002b, p. 32).

Master artisans traditionally trained apprentices through hands-on professional instruction. Authors such as K.A. Ivanovich (1958), A.T. Malenko (1980), G.M. Romantsev & A.A. Zhuchenko (1997), B.A. Sokolov (1983), E.V. Tkachenko (1990), K.I. Vasilyev (1996), A.N. Veselov (1961), I.K. Vsevolodskii (1973), K.A. Ivanovich (1958), I.A. Kairov (1930), N.I. Kravtsov (1977), V.P. Lednev (1975), as well as P.V. Prokhorovich and I.G. Kovalenko (1975) made significant contributions to the development and study of teacher training for initial professional education. They highlighted a system where organised training for vocational education teachers was absent until the 1920s, with training instead occurring on the job under the supervision of experienced teachers or skilled workers in industrial training. This on-the-job training system, although practical, often led to self-learning in pedagogical activities, not meeting the theoretical pedagogical standards of pedagogical university graduates (Kubrushko, 2002b, pp. 33-34).

According to P.F. Kubrushko, the preparation of teachers for initial vocational education underwent several stages: from individual on-the-job training before the 1920s through phases of organised professional-pedagogical preparation, interruptions, and expansions to the diversification of training programs by the late 1990s (Kubrushko, 2002b, p. 37). The present study proposes a division of the development of professional pedagogical education into seven stages, with stages two through five reflecting the complex evolution of the system's morphology and components from the 1920s to the present (Shapkin, 1989).

2.2.1 Foundations of TVET Teacher Training in the Early Soviet Period (1920s - mid-1930s)

In the 1920s, the Soviet Union established a system of professional teacher training. (Tenchurina, 1998, p.13) Its primary purpose was to compensate for a systemic shortage of specialists (Fonds: A-310 (1917), A-1565 (1920), R-7668 (1925), R-8060 (1932), R-8080 (1936), R-9396 (1946), R-9507 (1940), R- 9606 (1959); Directives of the VKP(B), 1947), characterised by both a lack of qualified teachers and the low quality of those available. This initiative led to the creation of specialised higher education institutions and retraining courses (Tenchurina, 1998, p.15-16). The authors of those programs were scientists such as N.I. Barbashov, A.F. Evstigneev-Belyakov, N.I. Ilyin, A.A. Peskov, and P.A. Shevarev considering domestic and foreign experience (Shevarev, 1928, p. 128).

Until the 19th century, Russia lacked a systematic approach to training teachers for real schools, (Secondary technical schools, 1909, pp. 238-253) and isolated attempts made in the 1870s ultimately failed. For example, in 1904, teacher training courses were discontinued due to a shortage of teaching staff (Tenchurina, 1998, p.18). From the end of the 19th century, Russian institutions undertook efforts to create a structured teacher training system, drawing on German models that emphasised a multi-level approach to education, including general scientific and specialised disciplines as well as psychology-pedagogical courses (Shevarev, 1928, p. 128).

In response to the shortage of teachers, in 1919, uncoordinated attempts were made to train teachers among practising specialists (Bulletin of Vocational and Technical Education, 1920). Rubinstein and Evstigneev-Belyakov made a significant contribution even though many of their works were lost or destroyed due to political or military reasons (Tenchurina, 1998, p. 28; Vyshinsky, 1932).

Evstigneev-Belyakov, advocating for the professional training of teachers, emphasised the need for specialised knowledge, an understanding of the audience, knowledge of the pedagogical process, and mastery of pedagogical skills, noting the particular difficulties in methodological training for special subjects (Evstigneev-Belyakov, 1927, pp. 104-107). Rubinstein's 1928 proposal for engineering teachers (Rubinstein, 1927, p. 6) aimed to meet the educational needs of expanding industrial and professional institutions by combining technical knowledge with pedagogical skills (Evstigneev-Belyakov, 1927).

Similarly, S. Ya. Kupidonov (1928, 1931) and others (Bulletin of Vocational and Technical Education, 1920; Lednev, 1975; Voevodskii, 1973; Dneprov, 1978; Skatkin, 1968) advocated for an integrated educational model that combines technical knowledge with psychological and pedagogical training, emphasising continuous professional development and practical experience (Kupidonov, 1928). I.A. Kairon proposed solving the problem of a shortage of teaching staff in professional technical organisations by developing Higher Pedagogical Courses, increasing enrollment, and creating new faculties and departments (Batyshev, 1974, 1979; Veselov, 1961; Voevodskii, 1973).

In the early 1930s, pedagogical universities carried out the training of teachers in polytechnic disciplines "for industrial and agricultural technical schools and the system of worker-state farm-collective farm education" (Tenchurina, 1998, p. 50).

Despite initial successes, including the creation of higher technical and pedagogical courses and the integration of pedagogical training into technical education, the system encountered problems, in particular with the transition to the pedagogization of higher education and technical schools by the 1930s (Fond R-8060, 1932). The outbreak of World War II led to the closure of pedagogical faculties and a transition to short-term training programs to meet the needs of vocational education during wartime (Tenchurina, 1998, p. 118).

2.2.2 Wartime Adaptation and Post-War Restructuring (1940s – 1958)

In 1940, factory and vocational schools were introduced in the Soviet Union, offering six-month courses for mass professions and specialised two-year programs for skilled labour in craft and railway production. The Soviet authorities enrolled fourteen-year-old students in the compulsory education system without their consent to train up to 1 million workers during wartime, (Tenchurina, 1998, p. 124) prioritising the rapid acquisition of basic skills over the quality of education. (Voevodskii, 1973, p.158) Industrial workers served as instructors, and after the mobilisation of young people in 1941, on-the-job training under the guidance of a master artisan became the predominant method (Fond R-9507, resource 54, pp. 1-24, 1940). By 1943, the Soviet authorities had reduced training periods to 3–4 months and introduced the institution of the 'assistant master artisan' in response to the military draft (Fond R-9507, resource 303, 1940). However, by 1944, 48.9% of master artisans and teachers lacked formal qualifications, which negatively impacted the quality of the workforce (Voevodskii, p. 160, 1973).

The war revealed an acute need for qualified vocational training masters, which led to the creation of special industrial technical schools under the Main Directorate of Labor Reserves, offering a combination of technical, pedagogical, and industrial training (Fond R-9507, resource 66, pp. 11-12, 1940). Thanks to industrial technical schools, the middle level of vocational and pedagogical education, which began in 1921, was restored. Applicants were required to have at least 5-7 years of school education, third-class worker qualifications, and pass entrance exams. The curriculum included general, technical, specialised, and pedagogical subjects, as well as practical classes, military training, and a final project (Tenchurina, 1998, p. 130-131). Graduates were required to work in their speciality for at least five years (Fond R-9507, resource 66, pp. 16-17, 1940).

In the 1950s, the network of secondary vocational teacher training institutions offering 2.5-year programs, which focused on theoretical, practical, and pedagogical training, expanded (Tenchurina, 1998, p. 139). In 1949, a "pedagogical minimum" was introduced for masters, senior masters, and teachers, with a special focus on teaching methods (Rozofarov, p. 90, 1950). Despite these efforts, more than 71% of vocational training masters did not have a secondary education. The state noted the lack of a systematic approach to the training of teaching staff for vocational schools (Fond R-9507, resources 2, 12, 23, 54, 93, 124, 1940).

By the end of the 1950s, the Soviet government had established Central courses for the improvement and retraining of staff at agricultural mechanisation schools and their branches (Rozofarov, 1950; Dvoinishnikov, 1977, p. 81). In the 1960s, compulsory eight-year education integrated with labour began, which emphasised the constant need for targeted training of teaching staff and vocational training instructors in vocational education organisations (Abakumov et al., pp. 48-61, 1974).

2.2.3 Expansion and Differentiation of Teacher Education (Late 1950s – 1979)

In the late 1950s and early 1960s, Soviet policymakers sought to integrate vocational and general education, leading to the establishment of polytechnic schools that offered secondary education and vocational training in various specialisations. These changes required the establishment of additional technical faculties and dual-speciality programs, such as "biology and agriculture" or "general technical disciplines and labour," in teacher training institutions (Ministry of Education of the RSFSR, 1984). By 1962, a broad network of higher education institutions was developed for training teachers in technical and agricultural disciplines, blurring the lines between professional and pedagogical education. However, the initiative to prepare qualified workers through middle polytechnic schools largely failed, and many graduates with dual specialities remained as school teachers (Tenchurina, 1998, p. 163). From 1964, leading industrial universities began establishing engineering pedagogical faculties to train vocational school teachers (Kubrushko, 2002b, p.36).

In the 1960s, significant changes occurred in vocational education, with the number of technical colleges training highly skilled workers for 1-2 years and vocational schools providing general secondary education and vocational training for 3-4 years increasing (Abakumov et al., pp. 129-130, 1974). The government sought to provide these educational institutions with highly educated teachers and skilled artisans, which led to the creation of engineering teaching faculties, industrial teaching faculties, and technical vocational education and training institutions (Prokhorovich & Kovalenko, 1975; Sharapov, 1967, pp. 82-87). Despite all efforts, a shortage of teachers persisted, necessitating the recruitment of experienced engineers, technicians, and graduates from technical universities as teachers (Council of Ministers of the USSR and the CPSU Central Committee, pp. 492-496, 1984). In 1966, the government established the All-Union Institute for the Advancement of Engineering-Pedagogical Personnel (renamed in 1976 to the All-Union Institute for the Advancement of Qualifications of Managers and Specialists in Vocational Education under the State Professional Education of the USSR), focusing on systematic retraining and qualification enhancement, including periodic certification every five years. Throughout the 1970s, the primary goal was to optimise the content of engineering-pedagogical education and expand international cooperation in the field of professional and engineering-pedagogical education (Fond R-9507, resource 6, 1868, p. 122-123, 1940). Starting in 1976, vocational school teachers underwent systematic advanced training every five years, including on-the-job training (Fond R-9507, resource 7058, pp. 183-190, 1940); yet, this did not solve the problem of persistently low teacher qualifications (Fond R-9507, resources 6, 1668, pp. 226-229, 1940).

2.2.4 Institutional Modernization and Research Integration (Late 1970s - Early 1990s)

In the late 1970s and early 1980s, the Soviet government revived its program for training vocational education teachers, which it had discontinued in the mid-1960s. Vocational training encompassed three specialities: "general technical disciplines and labour," "drafting, drawing, and labour," and "biology and the basics of agricultural production" (Tenchurina, 1998, p. 178). By the late 70s, vocational schools introduced a new type of educator - the "teacher-master of production training and technical disciplines," enhancing the synergy between pedagogical and technical universities and industrial-pedagogical technical schools (Tenchurina, 1998, p. 180). Despite the expansion of pedagogical faculties and the introduction of state exams in pedagogy and teaching methodology in 1981, challenges persisted, including a shortage of qualified teachers due to a lack of pedagogical skills in engineering faculties and inadequate theoretical training in pedagogical institutes (Litvinov, 1990). The establishment of the Sverdlovsk Engineering-Pedagogical Institute in 1979 (later renamed the Ural Professional-Pedagogical University) marked a significant step toward integrating scientific research into pedagogical education (Communist Party of the Soviet

Union, 1977, p. 1). However, the system faced problems, including teacher attrition and a mismatch between the pace of teacher training and demand in vocational schools (Formation of Qualified Workforce Under School Reform, 1987; USSR CENTRAL STATISTICAL SERVICE, 1982, 1984). These issues worsened as government policy underestimated the need for trained teachers and relied on industry specialists to fill teaching vacancies (Zeer, 1980; Ministry of Education of the RSFSR, 1984).

In the late 1980s and early 1990s, efforts to expand engineering-pedagogical faculties (USSR Committee on Public Education, 1988; State Committee for Public Education, 1988) and develop new types of professional educational organisations, such as colleges, aimed to alleviate the teacher shortage. These changes culminated in the "Engineering-Pedagogical Personnel" program, which became part of the national education development plan. Despite these efforts, problems with the availability of qualified teachers in technical vocational education and training organisations persisted until the 1990s, which once again highlights the issue of matching teacher training to the changing needs of technical vocational education. In the late 1980s and early 1990s, many higher professional educational institutions discontinued the training of teachers for initial vocational education despite existing challenges (Kubrushko, 2002b, p. 36).

2.2.5 Post-Soviet Transition and Conceptual Renewal (1992 – 2000)

In 1992, a new stage in the history of education in Russia began, and the goal of education shifted to the development of both the individual and society (Vyazemskii, 2013). The Federal Law “On Education” (Federal Law, 2005), adopted in 1992, established the foundations of the education system and the right to education, including compulsory basic education and the freedom of choice of type of educational institution. A classification of educational institutions was introduced, encompassing state, municipal, and private institutions. Types of education were also defined, including preschool, general education, secondary and higher professional education, as well as special and additional education.

In the early 1990s, G.M. Romantsev introduced the concept of professional pedagogical education, emphasising the necessity of mastering skills to perform all professional educational functions (Vinogradova, 2009). A.I. Yakimov advocated for continuous engineering pedagogical education from school to university, including mentorship and ongoing teacher qualification enhancement (Yakimov, 1990). V.P. Manzhai and G.A. Svetochyov developed a professional training methodology that combines theoretical knowledge with professional working skills, advocating for their integration after the third semester (Manzhai & Svetochev, 1991). The approach of E.F. Zeer and G.A. Karpova focuses on developing professional orientation, competence, and personal qualities in engineering pedagogical preparation (Zeer & Karpova, 1989). Based on the individual approach of Zeer and Karpova, A. Zh. Motovilov and A. L. Pechurin proposed a curriculum structure for the comprehensive development of the engineer-teacher, which encompasses natural, technical, and humanities disciplines (Motovilov & Pechurin, 1991).

The post-Soviet transition to a market economy led to financing problems and a decline in the prestige of pedagogical activity (Zhuchenko et al., 1999, p. 29), resulting in the dismantling of a unified system for training and improving the qualifications of professional pedagogical personnel in primary and secondary education (Zhuchenko et al., 1999, p. 28). Educational institutions have shifted their focus from engineering to the service sector, which has also affected teaching staff. The automation of education management is moving towards personalised and humanised education, driving the demand for individual and commercial professions (Zhuchenko et al., 1999; Romantsev & Zhuchenko, 1997). The vocational education system is evolving through automation, regional adaptation of content, and revision of qualification structures, which necessitates updates to teacher training methods. Educational institutions introduce new

specialities and alternative educational programs. At the same time, education authorities implement initiatives to improve teacher qualifications through training and the establishment of centres for the development of pedagogical education. Modular learning and research activity in pedagogical education expands, applying a comprehensive approach to various disciplines (Sokolov, 1993).

Since 1993, Russian policymakers have implemented significant reforms (Romantsev & Zhuchenko, 1997, p. 5; Zhuchenko et al., 1999, p. 25; Biktuganov et al., 2020, p. 452) in pedagogical education by adopting laws and programs to align teachers' competencies with socio-economic changes, introducing individualised educational technologies (Romantsev & Zhuchenko, 1997, p. 8), and developing continuous professional development (Coordination Plan of Research Work on Engineering-Pedagogical Education Issues for 1991–1995, 1991; Biktuganov et al., pp. 452-454, 2020). The "dynamic professiogram" concept highlights three substructures of a teacher's personality: cognitive (knowledge in the fields of philosophy, psychology, pedagogy, and specialised disciplines), activity (pedagogical goal-setting, designing the educational process, problem-solving), and personal (professional values, humanistic orientation, social intelligence, pedagogical reflection, social responsibility, empathy, tolerance) (Zeer et al., 1994). During this period, the unified speciality "Professional Training" was established, covering educational programs at professional pedagogical colleges and universities that prepare graduates for various roles in professional education and industry (Romantsev & Zhuchenko, 1997, p. 13).

Since 1998, the Ministry of Education has implemented a comprehensive program for the phased training of TVET engineering teachers in the continuing education system, aiming to integrate new pedagogical technologies and optimise educational processes (Ryabov, 1998). This period saw the differentiation of graduates' professional activities depending on the level of education - from bachelor's to master's - at different levels and in various sectors of education (Archive of Federal State Educational Standards for Higher Education 1993-1999, 1999). Teachers and policymakers place special emphasis on developing pedagogical thinking and modern teaching technologies (Ludina & Lvova, 1998), as well as adapting professional pedagogical education to new socio-economic conditions (Fedorov, 1999). The transition to a multi-level system of personnel training has begun (Fedorov & Tretyakova, 2017, p. 111), and the need to ensure the quality and development of professional education is recognised (Vain, 1998). All these changes have led to the establishment of educational standards and qualification requirements for pedagogical workers (Romantsev, 1997; Kubrushko, 2002a).

2.2.6 Reform, Standardisation, and Structural Realignment (2000 – 2020)

At the beginning of the new millennium, several key decisions had a significant impact on the development of the teacher training system for vocational education. Policymakers replaced the "Professional Training" curriculum in bachelor's and master's programs with "Technological Education," which combines professional training programs with general secondary education pedagogy, echoing the origins of engineering and pedagogical education in the 1960s (Romantsev & Zhuchenko, 1997, p. 36).
With these changes, the psychological, pedagogical, and technological aspects of education were no longer in alignment, resulting in a gap between continuous development programs for teachers and the pace of vocational school and industry development (Romantsev et al., 2009, p. 21).

Since 2000, education authorities have awarded the qualification of "Vocational Training Teacher" to individuals with higher professional pedagogical education (Feoktistov et al., 2023, p. 16). As unemployment levels declined from the early 1990s, the focus shifted to the challenge of training workers and addressing their shortage (Romantsev et al., p. 65, 2011). By the early 2000s,

professional pedagogical education, covering both higher and secondary education, was focused on training teachers for vocational education. This period was marked by the first definition of professional teacher education as a process of forming a capable personality for vocational training, resulting in a set of knowledge and skills for successful work in the field of vocational education. The 2002 initiative of the Russian Federation's Ministry of Education, "Professional Pedagogical Personnel of Russia," aimed to compensate for the lack of vocational teachers and optimise teacher training following the multi-level education system, as well as integrate higher and vocational education (Fedorov, 2001, p.23). All these actions, including the establishment of methodological associations and the description of the term "professional pedagogical education", did not help with the significant shortage of teaching staff. By 2001, 88,000 vacancies remained unfilled (Biktuganov et al., 2020, p. 499).

The Ministry of Education suggested new categories, such as "Vocational Training Teacher" (Biktuganov et al., 2020, p. 506), and established standard rules for teacher qualifications as a step to fill the gap. However, problems persisted, including a mismatch between traditional industry training requirements and the needs of innovative companies (Romantsev et al., 2007, pp. 24, 28, 46). Efforts to bridge this gap included dialogue with business and the creation of the National Agency for Qualifications Development in 2006, as well as contributions from academia and legislative reforms such as the 2012 Federal Education Act (Danilov, 1969; Konarzhevskii, 1986; Baranskii, 1989; Zagvyazinskii, 1982; Zborovskii, 2000, p. 29).

Unfortunately, the gap between the competencies developed through education and the needs of industry remained unresolved, highlighting a persistent skills gap. Moreover, it was a cause of the decentralisation of vocational education in 2012 and the development of the professional standard for vocational education teachers in 2015 (Ministry of Labour of the Russian Federation, 2015). However, a significant problem of teacher preparedness and the lack of relevant training programs led to the formation of the Federal Target Program for the Development of Education for 2016-2020 (Dubitskii et al., 2021). The primary goal of this program was to develop a competency-based approach in the continued development programs for teachers (Dorozhkin & Chernoskutova, 2020, p. 195; Fedorov & Tretyakova, 2017, p. 119).

The establishment of the WorldSkills Russia Academy in 2017 marked another step in the development of Continuing Professional Development. It helps to improve vocational education and training systems in general. WorldSkills Russia Academy played a crucial role in developing unqualified teachers in TVET and VET organisations and attempted to address the problem of low-quality education (Lyzhin & Sharov, 2019, p. 111; WorldSkills Russia Academy, 2021). Nevertheless, the professional standard for vocational education teachers was abolished in December 2019, resulting in a lack of a systematic approach to teacher training (Order No. 832, 2019).

2.2.7 Digitalisation and Practice-Oriented Transformation (2020 – Present)

In 2020, the COVID-19 pandemic prompted vocational education and training organisations to transition their teaching formats to online rapidly. For vocational education teachers, mastering digital technologies and new teaching aids has become crucial for conducting online classes. However, it quickly became apparent that the system, environment, and teachers were not prepared for such a transition, facing difficulties with the digital technologies of distance learning (Andryukhina et al., 2021). The primary issue was the scarcity of electronic educational resources: only 10% of vocational education programs had such materials, and access to electronic libraries did not significantly increase the number of available and relevant study materials. The issue was the insufficient qualification of teachers in the secondary vocational education system to implement this activity (Blinov et al., 2020).

Another vital problem was the lack of digital competencies among vocational education and training teachers, which caused the slow adaptation to new digital duties, such as organising online lessons and communicating with students remotely (Blinov et al., 2020). This situation also influences the workload of vocational education and training organisations, which has increased by 50% and demands rapid decisions from the organisation's management (Sergeev, 2020).

Analytical reviews (Blinov et al., 2020; Dudyrev et al., 2020) and government decisions (Minutes of the Meeting, Pk-1,2020; Glushko, 2020) emphasise the need for teacher training and retraining. Initiatives provide that, as of 2020, the Russian State Vocational Pedagogical University (Ministry of Education of the Russian Federation, 2021) will become the leading educational institution for training teachers in the field of vocational education, as well as various retraining and qualification improvement programs offered by different organisations (Institute for the Development of Vocational Education, WorldSkills Russia Academy, etc.) (Fedorov et al., 2022, p. 16).

In 2021, efforts to promote professional development, innovative ideas in vocational education, and advanced pedagogical experience led to the creation of the "Master of the Year" competition among vocational education teachers (Master of the Year, 2024). The pandemic also prompted ideas for developing "short" educational programs to rapidly prepare candidates for positions in vocational education and personalised approaches to training (Lyzhin & Feoktistov, 2021).

In 2022, the WorldSkills Russia Academy received a new name, and in October 2023, it ceased its activities in Russia. Another significant initiative was the Ministry of Education of the Russian Federation's project to modernise the system of vocational education, which introduced an innovative educational program, "Professionalitet," in September 2022. This program aimed to foster closer interaction between educational institutions and industries, establishing new requirements for the competencies and qualifications of teachers (Feoktistov et al., 2023, p. 3).

The federal project "Professionalitet" initiated the creation of Qualification Improvement Centers and federal technoparks of vocational education to develop teacher qualifications and integrate new technologies in priority industries (Creation of Training Centers for Vocational Education Staff—Federal Technoparks, 2023). The "Core of Vocational Pedagogical Education" project, launched to ensure a unified approach to teacher training and new programs in engineering pedagogy, emphasised the importance of integrating technical and pedagogical training, as well as the crucial role of industrial partners in developing educational programs (Core of Secondary Vocational Pedagogical Education, 2022; Dubitskii, 2023, p. 35).

The authorities abolished the professional standard for vocational education teachers without approving a new one (Order No. 675, 2023). According to the Federal Assembly report from February 21, 2023, Russian President V.V. Putin noted that "considering the large-scale tasks facing the country, we must seriously update approaches to the training system, to the scientific and technological policy," which includes modernising the training of pedagogical staff and the need to create new formats for advanced training of teachers for the system of secondary vocational education (Putin, 2023).

Summary

Cyclical periods of advancement and decline have shaped the history of teacher preparation for technical and vocational education in Russia. From early Soviet efforts to establish a specialised pedagogical infrastructure through wartime adaptations and centralised retraining initiatives to the post-war integration of engineering and pedagogical competencies, each stage reflected the socioeconomic imperatives of its time. The post-Soviet transition brought conceptual shifts, financial instability, and diversification within teacher education. Since the 2000s, reform efforts have aimed to align teacher competencies with the demands of an evolving labour market,

culminating in the adoption of competency-based models and initiatives such as the Federal Project "Professionalitet". This project includes a framework that can help develop continuous development programs for teachers in TVET and VET organisations. It also helps to make a comprehensive ecosystem that includes educational organisations, industry, and policy. Appendix B presents detailed characteristics of the historical stages of pedagogical education.

2.3 Pedagogical Theories and Adult Learning Models in the Context of Online Courses for Training TVET Teachers

In the history of pedagogical doctrines, one can trace the evolution of learning theories from scholastic to explicative-illustrative and problem-developing approaches. Teachers and scholars throughout different centuries placed varying levels of importance on course-based and subject-based systems of education, methods of visual and abstract learning, the use of technical means (such as computers), and the digitisation of educational activities (Belozertsev et al., 2004, p. 174).

Educational theories are, in turn, represented by a broad spectrum of approaches and research projects grounded in scientific studies of learning in children and animals (Knowles et al., 2005, p. 18). Over many decades, scholars have attempted to categorise educational theories; however, they have not yet established a unified classification. For instance, McDonald (1964, pp. 1-26) identified six directions of pedagogical thought: Recapitulation (Hall, 1984), Connectionism (Thorndike, 1989), Pragmatism (Dewey, 1933, 1938), Gestalt and Field Theory (Hartmann 1935; Lewin, 1942), Dynamic Psychology (Freud), and Functionalism (Judd) (Knowles et al., 2005, p. 20). Other approaches also exist: Hilgard and Bower identified eleven categories, while Gage identified three, and so on. Scholars generally divide educational theories into two major groups: behaviorist/connectionist theories (Thorndike, Pavlov, Guthrie, Skinner, and Hull) and cognitive/gestalt theories (Tolman and the classical Gestalt psychologists). It is essential to note that scholars consider this division somewhat arbitrary and acknowledge that the presented groups do not encompass all existing approaches (Hilgard & Bower, 1966, p. 8; Knowles et al., 2005, p. 22). In 1973, Reese and Overton introduced the concept of developmental models, proposing a "more general model for formulating theoretical concepts" (Reese & Overton, 1973). Researchers based on this study proposed two directions: the elemental model (Thorndike's connectionism, Pavlov's classical conditioning, and Watson's behaviorism) and the holistic models of individuals (Guthrie, Voeks, Sheffield, Skinner, and Hull's systematic behavior theory). Behaviorism reflected the "American" approach, suggesting the possibility of achieving significant results "provided there is a stimulus (opportunity), response (individual interest and initiative), and reward (fair treatment)" (Knowles et al., 2005, p. 33).

During these years, several holistic models emerged (Dewey's functionalism, Tolman's purposive behaviorism), along with field theories (Lewin's group and institutional dynamics, phenomenological psychology, perceptual psychology, humanistic psychology, and cognitive psychology) (Knowles et al., 2005, p. 34). Scholars currently recognise thirty-one learning theories and categorise them into five meta-groups: humanistic, behaviorist, cognitive, constructivist, and theories focused on intelligence and skills (Akpan & Kennedy, 2020, p. 2).

This study examines theories that transcend the presented groups and applies them to the development of online learning for TVET engineering teachers or uses them as the foundation for educational programs aimed at achieving learning objectives in TVET engineering teacher training.

2.3.1 Humanistic Theories

Scholars such as Abraham Maslow (Navy, 2020; Madsen & Wilson, 2012; Maslow, 1943, 1968, 1970), William Glasser (1999), Thomas Malone (1981), von Humboldt (Sjöström & Eilks, 2020), Carl Rogers, and James Bugental developed the foundations of humanistic theory (Khalil & Elkhider, 2016). This theory of learning posits that education is a natural necessity on the path to achieving self-actualisation. It encourages learners to engage in self-directed education by setting realistic goals. The learning process is structured around students observing the actions and outcomes of others, engaging in group work, and participating in discussions that create an environment for observing other learners (Akpan & Kennedy, 2020). The humanistic approach in educational activities resists the prediction of learning outcomes because it is not amenable to strict and objective research methods due to its focus on learners' free will. The humanistic orientation of education aims to stimulate learners' interest in self-education, thereby investing them in their learning and enabling them to achieve their set goals.

In the context of online learning for TVET engineering teachers, humanistic approaches can be implemented as follows (Khalil & Elkhider, 2016; Navy, 2020; Milford & Kiddell, 2020; Sjöström & Eilks, 2020):
- developing modular learning programs for adults that allow for the autonomous selection of educational materials;
- incorporating practical sessions and visual aids (images, short videos, face-to-face masterclasses) during training and projects, internships, and mentorships based on the material studied after the training;
- ensuring learners achieve better results when they are emotionally comfortable within the learning framework. Gathering feedback before, during, and after the training helps improve learning outcomes (Knowles, 1984);
- creating an environment where each student can enhance learning by contributing to the knowledge base, sharing experiences, recommending improvements to the structure and methods of training, and having the option to choose technical means, applications, and services;
- implementing a strategy of belonging through group activities and events, educational communication with peers, and support from teachers for learners;
- adopting learner-centred approaches, implementing productive strategies of questioning, and recognising efforts and achievements;
- implementing human-centred approaches to organising educational activities;
- use a personalised approach in program designing that is tailored to individual learners' needs and motivations (Rogers & Freiberg, 1994);
- promoting self-discovery and personal growth as integral components of training, alongside the acquisition of technical competencies (Maslow & Frager, 1987);
- including elements of self-actualisation in the educational process, which allow the development of skills in independent information retrieval and self-realisation through projects and individual research (Rogers, 1995);
- incorporating active learning methods (group work, role-playing, and practical exercises) to enhance motivation and engagement in the educational process (Knowles, 1984).

In summary, humanistic learning theory advocates for a learner-centred approach that fosters self-awareness, self-development, and intrinsic motivation through observation, group interaction, feedback, and discussion—creating a supportive environment both in face-to-face and online educational settings.

2.3.2 Behaviorist Theories

Psychologist B. F. Skinner (1965) (Corscadden & Sutipatanasomboon, 2022) was the first to apply the behaviorist theory of learning in the educational process; however, most scholars recognise I. Pavlov (Akpan, 2020; Corr & Perkins, 2006) and E. Thorndike (1898) as its founders. Behaviorist theories in education view behavior as determined by the environment in which one lives and as a response to stimuli (the stimulus-response formula). This theory does not consider internal mental processes, which are challenging to analyse scientifically (Ertmer & Newby, 2013). Unlike humanistic theory, behaviourist learning theory is based on rigorous experimental methods. The drawbacks of this approach include labelling learners as passive students due to the deterministic nature of the approach and attributing control over behavior to upbringing (Ertmer & Newby, 1993, 2013). Because behaviorist theorists focus on observable behavior, they tend to overlook educational processes that elude direct observation and fail to consider the underlying causes of behavioral issues (Akpan & Kennedy, 2020).

The behaviorist theory emphasises focusing on learner motivation to achieve educational goals. To achieve successful learning outcomes, it is necessary to demonstrate to students the correct responses to external factors through repetitive actions. The basis of an effective educational process is the positive reinforcement of correct actions by students (Bryant et al., 2013).

In the context of online learning for TVET engineering teachers, the behaviorist theory can be applied as follows (Blaise, 2011; Rumjaun & Narod, 2020; Edinyang, 2016; Frieman, 2002; Akpan, 2020; Mangal, 2015; Fontana, 1995; Bandura, 1977):
- utilising classical and operant conditioning in organising the educational process (Kumar et al., 2019), forming a "learning culture" through the creation of detailed instructions and precise algorithms ("behavior models") for working with educational materials (Skinner, 1961) and audiovisual materials;
- including positive reinforcement in the educational process: a reward system, additional privileges, verbal praise, and other incentives, as well as punishments (e.g., reprimands) where behavior management is necessary (Thorndike, 1989);
- incorporating observation of "model" practical demonstrations by the educator of the skills being developed by the learners (Al-Jarrah et al., 2019);
- integrating continuous feedback (before, during, and after training) to provide positive reinforcement when addressing problematic learning issues (Fields, 1996);
- implementing individualised learning approaches (self-directed learning, technology-assisted learning, and the use of flowcharts and sequential events) (Skinner, 1965; Jabsheh, 2024);
- preventive planning of the curriculum, breaking it down by technology from simple to complex (Ramirez, 2017);
- repeated practice of learned materials and tasks to reinforce skills and competencies (Watson, 1948);
- constant monitoring and observation of learners' behavior to enable prompt adjustments (Miller et al., 1966).

Thus, behaviorist learning theory is based on the "stimulus-response" algorithm, which strengthens skills and competencies through the use of motivating stimuli, systematic repetition, and positive reinforcement of actions in the educational process.

2.3.3 Cognitive Theories

The cognitive theory emerged alongside the birth of psychology but lost prominence for several decades as behaviorist approaches gained popularity. Cognitive learning theorists focus on key psychological processes—such as thinking, perception, information assimilation, and

problem-solving—and examine how these processes influence the effectiveness of learning (Akpan & Kennedy, 2020). All these fundamental elements become particularly relevant with the emergence and development of artificial intelligence, necessitating a new perspective on working with cognitive functions in the process of acquiring new materials (Duggan, 2020).

The key developments in cognitive learning theory include the works of J. Piaget (1962, 1971, 1974, 1985, 2013) on cognitive development and L. Vygotsky's (1978, 1986, 1987a, 1987, 1987b, 1997, 1999, 2005, 2010, 2019, 2022) sociocultural perspective. These scholars' contributions have laid the foundation for further research within various learning theories. J. Piaget developed a four-stage model for processing new information, although it is more applicable to children's learning than to adults. (Barrouillet, 2015) B. Bloom (1984) emphasised the importance of using individualised and differentiated instruction that can help teachers connect with each learner and provide the necessary support and assistance (Eisner et al., 1972; Bennett & Bloom, 1979). In D. Ausubel's works (1963, 1968, 2000), the primary focus is on building knowledge by layering new information onto the learner's existing experiences (Ausubel et al., 1978). J. Bruner (1986) and R. Gagné (1963) base their theories on the concept of learning as discovery (Bresler et al., 2002); however, J. Bruner views this as an educational process (Bruner, 1992; Bruner et al., 1957), whereas R. Gagné sees it as a combination of the educational process and guided discovery, leading to specific, product-oriented outcomes.

Summarising the research in the field of cognitive science directed at learning, the following points can be highlighted (Shaughnessy, 2004; Woolfolk, 2016; Woolfolk & Mowrer-Popiel, 2001):
- the educational process is inextricably linked with the brain and is formed through cognitive activity;
- knowledge and cognition are the results of educational activities (a person's existing knowledge becomes the foundation for forming new educational experiences and determines how information is perceived, attention is focused, and how the processes of learning, memorising, and forgetting occur) (Bransford & National Research Council, 2004; Sawyer, 2006);
- knowledge can be specific (belonging to a particular subject, discipline, or area of scientific knowledge) and general cognitive abilities (problem-solving, task planning, computer literacy, language comprehension) (Greeno et al., 1996);
- attention and its utilisation play a crucial role in learning and achieving educational goals (Bruning et al., 2011; Schunk, 2015);
- information processing in the educational process is achieved through the balanced work of working memory, attention, and the interaction between sensory and long-term memory (Ashcraft & Radvsnsky, 2010; Bruning et al., 2011; Sternberg et al., 2012);
- metacognitive knowledge and skills, also known as the awareness of one's learning processes ("knowledge or awareness of self as knower") (Fox & Riconscente, 2008), determine the speed and assimilation of new material through planning, control, and evaluation (Bruning et al., 2011).

Cognitive theory aims to develop learners' abilities to process information deeply and retain it in long-term memory.

Based on the aforementioned research, cognitive theory can be applied to online learning for TVET engineering teachers as follows (Ausubel, 1963; Dityatkina, 2018):
- using the knowledge-check questions both at the end and during the learning process;
- questions should be designed to immerse learners in the comprehension of educational material and foster the development of thinking processes and critical thinking skills. These questions are always formulated based on learners' responses. Its main aim is to help students analyse their educational experience and what they have already learned (Bruner, 1960);

- the design of practical tasks must include the ability to allow learners to make mistakes. Such task modelling helps identify gaps in the assimilation of educational material and redirect learners' cognitive activities towards finding the correct solution;
- incorporating a stage of self-reflection in the educational process to enhance understanding of their thinking processes. An example of successful implementation could be a self-analysis of acquired knowledge and skills at the beginning, middle, and end of the training. This format encourages students to reflect on the learning process (Flavell, 1979);
- providing opportunities for learners to observe one another during the learning process. The process of imitation is more characteristic of children, but the observation format is also applicable to adult learners who wish to acquire new skills;
- incorporating tools for visual representation of information (mind maps, diagrams, etc.) in the educational process, which help structure information and accelerate its perception;
- including elements that develop cognitive conflict by incorporating contradictory information that will maintain interest in the deep study of the material (Piaget, 1971);
- using analogies and examples to explain complex situations and linking new information to learners' existing experiences and knowledge (Gentner & Stevens, 2014).

In conclusion, the cognitive theory of learning contributes to the development of key psychological processes — attention, thinking, and problem-solving — through an individualised approach to each learner. Applying this theory when designing educational programmes can increase the depth of learning and contribute to the development of critical thinking. In the context of an AI-driven landscape, the cognitive approach to learning is becoming increasingly relevant.

2.3.4 Constructivist Theories

Constructivist learning theory is closely related to cognitive learning theory and ideologically intertwined in the implementation of educational approaches. The founders of constructivist learning theory include J. Dewey (1910; 1913; 1929a; 1929b; 1933; 1938; 1980; 1994; 1998; 2007), D. A. Kolb (Kolb's Learning Cycle) (1984; Kolb et al., 2001; 2014; Watson et al., 2019; Vince, 1998), J. Bruner (1960; 1977; 1986; 1992; 1997), and L.Vygotsky (1926; 1993; 1978; 1984; 1986; 1987; 1987a; 1987b; 1997; 1999; 2005; 2010; 2019; 2022). Offshoots of constructivist theory include the works of Ernst von Glasersfeld (Radical Constructivism) (1984; 1995; 2001a; 2001b; 2010; 2013; von Glasersfeld & Larochelle, 2007), George Kelly's Personal Construct Theory (Constructive Alternativism) (1963; 1969; 1969a; 1969b; 1969c), L. Vygotsky (1978; 1986), A. Leont'ev (1978; 1965; 1974; 1981; 2005), and Y. Engeström (Activity Theory) (1987; 1999; 2000; 2001; 2008; 2014; Engeström & Sannino, 2010) among others.

The essence of the theory lies in empowering learners as active participants in their educational process. In other words, learners base their knowledge on the experiences they gain through learning. They reflect on previous experiences, apply new knowledge to them, and construct mental models (schemes) that help them make educational progress. Learners construct their knowledge by layering new information onto previous experiences and adjusting their mental schemas (Woolfolk, 2016).

Constructivism represents a synthesis of knowledge from various fields of science, including psychology, pedagogy, sociology, philosophy, neuroscience, computer science, and anthropology. There are three ways of knowledge construction in constructivist theory (Akpan & Kennedy, 2020):
1. Knowledge acquisition occurs through the restructuring of external reality (e.g., changing information processing models in the educational process).
2. Knowledge growth occurs through the "layering" of new knowledge onto existing experience or the transformation of existing experience and knowledge (based on Jean Piaget's theory).

3. Knowledge acquisition is a combined model of external world cognition and the internal transformation of existing knowledge (based on Lev Vygotsky).

The general types of educational activities that characterise constructivist theory include (Windschitl, 2002):
- problem-oriented complex and substantive tasks;
- forming a pool of learners' ideas on specific topics and building an educational process capable of improving the level of knowledge;
- joint execution of problem-oriented tasks in groups;
- applying learners' knowledge and experience to explain concepts, interpret phenomena, and construct arguments based on evidence;
- using various methods to assess students' progress and knowledge in order to adjust their educational path and provide feedback.

Constructivist approaches tend to be effective in practical settings, as they help learners connect the educational discipline with their experiential knowledge. An educational framework can highlight the main topics and focus on them while incorporating teamwork helps students develop social skills. Unfortunately, implementing this approach could cause significant investments, as well as the allocation of material and technical resources.

In the context of online learning for TVET engineering teachers, constructivist theory can be applied as follows (Vygotsky, 1978; Wenger, 1998; An & Reigeluth, 2008; Papert, 1982):
- establishing an understanding of the "starting" level of knowledge and skills of learners before the educational process begins through methods such as discussions or entrance testing;
- incorporating synchronous learning into the educational context to satisfy social interaction needs. Synchronous formats in online learning can include webinars, live masterclasses, live Q&A sessions, etc. To develop collaboration and collective interaction skills, it is better to use group projects;
- to stimulate this process, course designers can integrate discussion platforms into the online course—spaces intended for exchanging experiences and supporting problem-oriented learning (Dennis, 2003). Moreover, an online course with a well-structured educational path can include tools to stimulate self-learning. These can include external informational links, a knowledge base within the course, methodological recommendations for the educational course, additional features (e.g., keyword search within the course), and so on;
- shifting the teacher's authoritarian role to a facilitative one. In constructivist learning theory, teachers need to create learning conditions that stimulate cognitive activity. Techniques that stimulate cognitive activity include problem-based learning, independent work with educational literature, creative assignments, solving practical tasks, etc.;
- integrating reflection into the educational process to analyse learning dynamics and adjust the further educational path (Bogumil, 1985);
- utilising project-based learning, which allows learners to apply their knowledge, analyse missing knowledge and skills, and assimilate information through hands-on engagement;
- establish a community of TVET engineering teachers that serves as an environment for practical discussions and the exchange of experience between teachers and learners.

To sum up, the constructivist learning theory helps to develop interactive and dynamic educational programs by balancing theory and life experience within it. This approach led to the comprehensive development of TVET engineering teachers during the educational program.

2.3.5 Diethelm Wahl's Pedagogical Double-Decker (Der Pädagogischer Doppeldecker)

The Pedagogical Double-Decker, as a didactic model, is currently associated with the name of German professor Diethelm Wahl; however, its founder is Karl-Adolf Geissler (Geissler, 1985). In 1985, he presented a learning model that involved the simultaneous demonstration of educational material by the teacher and its explanation. This model combines theoretical knowledge with practical application. Its main goal is to help students understand key terms and concepts and apply everything in practice. The application of this model becomes especially important and necessary in teacher training, where the process of knowledge transmission itself represents a practical demonstration.

In his work, Geissler describes the term "Pädagogischer Doppeldecker" as a process in which the learner not only studies the content intellectually but also experiences it through personal engagement, thereby actively integrating this experience into cognitive interaction with the material (Geissler, 1985).
The practical application of the Pedagogical Double-Decker model is discussed in the works of D. Wahl (2013; Wahl et al., 2020) and involves the following four metacognitive stages (Wahl, 2023):

1. Meta-Communicative Introductory Phase:
Learners understand that the teacher is demonstrating theoretical concepts in practice. For example, suppose a teacher needs to present the theoretical basis of impartiality, present competent material, and communicate effectively with a heterogeneous audience. In that case, the teacher must demonstrate impartiality, present material competently, and employ individualisation and differentiation methods to work with a heterogeneous audience, exemplifying this in their teaching.

2. Intermediate Phase:
This phase involves analysing successful demonstrations of applying theoretical materials ("flugfähiger Doppeldecker") or discussing parts of the educational process theoretically presented but not successfully demonstrated ("abstürzender Doppeldecker").

3. Meta-Communicative Concluding Phase:
During this phase, learners have a reflective discussion with their teachers about the covered material, then analyse the successful demonstrations of theoretical material in practice, as well as moments where practical demonstrations do not go well.

4. Consequences for Personal Change Processes:
This phase involves transferring the lived experience to personal practice and future actions of learners. It is implemented through group or individual work, where learners discuss the key question of how to apply the acquired knowledge in their future practical activities.

This pedagogical model applies universally in contexts involving education, training, and upbringing. However, it cannot be applied where the teacher cannot visually demonstrate specific processes (e.g., abstract mathematical concepts or genitive attributive phrases in grammar) or "live" the essence of what they are teaching.

<u>Application of the "Pädagogischer Doppeldecker" Model in Online Learning:</u>
- integration of theoretical and practical parts can be achieved through combined educational courses that include both lectures and virtual labs/simulators, allowing learners to apply acquired knowledge in a virtual environment (Neuweg, 2011; Wahl, 2013);
- use of interactive platform solutions (e.g., forums, webinars, social media groups) to share experiences, discuss acquired knowledge and observations with teachers and peers, and reflect on studied material (Neuweg, 2018, p. 191; Wahl, 2013, p. 301);

- inclusion of multimedia components (e.g., video lessons, podcasts, interactive presentations) to increase learner engagement and adapt materials to heterogeneous groups (Wahl, 2013, p. 299).

In 2016, M. Martin expanded the model and named it "Der Berufsdidaktische Dreidecker." This conceptual model is designed to combine different levels of competencies in TVET teacher training, based on the idea of "Pädagogischer Doppeldecker," supplemented with non-pedagogical professional competencies (Wildt, 2005). This model integrates not only the development of pedagogical skills but also professional practice and the involvement of enterprises in the educational process. This addition enables role switching (both teacher-learner and specialist-learner) during training, creating the necessary conditions for TVET teachers to successfully combine theoretical and practical knowledge, including specialised, sectoral, and professional skills (Martin, 2016).

Application of the "Pädagogischer Doppeldecker" and its expanded version "Der Berufsdidaktische Dreidecker" in TVET engineering teacher training through online courses:
- creation of a modular curriculum that divides material into various aspects of professional training (e.g., pedagogical methods, specialised subjects, practical skills). This division will allow the principles of the model to be implemented as effectively as possible and will also enable teachers to undergo training in stages and at a pace that suits them (Yutsyavichene, 1989; Neuweg, 2018, p. 207; Wahl, 2013, p. 295);
- inclusion of virtual practical sessions and simulations to develop pedagogical skills in a controlled and safe environment, utilising various online tools for both group and individual work. This technology helps teachers practice skills and better prepare for real-world teaching scenarios (Martin, 2016; Neuweg, 2018, p. 179);
- incorporation of regular automated assessment systems and personalised feedback from teacher trainers to improve material retention and error correction (Neuweg, 2018, p. 215; Wahl, 2013, p. 297);
- use of situational learning tasks, effectively implemented through the expanded "Der Berufsdidaktische Dreidecker" model (Haasler et al., 2003; Grottker, D., 2010, p. 27);
- observation of professional processes (e.g., video lectures or live broadcasts of assembling and processing parts) and project-based learning to study real production situations. This process enables learners to gain experience in work processes through observation, participation, or action, thereby increasing the amount of material they can remember (Aebli, 1990; Reich, 2009).

In summary, the "Pedagogical Double-Decker" brings theory and practice together in a single lesson. Instead of separating explanation and application, the teacher does both at once, helping learners better internalise the material through immediate practice.

2.2.6 Andragogy

Andragogy is the science of adult learning, which began its active development in the mid-20th century. The term "andragogy" was first introduced by German educational historian Alexander Kapp in 1833 (Kapp, 1833). However, it gained widespread recognition through the works of Malcolm Knowles (Knowles, 1973; Knowles et al., 2020), P. Jarvis (2001), and R.M. Smith (Tukhvatullina, 2013) in the 1970s. Some characteristics of adult learning can also be found in the works of scholars such as K.D. Ushinsky (who identified several features of adult learning in Sunday schools and the connection between learning and production activities) (Ushinsky, 1952; 1974), E.N. Medynsky (1936) (who summarised the experience of extracurricular education in pre-revolutionary Russia), N.K. Krupskaya (1959; 1978) (who highlighted important factors defining the specifics of adult learning, including the training of workers), A.V. Darinsky (who determined the features of general education for adults) (Kairov & Petrov, 1964), A.D. Pint and

N.I. Bokareva (who described the distinctive features of adult pedagogy) (Gromkova, 2017), Yu. N. Kulyutkin (who highlighted certain features of the psychology of adult learning) (Kulyutkin, 1985), J. Dewey (1938; 1980) (who emphasised the need for learning based on the learner's experience and practical goals), E. Lindeman (1926) (who formulated the philosophical premises of adult education), A. Maslow (1953; 1971) (hierarchy of human needs), and C. Rogers (1970; 1995) (who emphasised the leading role of the individual in the learning process), V.P. Vakhterov (1896; 1987; 1913) (who studied various forms of extracurricular adult education), and A.V. Lunacharsky (adult school for literacy elimination) (Lunacharsky, 1976; Mandel', 2017; Zmeev, 2000c). This list of scientists is by no means exhaustive, but it confirms that the issues of adult education and training have been of interest long before andragogy emerged as a distinct field of study (Kolesnikova, 2003; Knowles et al., 2005; Gromkova, 2017; Shtanko & Morozova, 2022; Malinen & Piirainen, 2023).

The andragogical model of learning is built on key postulates of constructivist learning theory and is characterised by the active participation of learners in the learning process ("The learner takes the leading role in their learning process, which is why they are referred to as learners, not as passive recipients of instruction") (Zmeev, 1996), the use of life experience ("As individuals develop, they accumulate significant experience which may be leveraged to facilitate learning.") (Zmeev, 2000c, p. 31), solving specific life problems ("In the andragogical model, learners' readiness to learn is determined by their need to acquire knowledge in order to solve specific real-life problems") (Zmeev, 2000c, p. 32), and achieving specific goals ("An adult learns to solve vital life problems and achieve specific goals") (Zmeev, 1996, p. 314; Knowles et al., 2020), which are the essence of constructivism (Uday, 2019; Zmeev, 2000a; Orinina, 2018; Fedeli & Bierema, 2019; Loeng, 2023).

However, andragogy has unique characteristics, such as:
- learning is organised in a collaborative format between the teacher and the learner at the stages of planning, implementation, and evaluation of results (Zmeev, 2000c, p. 31-32; Mandel', 2017, p. 142);
- learning involves a more flexible approach to organising the educational process, considering the diverse contexts in which learners find themselves by adapting the content and methods of instruction to specific factors (temporal, spatial, domestic, professional, social) (Zmeev, 1996, p. 314; Gromkova, 2017, p. 12);
- the educational process is structured to develop learners' autonomy and self-direction, taking a "leading role in their learning process," thereby increasing motivation to learn (Knowles et al., 2005; p. 81; Zmeev, 1996, p. 314; Tough, 1979);
- the primary methods in education become empirical methods, allowing the accumulation of more experience (experiments, discussions, simulators, field research, etc.) (Knowles, 1980, p. 44);
- learning shifts from subject-oriented to outcome-oriented, enabling the application of acquired knowledge in practice and the development of professional expertise (Knowles, 1980, p. 45).

Based on Knowles' principles of learning (Knowles et al., 2020; Knowles et al., 2005, pp. 64-69), andragogy can be applied to online learning as follows (Bilenko et al., 2020; Arghode et al., 2017):

1. When discussing online courses for adults, it is paramount to recognise that they aim to acquire specific knowledge and skills. That is why online courses should be designed with the result in mind (the knowledge, skills and competencies that learners acquire). The course curriculum must align with students' learning expectations and meet their requirements.

2. Adult learners value autonomy. When they are given the flexibility to choose the time, place, format, and pace of their studies — and to shape their educational path — it helps them feel more in control of their learning, which in turn supports engagement and persistence.

3. When designing an educational course, it is essential to assess the prior experience of future students and incorporate it into the learning process to develop specific skills and competencies. The necessary information can be obtained through testing, feedback collection, preliminary analysis of the target audience, and other product-based approaches.

4. An essential element of successful online learning is the practical application of the knowledge gained. That is why it is necessary to use tools that allow students to practise their skills and knowledge immediately after learning them. Such tools can include workbooks, guides, checklists, control lists, and others (Bilenko et al., 2020, p. 29).

5. Adult learners are often limited in terms of time for the educational process, so it is essential to convey the main essence of information in online training. This effect can be achieved by including case studies (Lewis & Bryan, 2021) and involving learners in research and project activities. One of the key ways to make online courses more engaging is to encourage regular interaction — both between teachers and learners and among the learners themselves. It is better to do this with the help of such tools as webinars, chats, and discussion forums that facilitate real-time communication and collaboration (Gromkova, 2017, p. 12; Bilenko et al., 2020, p. 18; Skachkova, 2022).

6. Motivation is a complex topic and is not always easily determined. The research on adult learning motivation is extensive, including authors such as Sheffield, Bosher, Burgess, and Grabowski, who followed Knowles' typology, and Knox and Videbeck, who supplemented the typology with psychological motives (Hubackova & Semradova, 2014). However, the foundational typology of adult motivation was established by Cyril Houle in 1961, identifying three key motivations for adults: goal-oriented, activity-oriented, and learner-centred (Houle, 1956; Whipple & Williams, 1963; Brockett & Donaghy, 2005).

In online education, it is crucial to initially determine the learners' motivation, as their motives develop during the adaptation phase of the educational process (Mandel', 2017, p. 94). Because adult learners face constant changes in their level of motivation, measuring it becomes not only difficult to implement but often meaningless (Bilenko et al., 2020, p. 16). To maintain the level of motivation among adult learners, it is essential to focus the course content on real-life practical tasks that they use daily (Bilenko et al., 2020). Another helpful tool is a place for communication. It is necessary to create a space where students can share their experiences and problems and discuss learning questions. Such communication helps to develop willpower and increases the effectiveness of learning (Podobeda & Maron, 2003, p. 87). Consider both practical motives (such as qualification improvement, diploma acquisition, and promotion) and social motives (such as changing social roles and status enhancement) in the design process (Long, 1983; Hubackova & Semradova, 2014; Mandel', 2017, p. 335; Selivanova, 2020).

For TVET engineering teacher training through online courses, andragogy can be applied as follows (Podobeda & Maron, 2003; Biryukova, 2008; Gromkova, 2017; Bilenko et al., 2020, p. 29; Volobueva, 2021; Maksyutova & Li, 2022; Burtseva, 2022; Moll, 2023):

1. The use of platform solutions in the training of TVET teachers (e.g. LMS (Learning Management System), Canvas, Moodle platforms) will allow for the inclusion of an interactive component in the training process, meet social needs through communication with fellow students and teachers, and monitor the training process, thereby responding to the key principles of andragogy.
2. The use of a blended learning format is the most effective way to combine the study of theoretical materials online with practical training in face-to-face meetings, thereby applying the knowledge gained in real-life situations.

3. The use of virtual laboratories, simulators and trainers will allow students to apply the skills they have acquired and gain experience in a controlled environment.
4. Adapting courses to individual needs and educational progress through a modular approach and asynchronous delivery of the educational programme.
5. Incorporate M. Kapur's theory of productive failure (using complex tasks at the beginning of learning to stimulate deep understanding of the material, analysis of failures and reflection, followed by instructions on how to overcome failures and clarification of the situation by the teacher, and application of the acquired knowledge in new situations) (Kapur & Rummel, 2012; Kapur, 2008; 2011; 2012; 2013). The application of this theory within the andragogical approach will enable teachers to foster creative thinking, enhance their level of adaptability, and improve learning outcomes.

Andragogy closely interweaves with various approaches and intersects with other theories and disciplines (pedagogy, psychology, social sciences, etc.), yet it can also function independently. However, it will always partially reflect other pedagogical theories, considering learners' age-specific characteristics (Kolesnikova, 2003; Gromkova, 2017; Lewis & Bryan, 2021).

Taking everything into account, andragogy emphasises the importance of utilising learners' life experiences and addressing specific real-life problems in adult education by adapting content to the individual needs of the audience and utilising modern learning formats. This approach enhances engagement and motivation while ensuring an effective educational process.

2.3.7 Albert Bandura's Social Learning Theory

The initial works on social learning theory were published in 1941 by Miller and Dollard (Dollard & Miller, 2013), who aimed to "combine psychodynamic theory, learning theory, and the influence of sociocultural factors into one theory" (Rumjaun & Narod, 2020). Chomsky (1959; 1967) and Rotter (1954; 1960) continued efforts to expand behaviorist theory beyond the "stimulus-response" model, emphasising the need to include cognitive factors in the learning process. Despite early attempts by scholars to broaden behaviorist learning theory, it was A. Bandura (Zimmerman & Schunk, 2014) who established and solidified the Social Learning Theory (SLT). His research focused not only on studying behavioral patterns but also on the mutual influence of behavioral, cognitive, and environmental factors. The theory shows that people learn better by observing others' behavior and then adopting and imitating it ("observational learning"). Bandura demonstrated that learners could observe, imitate, or model something without necessarily being able to use it later.

In his theory, Bandura identified the necessary elements that enable one to learn observable behavior: attention, retention, reproduction, and motivation (Bandura, 1977; Pierce & Bandura, 1977). Below is an analysis of each of these elements in the context of online learning.

- **Attention**

Attention enables learners to focus on behavioral models, imitate actions, and internalise them during the learning process. To achieve educational outcomes in asynchronous courses, webinars with teachers or experts, as well as video lectures, can be utilised (Salmon, 2003; Krause & Coates, 2008; Ebner & Gegenfurtner, 2019). The implementation mechanism is as follows: during a webinar, the teacher demonstrates specific tasks, followed by opportunities for students to ask questions about the process, applicability, and results. In synchronous learning, teachers draw attention through student discussions (Gokhale, 1995; Brookfield & Preskill, 1999), attention-grabbing headlines (Mautone & Mayer, 2001; Mayer, 2009), educational storytelling (Miller, 2011; Haven, 2007), and guiding questions (King, 1991; Graesser & Person, 1994), among other

methods. The best way to advance (Reeve, 2006) the level of engagement and concentration (Schiefele, 1991; Hidi & Renninger, 2006) is to increase learners' attention (Dewey, 1913; Ainley et al., 2002; Harackiewicz & Hulleman, 2010).

In preparing TVET engineering teachers through online courses, the following tools can be used to capture attention (Chuang, 2021):
- video recordings of lessons by experienced teachers, which learners can watch to observe how they conduct classes and masterclasses and analyse their methods and approaches (Hattie, 2009);
- participation in live demonstrations and online seminars helps to apply theoretical knowledge to practice (Schunk & DiBenedetto, 2020);
- modelling behavior through mentors and program guides demonstrating effective methods and practices, which can later be adapted to the needs of learner-teachers and used in their practice (Lave & Wenger, 1991).

- **Retention**

At this stage, the learner must recall what they observed in the demonstration model. The basis of social learning theory is social learning itself. It is a key element that allows students to retain the information they receive during the educational programme. Discussing the information students have learned during the learning process allows them to relate it to their personal experiences (Brookfield & Preskill, 2012), making it particularly effective for adult education (Knowles et al., 2020). Online learning should include interaction opportunities in asynchronous formats (Salmon, 2011; Hrastinski, 2008b; Berge, 2013), such as messenger chats or forums on educational platforms (Susilawati & Supriyatno, 2020) and in synchronous formats, such as individual feedback from the instructor (Hrastinski, 2008a; Anderson, 2008). Including emotional components in the educational process enhances information retention and comprehension (Kensinger, 2004; Phelps, 2004). Positive affect, based on Donald Norman's three levels of design, can be employed in online learning. Positive affect refers to the human capacity to experience positive emotions, which influence perceptions, mood, and other aspects of well-being (Naragon-Gainey & Watson, 2019; Fredrickson, 2001). Norman notes that everything learners do has cognitive aspects that determine the significance of something and affective aspects that determine its value. Positive affect fosters curiosity, creativity, and effective learning by enhancing brain capabilities, whereas negative affect has the opposite effect, impacting learners' outcomes (Fredrickson, 2001; Isen, 2001; Fredrickson & Joiner, 2002; Norman, 2004).

Using emotional design in multimedia projects, which encompasses visceral, behavioral, and reflective elements, can enhance the online learning process, improve material retention (Plass et al., 2014; D'Mello & Graesser, 2012), and contribute to achieving long-term educational outcomes in online learning (CAST, 2024).

In preparing TVET engineering teachers through online courses, the following tools can be used to improve retention:
- development of additional materials such as presentations (Mayer, 2014), infographics (Yuruk et al., 2019), mind maps (D'Antoni et al., 2010; Alsuraihi, 2022), and notes (Friedman, 2010) to better remember observed models (Ausubel, 1963);
- organising group reflection and discussions after observations, where learners analyse what they saw and remember key points (Marcarelli, 2010; Maddix, 2012; Omar & Taib, 2022; Pillay & Govender, 2023);
- including practical tasks and exercises in the educational course, such as virtual simulators, (Shen et al., 2024) to reinforce observed methods and techniques (Ericsson et al., 1993; Abuhassna et al., 2020; Kist, 2022).

- **Reproduction**

After learners have been introduced to a new form of behavior and have retained the information, they must be able to apply the acquired skills, i.e., put the information into practice. For this transition to be successful in online learning, it is necessary to use methods that allow learners to practise the skills and knowledge they have acquired. Laboratory and practical classes facilitate improved learning outcomes, particularly in engineering and scientific disciplines (Kang, 2016; Kist, 2022). Other effective methods include, for example, joint projects and case studies (Deaton, 2015), as well as joint work on projects and collaboration using digital tools (Sobko, 2020; Darius et al., 2021).

In preparing TVET engineering teachers through online courses, the following tools can be used to improve reproduction:
- learner-teachers conduct mini-lessons to reproduce the methods and techniques they learned during the training (Allen, 1967; Feng & Zhan, 2021; Megawati & Trisnawati, 2022);
- using gamification (e.g., role-playing games) (Nurhikmah, 2022) and simulations of real teaching scenarios for educational purposes by learner-teachers (Kara, 2021; Ertan & Arkün Kocadere, 2022; Chukwu, 2024);
- applying experiential learning methods, where learners can use observed models and approaches in a controlled environment (Kolb, 1983; Wurdinger & Carlson, 2009; Kolb, 2014; Kumar Misra, 2023).

- **Motivation**

A. Bandura points out in his work that learners must have a need or motivation to acquire new forms of behavior. Students' observation of punishment and reward plays a crucial role in shaping behaviour through observation (Bandura & National Inst of Mental Health, 1986; Hidi, 2016; Zajda, 2023). Rewarding students contributes to their motivation to continue learning, while, for example, ignoring them on the part of the teacher will cause them to reject the model behavior. Highlighting the benefits of studying behavior leads to positive learning outcomes. In contrast, a lack of information about the reward and its low value can lead to falsification and imitation of behavior, negatively impacting learning outcomes (Cameron & Pierce, 2002).

It is essential to understand the needs and motivations of learners to increase the effectiveness and success of online learning. Moreover, it is helpful to have this knowledge to select practical motivation tools. For example, understanding the needs, goals, and other individual characteristics of the learning audience before the training begins is important (Schunk & DiBenedetto, 2020).

In preparing TVET engineering teachers through online courses, the following tools can be used to improve motivation:
- including regular constructive feedback from mentors and colleagues in the educational process to encourage learner-teachers to improve their competencies and continue developing (Hattie & Timperley, 2007; Hattie & Clarke, 2018; Burns, 2024);
- creating a reward system, such as certificates, awards, and various forms of public recognition, to motivate learner-teachers to participate in the educational program actively (Deci & Ryan, 2000; Hanson, 2003; Saraswati et al., 2020);
- creating conditions for intrinsic motivation by training teachers in goal-setting, achieving them, and developing internal motivation and interest in professional activities (Locke & Latham, 2002; Pink, 2012; Urhahne & Wijnia, 2023; Criss, 2024).

From all of the above, Albert Bandura's social learning theory demonstrates the importance of the mutual influence of behavioral, cognitive, and environmental factors, making it effective for use in both face-to-face and online formats.

2.3.8 Heutagogy

Heutagogy was first described by Stuart Hayes and Chris Kenyon in 2000 (Hase & Kenyon, 2000) and is the science of self-determined learning, in which learners control their educational process, choosing what they want to study and how they want to learn. This approach is based on theories such as transformative learning (Paprock, 1992), constructivism (Vygotsky, 1978; 1962; 1984), and self-determination theory (Ryan & Deci, 2000; 2018; 2022; Deci & Ryan, 2009). It is rooted in the humanistic approaches to learning that emerged in the 1950s. The authors of the theory assert that the success of any educational project lies in the learner's motivation to "seek more interesting information and find answers to their questions," which is the essence of successful learner-centred education (Hase, 2013). While heutagogy's applicability is quite broad, it is most effective when used as a supplementary educational theory, building on pedagogy and andragogy with their didactic and pedagogical approaches. For TVET engineering teachers, it is crucial that their training not only satisfies their interests but also allows them to practice and master specific skills before commencing their teaching careers (Stewart & Kenyon, 2001).

The key principles of heutagogy rest on the following core ideas:

1. The use of a non-linear approach to learning, where learners develop educational pathways by setting goals and determining assessment methods themselves. In turn, the teacher expands their competencies and becomes a facilitator who suggests topics for learning that will not only be interesting for the learner but also relevant to the educational course they are taking. However, the learner's involvement in 'managing' their educational process increases their level of interest, motivation and deeper engagement in the subject that they need to learn (Damasio, 2003; Dolcos et al., 2004; Albon, 2006; Hall et al., 2021).

2. Heutagogy aims to develop learners' ability to apply skills in new and complex situations, responding to the challenges of rapidly changing external conditions. Furthermore, incorporating it into the curriculum helps develop learning skills, promotes curiosity, and trains information-processing skills (Stephenson & Weil, 1992; Hase & Kenyon, 2003; Blaschke, 2012).

3. To enable learners to understand and analyse the knowledge they acquire during the learning process, it is advisable to use reflection tools, include feedback from teachers, and incorporate discussion of the educational process into the course curriculum. This process lays a foundation for deeper, transformational learning. This deep cognitive process is based on the principles of double-loop learning and action learning (Paprock, 1992; Hase, 2013). These forms can be used in both individual and group work within a lesson (Canning & Callan, 2010).

Applying heutagogy to online education and TVET teacher training through online courses shares the same fundamental principles. Therefore, researchers and teachers should consider how to apply heutagogy to the online training of TVET engineering teachers. Heutagogy can be implemented in the following ways (Coomey & Stephenson, 2001; Ashton & Newman, 2006; Eberle & Childress, 2009; Hase, 2011; Freeman & Wash, 2013; Wong et al., 2020; Ceylan, 2020; Ettyani et al., 2023):

1. Using digital tools that allow students to manage their educational process, thereby implementing the main principle of heutagogy: self-determined learning. Moreover, it encourages

them to adapt to modern technologies, learn how to utilise them and develop the competencies necessary for full professional development in the digital age (Irdianto et al., 2023).

2. With the help of online courses, learners can independently set learning goals, choose resources, and select teaching methods, which contributes to the development of independent learning skills and has a positive effect on learner motivation. Heutagogy enables the educational process to focus on the ability of TVET engineering teachers to apply their knowledge in professional contexts, thereby contributing to their rapid preparation for rapidly changing conditions.

3. Heutagogy supports the integration of modern digital solutions (e.g., simulators, virtual classrooms, mobile applications, and collaborative platforms such as Learning Management Systems or LMS), allowing learners to tailor their educational pathways to their personal goals and needs. It also promotes the development of digital literacy and skills in using new educational tools (Irdianto et al., 2023).

4. The introduction of electronic journals, blogs, and other tools for recording thoughts and analysing the learning process enhances metacognition and promotes more cognitively aware learning (Blaschke, 2012).

5. The flexibility and adaptability of online learning enable adult learners (and others) to balance educational activities with other responsibilities, thereby increasing engagement and motivation, as well as the completion rate of online courses (Allen, 2010).

6. Online courses can also foster social learning and collaboration by facilitating the exchange of experiences and joint problem-solving. Such collaborative environments help to create a community of practising TVET teachers and provide a space for them to improve their skills (Narayan et al., 2019).

An example of the application of heutagogy in the training of TVET engineering teachers is the Indonesian TPE (Teacher Professional Education) program, which allows teachers to independently determine their study plans and choose educational resources and methods. Furthermore, the programme provides opportunities to participate in professional communities and other professional associations, allowing for the exchange of experiences (Amiruddin et al., 2023). Another successful example is the PembaTIK programme, which employs heutagogy approaches to teach teachers how to adapt to modern digital challenges and quickly integrate new digital tools into educational activities (Irdianto & Petrova, 2023). An additional notable experiment is the application of Andra-heutagogy in Kuala Lumpur. This new branch combines blended learning and team teaching using modern information technologies. The team-teaching experience proved most effective under the guidance of an expert educator, confirming that heutagogy can be used independently as well as in various hybrid theories and learning models. Practitioners often combine this approach with others, though they may also apply it independently in informal educational settings. The use of heutagogy combined with modern digital tools will create educational programs that prepare TVET engineering teachers for pedagogical activities in new realities (Uday, 2019).

Concisely, heutagogy continues the traditions of pedagogy and andragogy, drawing upon humanistic approaches, constructivism, self-determination theory, and the foundations of transformational education. It focuses on the development of metacognition, motivation, and social learning, which are essential elements for achieving educational outcomes in a rapidly changing world.

2.3.9 Digital Didactics

Digital didactics emerged in the 2000s, replacing the term "informatisation of education" (Buzaubakova et al., 2023, p. 34). However, as a scientific discipline, it began to develop only in the 2010s and became a new branch of pedagogical science, allowing the adaptation of traditional didactic approaches and methods to the rapidly changing and evolving digital environment (Alekseeva & Solomonova, 2020; Buzaubakova et al., 2023). Digital didactics represents a system of methods, practical approaches, and tools that organise learners' activities in a digital environment using digital technologies and learning tools (Bilenko et al., 2020, p. 31; Remorenko, 2022, pp. 5-35; Buzaubakova et al., 2023, p. 34).

Within this educational theory, there is a shift in the teacher's primary activity—from teaching to a variety of pedagogical functions in the digital educational space, allowing for the construction of individual educational pathways, designing educational environments, and expanding learning environments and spaces (including VR, AR, AI, etc.) (Bilenko et al., 2020, pp. 31-32). Digital didactics serve as a logical complement to fundamental educational theories, allowing the selection of appropriate digital tools for the educational process and regulating their use.

Digital didactics aims to prepare learners for life in a digital society and effective work in a digital economy, as well as to develop problem-solving skills for professional tasks in the technical vocational education and training system (Bilenko et al., 2020, p. 36; Ibragimov et al., 2021).

Digital didactics inherently includes an online component, thus meeting all the key characteristics of online education mentioned earlier (interactivity, personalised approach, adaptability and flexibility, inclusivity, practical orientation, digital pedagogical technologies, and meta-digital educational complexes like simulators and trainers) (Buzaubakova et al., 2023, pp. 35-36).

<u>Ways to use digital didactics in organising TVET engineering teacher training through online courses:</u>
- applying the hermeneutic approach (as a process of information exchange on studying technical and software components) in designing online courses for TVET teachers will contribute to the humanisation of educational content and increase readiness for didactic communication in a digital environment (Slastenin & Asadullin, 2005; Zakirova, 2011; Berulava & Kanke, 2011; Neupokoeva & Chapaev, 2019);
- developing skills in using digital tools to create and conduct educational courses (Lysenko, 2021);
- training in the use of multimedia educational materials such as electronic textbooks, online testing, interactive whiteboards, and interactive platform solutions (Skachkova, 2022);
- implementing real-time assessments to monitor teachers' comprehension of educational material and identify gaps in understanding and retention (Bilenko et al., 2020, p. 46).

It is important to note that digital didactics is difficult to classify as a pedagogical theory. However, when studying online learning and identifying key factors for the effectiveness of online courses for TVET teachers, it seems appropriate to consider this direction of didactics as an integral part of the research. This approach enables the organisation of learning with the use of digital technologies in a way that expands pedagogical functions and creates individualised educational pathways. To sum up, digital didactics is a tool that prepares learners for life in a digital society and professional activities that meet the modern challenges of technological development.

Summary
A comprehensive analysis of pedagogical theories has indicated that many theories are interrelated and can be applied both separately and in coexistence in the preparation of educational materials.

Moreover, many similarities suggest that theories can be interchangeable and applied in different contexts. This study analysed fundamental and modern theories of learning that can be used in the process of creating educational programmes. Moreover, by combining various approaches, it is possible to create a programme that not only meets market demands but also allows for adaptation to vocational education teachers, developing their personal and professional skills by focusing on the unique characteristics, needs and interests of learners. The tools and strategies that were considered in the study of pedagogical theories can be effectively integrated into online courses for TVET engineering teachers. Consequently, the presented analysis provides the necessary theoretical and fundamental basis for the further design of online courses and the identification of key factors determining the effectiveness of online courses for TVET engineering teachers.

2.4 Formats of Distance and E-Learning in TVET Educator Training: Classification, Didactics, and Practical Application

This study provides a detailed analysis of the types of distance and e-learning that define the industry landscape and contribute to the transformation of pedagogical approaches and methods. It can also serve as a basis for developing educational programmes for training teachers in the secondary vocational education system within the regulatory framework.

2.4.1 E-LEARNING

The development of e-learning began long before the advent of the internet, dating back to the 1840s, thanks to Sir Isaac Pitman and his correspondence courses that utilised shorthand (Moore et al., 1992). From 1920 onwards, distance education continued to evolve with the introduction of educational radio courses (Moore & Kearsley, 2005), telephone and television technologies (A journey to legitimacy, 2008), as well as the first distance online programs (Schlosser & Simonson, 2019). With the advent of personal computers at the end of the 20th century, online education began to develop rapidly, changing pedagogical practice and expanding the use of technological solutions in the educational process (Rahimi & Pourshahbaz, 2019). In subsequent years, electronic and distance education took various forms, including training via compact discs (Rosser, 1996), integrative Communicative Computer-Assisted Language Learning (CALL) (Rahimi & Pourshahbaz, 2019), e-mail correspondence, and virtual tours (Niaz et al., 2021). Since the advent of the World Wide Web (WWW) in 1998 (Blackmore, 1998), education has been enriched with new tools, including study groups, chats, and interactive content (Bezhovski & Poorani, 2016). From the early 21st century, Learning Management Systems (LMS) (Sabharwal et al., 2018; Turnbull et al., 2021) gained popularity, expanding the pedagogical toolkit (Bezhovski & Poorani, 2016) and creating a digital environment for knowledge formation (Turnbull et al., 2021). The emergence of Massive Open Online Courses (MOOCs) (Plaksina, 2022) in the early 21st century ushered in a new era in distance and electronic education, providing new interactive and communicative tools for open access to educational materials and self-learning (Margaryan et al., 2015) while stimulating the development of innovative pedagogical models (Niaz et al., 2021).

Since the widespread proliferation of mobile devices, education has become not only distant and electronic but also mobile. Mobile learning is a constituent part of electronic education and serves as a logical evolutionary continuation of technology-assisted learning (Traxler, 2005; Pachler et al., 2010). Particularly during the COVID-19 pandemic, electronic and distance education experienced significant expansion (Cucinotta & Vanelli, 2020). There was a surge in the use of social networks and microblogs, fostering collaborative learning and personal learning networks (PLNs) (Wheeler, 2012). The swift transition to distance learning was accompanied by digital and technological challenges (such as a lack of proficiency in software usage, limited internet access, and low internet connection speeds) (Shugal et al., 2023), as well as a deficit in technological literacy. (Crawford et al., 2020) The COVID-19 pandemic exacerbated social stratification since

not everyone could afford computer technologies and high-speed internet (Adnan & Anwar, 2020). From the 2020s onwards, the active development of artificial intelligence initiated a new phase in the evolution of distance education, rendering it increasingly technologically sophisticated (Mishra et al., 2023). Throughout the centuries, distance education has been characterised by stability and adaptability to external changes, maintaining its conceptual basis throughout the entire period of technological evolution (Xiao, 2023). (Table 2.3)

Table 2.3 *The Changing Focus of Educational Technology over the Past Years*

Era	Focus	Educational Characteristics
1975 - 1985	Programming; Drill and practice; Computer-assisted learning-CAL.	Behaviourist approaches to learning and instruction; Programming to build tools and solve problems; Local user-computer interaction.
1983 - 1990	Computer-Based Training; Multimedia	Use of older CAL models with interactive multimedia courseware; Passive learner models are dominant; Constructivist influences begin to appear in educational software design and use.
1990 - 1995	Web-based Training	Internet-based content delivery; Active learner models developed; Constructivist perspectives common; Limited end-user interactions.
1995 - 2005	E-learning	Internet-based flexible courseware delivery; increased interactivity; Distributed constructivist and cognitive models common; Remote user-user interactions
2006 - 2020	Blended Learning & MOOCs, Mobile and Social Learning	Rise of Massive Open Online Courses (MOOCs); increased use of blended learning combining online digital media with traditional classroom methods; growth in personalized learning through adaptive technology; social media integration for collaborative learning.
2020 - 2024	HyFlex & AI-Driven Learning, Microlearning	The adoption of the HyFlex (Hybrid-Flexible) model allows students the choice to attend sessions in person, online live, or watch recorded sessions. This approach also increases reliance on AI and machine learning for personalised learning experiences and analytics. Widespread use of educational chatbots like ChatGPT for interactive learning and increased focus on virtual and augmented reality for immersive learning experiences.

Nicholson (2007) (1975-2005), author (2006-2024)

The term "e-learning" is considered within the context of terms such as "open distance learning" (ODL), "open and distance learning," and "distance education," which share theoretical and practical similarities alongside conceptual distinctions. Open learning, originating in the 1950s and 1960s, enables learners to choose their access to courses, convenient times, and locations for learning. In turn, distance learning refers to the methods and means of interaction between students and teachers while also allowing students to choose the form of education that suits them best (Gaskell, 2017). There is no clear terminological distinction, as each concept enriches and complements the other. Hence, in the late 20th century, the term "open and distance learning" gained particular popularity, combining flexible approaches to organising the educational process and interaction among participants regardless of location or other factors (UNESCO, 2002).

Distance education is often used synonymously with online learning, but it encompasses a broader concept. It extends beyond the tools and methods of delivering educational services, encompassing various organisational forms that facilitate education without territorial constraints (Atkinson, 2023). Thus, it can be noted that electronic learning and open distance learning serve as «an umbrella term to describe a range of approaches» (COL, 2023), emphasising the fundamental restructuring of knowledge transmission through technological solutions (Wheeler, 2012).

In Russia, "e-learning", as defined by Article 16 of the Federal Law "On Education in the Russian Federation," refers to the utilisation of information technologies, databases, and the Internet for educational purposes. The definition encompasses computer programs, online courses, and other electronic resources that can be utilised in both traditional classroom settings and remotely. Educational institutions implement distance education as a form of e-learning through information and telecommunication networks such as the Internet (Federal Law No. 273-FZ, 2012).

The literature review reveals a lack of an established typology for e-learning. Consequently, this study will explore the most prevalent formats utilised by educational institutions for e-learning implementation from the perspective of the learning environment (Pavlyutenkova, 2014).

ONLINE COURSES

The term "online course" in the legislation of the Russian Federation refers to "a course of study implemented exclusively through e-learning, distance educational technologies, hosted on official websites of educational organisations and educational platforms, access to which is provided via the Internet, and aimed at ensuring learners achieve specific learning outcomes" (Resolution No. 1678, 2023). Online courses constitute an integral part of electronic education and are regulated by Federal State Educational Standards and other normative documents (Grechushkina, 2018; 2021). Within the Russian professional education system, two commonly accepted formats of Massive Open Online Courses (MOOCs) are distinguished:

- xMOOC represents clearly defined pathways and stages of learning, wherein the educational process is characterised by a teacher-centric model and structured around pre-recorded materials and interaction organised in deferred time (Liyanagunawardena, 2014). This type of MOOC is referred to by international researchers as commercial and is considered more regulated and subject to control (Weller, 2023).
- cMOOC represents massive online courses structured around collaboration as the primary attribute of interaction and the organisation of the pedagogical model, as well as the Participant-driven Content model (Ferreira, 2016). cMOOCs are more open to new pedagogical approaches, community formation, and the integration of various technological solutions (Titova, 2015; Weller, 2023).

As MOOCs continue to develop in Russia, they are becoming prototypes of traditional courses, ceasing to be both mass and open and creating a virtual duplicate of an educational institution (Lapchik, 2017, pp. 217-218).

Online courses can be classified according to the following criteria, based on the analysis of research by K. Bugaychuk (2013), O.P. Mikheeva (2015), and A.N. Golubeva (2017), as well as N.V. Grechushkina (2018; 2021) and A.Kh. Shelepaeva (2022):

1) Based on the principle of construction

This category encompasses courses organised according to traditional face-to-face pedagogical approaches, as well as those utilising modern pedagogical methods. The essence of the approach lies in transferring educational materials from the physical classroom environment to the electronic educational space.

Didactic Characteristics:

- Pedagogical Approach of Face-to-Face Learning: Education is presented in the format of sequential modules containing lecture and textual materials, as well as incorporating student self-study through project-based activities, practical tasks, and assessments. Learners are familiarised in advance with the calendar and thematic plan of the curriculum, rendering this format closely resembling traditional classroom learning.

- Modern Pedagogical Approaches: Education is entirely formed within a virtual space through networked interaction and cannot be transferred to a face-to-face format without loss of content or quality. Such courses encompass connectivist (where the learning process equals network construction), rhizomatic (where audience characteristics and interests determine themes, formats, scope, and sequence), and adaptive (oriented towards flexible material adjustment based on learners' assimilation assessment data) methodologies.

2) By interactions among learners

This type of course represents the principles governing interaction between students and teachers during the learning process.

Didactic Characteristics:

- Courses that do not involve organised interaction and moderation of learner discussions. This educational format allows learners to communicate with each other through open forums, but it is not mandatory for the learning process;

- Courses that involve group interaction, where learning is organised in groups of up to 10 people (the number may vary depending on the goals and formats of the course), formed according to criteria that correspond to the course objectives and tasks (e.g., professional, geographical, and other principles);

- Courses that utilise mobile devices and are designed for mobile learning formats (Sharples & Spikol, 2017). It is better to organise the course with the help of online technologies, and it also must allow students to study together and interact with each other regardless of place and time Diacopoulos & Crompton, 2020; Šramová, 2024);

- Courses that involve the use of interactive teaching methods, allowing students to organise their educational trajectory independently. The focus in organising learning is on social interaction, which provides support and peer-to-peer assessment of learners' achievements.

3) by duration of study

The duration of online courses can be categorised into four categories: long-term (18 weeks and longer), medium-term (4-18 weeks), short-term (12 hours - 4 weeks), and microlearning, which are aimed at developing specific skills (material fragments up to 15 minutes, with a total time not exceeding 12 hours) (Bal, 2023).

Didactic Characteristics: These categories of courses can be utilised in various educational activities, allowing for modifications that enable the course to be more outcome-oriented. Short-term courses can serve as elements of a modular program as well as standalone courses (Maytin et al., 2023). Each category can be combined with another to form a separate series of courses focused on professional development or vocational training. However, post-2020, the most popular format has become microlearning, which resembles TikTok videos (Aziz & Dali, 2023; Abdul Wahid et al., 2023; Yasmin Onn et al., 2024) and allows for rapid knowledge acquisition

anywhere (King, 2021; Šramová, 2024). Microlearning, from a didactic perspective, necessitates ongoing interaction between teacher trainers and learners, the provision of personalised and adapted content, the use of various assignment formats and questions for assessment, and the provision of instant feedback (Busse et al., 2020).

4) by the method of organizing instruction

In terms of instructional organisation, Synchronous, Asynchronous, Semi-synchronous, and Balanced Learning are distinguished.

Didactic Characteristics:

- Synchronous Learning is organised to conduct the educational process and monitor material assimilation in real time. The didactic features of synchronous learning involve particular attention to the motivation and engagement of learners through relevant, engaging, and interactive educational content (Wang et al., 2023). Supplementing training with real-life tasks that allow for application upon completion is necessary (Lee et al., 2021).

- Asynchronous Learning allows for education without rigid deadlines and fixed dates, considering the possibility of grouping learners based on their start date for joint discussions and material progression. All materials are uploaded to the platform in advance and provided to learners as they connect to the course. The use of sequential learning in asynchronous education enhances the ability to memorise and assimilate material (Cepeda et al., 2008). In contrast, the use of metacognition enables learners to determine what works for them and to process various cognitive aspects of the activity (O'Loughlin & Griffith, 2020). Prompt feedback, active interaction, creating a unified educational space, and a flexible approach to material formation facilitate achieving the goals of the educational course (Varkey et al., 2023).

- Semi-synchronous Learning is a regulated learning process with defined program timelines and soft and hard deadlines for the submission of assessment materials and assignments. Within semi-synchronous learning, time norms for studying specific material and submitting assessment tasks are established, after which access to assessment materials is closed. Educational materials are also pre-formed and uploaded to the online educational platform, with subsequent access provided according to the educational course schedule (Grechushkina, 2018).

- Balanced Learning is a combination of synchronous and asynchronous learning that enables "continuous education without disruptions" (Picciano, 2009). This approach involves the exchange and acquisition of knowledge through the mastery of material using digital resources, including basic training and distance learning under a teacher's guidance (Fernandez et al., 2022). Balanced learning serves as an analogue to blended learning, the investigation of which is presented below, as it represents a separate extended interest from the perspective of typology and didactic characteristics.

5) by the purpose of education

There are three types of educational courses based on their learning objectives: educational, enlightening, and research-oriented.

Didactic Characteristics:

- Educational courses are academic courses in subjects covered by vocational and higher professional education programmes, as well as courses for professional development and

retraining. Educational courses are formulated within the regulatory framework that governs the direction of training. Materials are prepared by teacher trainers in compliance with requirements, which include mandatory and variable components. Training can be organised in various formats, including face-to-face learning, e-learning courses, and courses utilising distance educational technologies.

- Enlightenment courses are "open" courses not included in educational programs, allowing learners without basic training to become participants. Such courses may consist of two types. The first one is career guidance courses, which comprise informational materials on specific professions and fields of activity, as well as various diagnostic tests to determine aptitude for a profession. The second one is thematic courses for a broad audience. It allows studying various topics at different levels (from short introductory materials to in-depth professional knowledge in different fields). Moreover, thematic courses allow students to choose a place and time when they can learn the material.

- Research courses (MOOR - Massive online open research) represent a unique method of organising scientific research activities, open to all interested individuals, and may also be part of an educational program. This format is structured as a research project, the outcome of which could be a peer-reviewed publication or another format of research work.

6) by access to online course materials

There are three categories of access to online course materials: open-access courses, partially open courses, and restricted-access courses.

Didactic Characteristics:

- Open-access courses allow students free access to all materials of the curriculum without any restrictions. They can download materials in advance or have access gradually, completing the course. The distinctive feature of these courses is that feedback is delivered in either asynchronous or synchronous format.

- Partially open courses have restrictions on access to certain parts of the material or on obtaining a certificate of completion. These may include courses offering freely accessible materials posted on a platform, where obtaining a certificate or access to an advanced version of educational materials, as well as feedback from teacher trainers and passing assessments, requires payment or submission of documents attesting to relevant educational profiles. Extended versions may offer additional lectures, webinars, individual consultations, or internships.

- Limited-access courses consist of commercial courses offering access on a paid basis, as well as intra-corporate courses (SPOCs) (Alario-Hoyos et al., 2017) designed for internal training (Han & Shi, 2022). Such courses are developed by individual specialists, with materials uploaded to closed platforms. Upon meeting the requirements, learners gain access to materials and may obtain a certificate or diploma upon completing the course, subject to the stated conditions.

7) by models of integration of Online Courses

In Russian research works, the integration of online courses is categorised into overarching models, which include the autonomous model, implying the absence of direct interaction between the teacher and the student; the blended model, involving the incorporation of online courses as a component of face-to-face learning (replacing or partially substituting classroom work); and the

supplementary model, involving the use of online courses without modifications to the curriculum (Veledinskaya & Dorofeeva, 2015; Mozhaeva, 2015; Lapchik, 2017; Semenova & Vilkova, 2017).

In 2021, a more detailed classification of models emerged, as presented in the work of N.V. Grechushkina, which includes the following divisions:

1) *Models of Utilising Online Courses in a Professional Educational Organization*

This model can be utilised within both regulated educational activities (institutional) and in the format of unregulated initiatives by teacher trainers and learners (non-institutional).

Didactic Characteristics:

- Institutional models may utilise both their online courses and those on third-party platforms. They can be employed either based on an exchange agreement or a transfer-receipt agreement. The peculiarity of this type lies in the mandatory completion by students of the courses offered by the educational institution within the framework of the studied discipline. There is a restriction on the choice of courses, which is regulated by contractual obligations between the educational organisation and online platforms.

- Non-institutional courses offer greater freedom in choosing online educational courses, but the teacher must also approve them as being consistent with the goals and objectives of the discipline.

2) *Models of Online Course Utilization in Curriculum Development*

There are four models of online course utilisation within the framework of curriculum development: the substitution model, the augmentation model, the partial substitution model, and the resource model. All models can be employed in blended learning contexts.

Didactic Characteristics:

- The resource model involves utilising an online course as a library of materials within the scope of the studied discipline without assessing students' knowledge on the platform or considering the results of completing the online course. Teachers conduct knowledge assessments through face-to-face interactions. This model serves as a variation of foreign models, such as MOOCs as a Service, MOOCs as an Added Value (Pérez-Sanagustín et al., 2017), Face-to-Face, and Canned Teaching (Delgado Kloos et al., 2015).

- The expansion model involves increasing the volume of educational content beyond the hours prescribed by the discipline's curriculum and can be implemented both within the framework of an educational discipline and after its completion. The model can also be used in blended learning by supplementing the discipline with additional educational materials for outstanding or motivated students and may serve as a variant of the Self-Blend Model (Staker et al., 2011).

- The partial substitution model entails replacing or substituting part of an educational discipline with an online course and can be applied to both academic disciplines and types of activities. This model involves replacing a small portion of the discipline with online courses, such as individual modules of online courses supplemented with educational materials or using several online courses within a single discipline (Bruff et al., 2013; Chingos et al., 2015).

3) *Models of online course utilization from the perspective of learner-educator interaction utilizing digital tools*

The utilisation of online courses in the educational process impacts the structure of interaction between teacher trainers and learners. The utilisation of online courses influences the behaviour, activity, and relationships between teachers and students. Furthermore, the use of online courses allows for the expansion of participant involvement, incorporating tutors, lecturers, and assistants into the educational process. Interaction among participants in the educational process when using online courses has its own characteristics determined by both the typological features of the course itself and the models of its integration into the educational process. Two models are distinguished: based on the type of pedagogical interaction and based on the type of pedagogical support.

Didactic Characteristics:

- The model, based on the pedagogical interaction between the subjects of the educational process, involves both individual interaction between the teacher and learners, as well as group interaction, where one teacher interacts with a group of learners. This model is limited by the capabilities of the teacher and their assistants, as it entails individual work that cannot be extended to all interested parties. Online courses and personal support in this model may be an option for a specific group of individuals selected based on specific requirements or those who have paid for this opportunity.

- The model based on pedagogical support provided to learners consists of three subtypes of models: constant support (combining face-to-face and online courses, with the course being studied from the perspective of both the teacher and the students, where the teacher acts as a second educator, for example, in Hybrid Classroom models (Kang & Tseng, 2016), Flex Model (Staker et al., 2011), periodic support (comprising consultations, monitoring of material assimilation, and corrective behaviour measures, for example, in Soft Classroom models (Kang & Tseng, 2016), Digital Teaching with Face-to-Face Tutoring (Staker et al., 2011), and autonomous learning without the involvement of the teacher but with possible tutor support (Mozhaeva, 2015).

In summary, there is currently no unified pedagogical approach to the typologization of online course models and their application in educational activities. However, the typologization presented above enables a multifaceted assessment of the possibilities for applying electronic learning in professional education. It is essential to note that many models can be utilised in blended learning; therefore, a separate subsection is allocated for blended learning, which will describe the possibilities and formats provided not only by the use of online courses but also by modern didactic and pedagogical approaches.

BLENDED LEARNING & HYBRID LEARNING

The term blended learning, also referred to as hybrid learning, gained widespread popularity after the 2000s (La Fleur & Dlamini, 2022). However, scholars first mentioned this term back in the late 1990s (Driscoll, 2002; Bliuc & Ellis, 2007). The evolutionary development of the term has progressed from describing blended learning as the use of web technologies, collaborative learning, and streaming video employing various pedagogical approaches such as cognitivism, behaviorism, and constructivism, as well as combining virtual and face-to-face learning under the guidance of an instructor (Boutarti et al., 2022), to a fully-fledged pedagogical approach (Garrison & Vaughan, 2008) that integrates traditional face-to-face instruction with virtual education (Driscoll, 2002; Bernard et al., 2014). Although many researchers consider hybrid and blended learning to be identical concepts, there are significant differences in their implementation. Hybrid learning involves a clear division between online learning and face-to-face classes, whereas blended learning involves the possible combination of these forms in the educational process (Oliver & Trigwell, 2005; Picciano, 2011; McGee & Reis, 2012; Graham, 2013).

However, defining the term "blended learning" has become a challenging task due to its widespread use and variations in its application by different institutions (Twigg, 2003; Picciano, 2009; Picciano, 2017; Hrastinski, 2019; Graham, 2022). In 2020, Graham C. & Halverson L. proposed a broader definition of hybrid learning (Graham & Halverson; 2022), focused on the integration of modalities (defining the conditions of learning, combining online and face-to-face learning) (Allen & Seaman, 2007; Watson et al., 2014), technologies (integrating various technological solutions optimal for specific conditions) (Bersin & Associates, 2004), and methods of their use (pedagogical approaches and theories) (Picciano, 2009, p. 10). Analysing blended learning models, it is necessary to combine physical and pedagogical components. Several researchers have reported that pedagogical methods are more important than the way of presenting materials and technologies that teachers use (Clark, 1983, 1986, 1994a, 1994b; Cunningham, 1986; Kozma, 1991, 1994; Cunningham, 1986; Dziuban et al., 2018; Dziuban et al., 2023).

The COVID-19 pandemic in 2020 has expanded the use of blended learning across all levels of education and underscored the need for the development of new pedagogical approaches in blended learning tailored to diverse target audiences (Ferdig et al., 2020; Watermeyer et al., 2021). Discussing the consequences of the rapid development of blended learning for teachers (Mourtzis et al., 2021; Elkhatat & Al-Muhtaseb, 2021; Li et al., 2021; Al-Ataby, 2021; Lorenzo-Lledó et al., 2021; Gamage et al., 2022), it is notable that the majority of research focuses on studying the experiences of learners, with minimal attention paid to teachers and their preparation for working in the new pedagogical environment (Linder, 2017; Wong et al., 2022; Mei et al., 2023). Research highlights (Mu et al., 2021; Rodriguez-Paz et al., 2021) that when implementing the blended learning model (Pucciarelli & Kaplan, 2022), teachers encounter challenges such as engaging students in the educational process, regulating assessment systems, balancing an increased workload with the creation of quality blended course content, and preventing a gap between traditional instruction and digital platforms (Li et al., 2023).

Starting in 2022, the significant influence of the blended learning transformation will affect the development of artificial intelligence and machine learning models (MLMs) (Labadze et al., 2023; Kasneci et al., 2023). These models provided tools for deeper engagement and offered opportunities for interactive learning within existing blended learning models. ChatGPT enriches the model with instantaneous feedback and a broad spectrum of information (Stojanov, 2023; Wu et al., 2024) but also serves as a source of cognitive challenges (Chan & Hu, 2023; Ding et al., 2023; Lee et al., 2024) due to its ease of use and potential dependence on artificial intelligence in educational organisations (Cooper, 2023; Montenegro-Rueda et al., 2023). However, the most effective way to solve these problems is to create a comfortable and supportive environment for teachers. It also helps to utilise new technological tools freely to make educational programs more effective. Compared to traditional classes, learning in an environment that utilises blended learning technologies makes education more engaging and motivating, encouraging active student participation, independent contributions, and improved communication skills, particularly the ability to listen actively and provide constructive feedback (Motschnig Cornelius-White, 2012).

Although blended learning expands educational opportunities, it also creates challenges, such as a lack of adequate technological skills among students and teachers (Zemtsov et al., 2022), access to information resources for people from different social strata and remote areas (Goncharova et al., 2019), and the need for adequate training and professional development for teachers (Boychenko & Smirnova, 2019; Lakhal & Meyer, 2020).

In Russia, there are legislative restrictions within the technical vocational education and training system that regulate the list of professions or specialities for blue-collar workers where the use of solely electronic and distance educational technologies is not permitted (Order No. 932, 2023). This limitation highlights the need to incorporate a mix of educational activities in technical and

vocational education to adopt a vocational education and training system, as well as to adopt flexible educational formats. Isakovich A.P. (Isakovich, 2023) has defined the concept of "blended learning" in Russia, which entails a combination of traditional educational formats (face-to-face learning) (Blended Learning Models, 2024), self-directed learning (without direct contact with a teacher) (Ushinsky, 1950; Kharlamov, 2003; Azimov & Shchukin, 2009), and e-learning (utilising the full spectrum of technological devices) (Lesin et al., 2020). The regulatory framework of the Russian Federation describes blended learning as a «pedagogical technology that involves combining networked (online) learning with face-to-face or autonomous learning» (Federal Agency for Technical Regulation and Metrology, 2006). This definition delineates two subtypes of blended learning: one involving the traditional combination of online and face-to-face learning, and the other online learning combined with autonomous learning, i.e., using computer technologies without connecting to an information and telecommunication network. Within the scope of this study, the focus will shift towards examining the combination of online learning with face-to-face learning to standardise conceptual terminology and align with international terminology frameworks.

Initially, in Russia, there was a single model of blended learning in the technical vocational education and training system. However, in 2021, a study emerged challenging the monogamy of the model and identifying five key directions of the learning technology level), where various models of blended learning exist (Blended curriculum, Blended individual learning curriculum, Self-blend, Face-to-face session, Blended course, Face-to-face driver, Flipped classroom, Blended lesson, Blended project / blended study) (Blinov & Sergeev, 2021). This typological division will be utilised in the study, supplemented by modern models of blended learning, which are relevant for preparing teachers for the technical and vocational education and training system. These models demonstrate advanced didactic approaches to organising learning aimed at creating meaningful educational experiences (McDonald & Yanchar, 2020).

- *CURRICULUM LEVEL*

At the curriculum level, the blended learning model encompasses elements of the educational program presented in an online format. These elements may include educational modules, courses, disciplines, practical sessions, and the like. Examine blended learning models used within the Russian technical vocational education and training system, as well as in preparing pedagogical personnel for this system.

- *Blended Curriculum*

The model involves the online delivery of components of an educational program, taking into account the regulatory framework and the individual characteristics of specific educational disciplines. For instance, an online format can accommodate subjects that are not core to the profession, as well as some professional disciplines, additional lessons, and electives. However, specific subjects, such as industrial practice (internships), disciplines requiring specialised equipment or software, and complex subjects necessitating direct personal interaction between the educator and the learner, should remain in a face-to-face format (Blinov & Sergeev, 2021, p. 4).

The implementation of this model relies on the legislative framework, material and technical resources, as well as the level of preparation of pedagogical staff. Without full provision of these conditions, teachers may struggle to implement the model. Moreover, they typically choose this model when its use aligns with their intended educational objectives.

The utilisation of the "Blended Curriculum" (Blinov & Sergeev, 2021, p. 5):

1) From an organisational-pedagogical perspective, it implies:

- Reduction of time spent in classrooms and freeing up classroom space;
- Decrease in face-to-face interaction under external constraints (such as pandemics, wars, etc.);
- Decrease in pedagogical workload provided network interaction and educational resources are utilised, along with adaptive learning management systems (otherwise, the workload may increase due to expanded preparation volume);
- Effective utilisation of time for studying educational material.

2) From a didactic standpoint, it involves:

- Organised pedagogical support and high-quality educational content, facilitating the development of independent and responsible attitudes towards the educational process among learners;
- Enhancement of learners' digital literacy levels;
- Individualisation of the learning process, enabling learners to choose the pace of material assimilation and the level of complexity (Blinov & Sergeev, 2021, p. 6).

The implementation of the model into the educational process should occur gradually, starting with one to two disciplines presented in an online format. Vocational education and training teachers often mention that many discuss such an approach to educational activities, but no educational institution has fully implemented it. To facilitate this transition, it is necessary to improve rules and laws to make it easier to convert a portion of the educational program to online delivery. Moreover, several conditions are necessary for implementing the model, such as the availability of a digital educational space for teacher trainers and students within the educational organisation equipped with essential technical resources; the development of methodological guidelines for students for self-directed learning of materials in an online format, study schedules, variability of difficulty levels; the availability of prompt or automated feedback, as well as a balance of educational workload on students. The requirements presented apply to many blended learning models and serve as the foundation for a successful educational process (Blinov & Sergeev, 2021, p. 7).

Despite the wide range of positive characteristics of the model, several drawbacks need to be noted:
- Teachers highlight the tendency of students in vocational education to ignore or diminish the importance of disciplines in the online format;
- the problem of students organising their time and missing deadlines for submitting tests and mastering the material required for part of the classroom-based learning;
- teachers feel overworked due to the poorly organised balance between classroom-based and online formats, which contributes to a decline in the level of education (Blinov & Sergeev, 2021, p. 8).

- *Blended Individual Curriculum*

The blended individual curriculum addresses the particular characteristics of each student — including those with diverse inclusivity needs, employed learners, and gifted or highly motivated students. A distinctive feature of this model is the adaptation of educational material to the pace and level of the students. This model serves as both a form of electronic education and a type of distance learning.

A key challenge in implementing this format is the necessity of conducting teaching for a single subject in two different formats (face-to-face and online), which gives rise to organisational and

methodological obstacles, especially when a single teacher is responsible for the subject. One solution to this situation is to assign a specialisation to teachers based on the course delivery format, where two teachers teach one discipline: one online, the other face-to-face. Another option could be the creation of a networked learning model, where one teacher delivers a course in an online format for educational institutions within the network. The use of MOOCs and adaptive learning systems can also alleviate the workload on teachers and make learning more balanced.

This model involves the development of both online courses and learning management systems (LMS) that will reduce organisational and pedagogical risks (untimely assignment checking, teacher overload) and provide a didactic framework (fostering responsibility and independence in learners, digital literacy among students, and individual learning pace). Implementing this model is fraught with regulatory complexities, challenges in implementing specific parts of the educational program in an online format, a lack of sufficient experience and methodological materials for seamless integration into the educational process, and a reduction in student engagement due to the absence of group work formats (such as discussions, projects, business simulations, etc.) (Blinov & Sergeev, 2021, pp. 9-12).

Given that practical sessions, industrial internships, and equipment handling impose limitations on the implementation of the blended individualised curriculum model, the optimal solution would be to strike a balance between face-to-face instruction and its obligatory subject pool, online learning and potential subjects for proficiency in this format, and the variable component, where students can choose their developmental trajectory.

- Self-Blend

The Self-blend model represents the utmost individualisation of the educational process. Each student can choose the format in which they want to study the educational subject, whether online or face-to-face. However, in Russia, this model faced resistance from the teaching staff. In the majority of cases, they emphasised that students often choose online courses over offline courses unconsciously, and they may miss the unique experience of attending offline courses. Moreover, Russian educational institutions in technical vocational education and training, as well as in higher education, predominantly use traditional teaching approaches and organise stream-based courses supported by digital tools. However, a model of individual educational trajectory, whereby students could choose learning formats, is absent.

In the Russian system of technical vocational education and training, there is a lack of infrastructure for implementing this blended learning model and a flexible model for forming study groups. Furthermore, managing individual educational trajectories is a skill that is developed within the general education system, and its development requires a comprehensive transformation of the existing, strictly regulated, class-based system.

With the development of digital technological solutions, more opportunities arise for automating the process of creating individualised educational programs and tracks, compiling flexible schedules, and combining online and face-to-face formats within a single educational course. However, a challenge lies in the rigidity of the normative-legal framework compared to the rapidly growing volume of innovative technological solutions. The Self-blend model holds the potential for preparing technical vocational education and training system teachers, as it allows for the combination of formats and the creation of individual tracks for specialists already possessing a basic profession and wishing to transition into the training system for engineering blue-collar workers (Blinov & Sergeev, 2021, pp. 12-13).

- COURSE LEVEL

At the course level, the blended learning model involves presenting sections or specific stages of the academic discipline in an online format.

- *Face-To-Face Session*

At the core of the blended learning model, termed "face-to-face session", lies a straightforward organisational and didactic scheme, enabling the entirety of the educational process to be conducted online while still allowing for periodic in-person meetings. This model is prevalent in distance and blended learning formats within technical vocational education and training organisations. Educational institutions and training providers often use it for professional development courses or retraining programs.

The learning process is structured as follows: learners complete all activities related to mastering educational materials, reinforcing skills, and working on projects in an online format. Face-to-face meetings are integrated into the educational process to reinforce theoretical knowledge or conduct interim and final assessments. It is important to note that online counselling for students and, in rare cases, final assessments can also be conducted. The programme allocates more time to the full-time stage to support the development of theoretical and practical skills.

The balance between face-to-face and online learning varies depending on the educational programme. It may alternate between one week online and one week face-to-face, three months online and one week face-to-face, or other variations suitable for the specific programme. This mode of instruction enables the use of simple digital solutions to achieve the stated outcomes, including messaging apps, emails, file-sharing platforms, social networks, and others. A more detailed description of the use of social networks in the educational process is provided in the subsection on distance educational technologies.

From a didactic perspective, this model enables the adaptation of difficulty levels to individual learner characteristics, employing digital technologies of varying complexity levels (from basic messaging apps to innovative educational platform solutions). These characteristics are critically important in organising training programs for professional development and teachers' retraining. However, there is also a risk of "internet cheating," which necessitates careful and creative development of educational tasks that prevent blind copying from the internet.

The "Face-to-Face Session" model can function independently or be combined with other blended learning approaches. It can also help other blended learning models choose the most effective strategy for working with different groups of students (Blinov & Sergeev, 2021, pp. 13-15).

- *Blended Course*

The blended course model involves moving part of an educational course online for all learners. It is important to note that the didactic stages of educational material acquisition (study, reinforcement, application, assessment) are entirely conducted online. This characteristic constitutes a fundamental distinction from the "lecture-based class" and "flipped classroom" models, where the emphasis is on transferring not thematic materials or course sections online but rather individual didactic stages of their acquisition.

This model enables students to learn material independently online, without direct teacher involvement. The proportion of educational material presented in an online format for each

organisation will be determined by local regulatory enactments. When designing an educational program based on this model, particular attention should be paid to specific characteristics of the educational discipline.

In an online format, the following can be implemented: education that entails a significant amount of independent student work bears similarity to previously studied material, does not impact future professional activities or final assessment, enhances students' digital literacy, and possesses an extensive theoretical basis that does not require elaboration within practical, laboratory, and group formats. Another critical element in composing a blended learning subject is the necessity to implement educational material that requires the use of specialised equipment or licensed software, as well as group formats and mastering complex material in a face-to-face format.

In the case of a low-motivated student group, a lack of self-organisational skills, and a low baseline knowledge level, the volume of material in online format is minimised, and emphasis is placed on face-to-face learning.

One of the key didactic advantages of this model is the ability to devote special attention to studying the most complex and significant course sections, which contributes to improving the quality of material assimilation. The use of digital technologies also frees up classroom space and allows for reducing the workload on teachers.

The "Blended Course" model enables balancing online and face-to-face formats, thereby developing self-learning skills at one's own pace in a digital environment. When implementing the model, online learning should be introduced gradually, accompanied by subsequent methodological support for online learning, and a clear differentiation between online and face-to-face formats should be maintained to achieve the educational course's goals systematically and consistently (Blinov & Sergeev, 2021, pp. 15-17).

- UNIT/TOPIC LEVEL

At the level of a unit or topic within an academic discipline, a varied combination of face-to-face and online formats is used to implement the typical didactic stages of learning, reinforcement, and assessment of educational materials.

- *Face-To-Face Driver*

The Face-to-Face Driver model represents a combination of traditional and online education, in which the initial learning of a topic or section occurs in a face-to-face format, with the instructor explaining the material and providing examples in the classroom. Meanwhile, the practical component and reinforcement of the material take place in a distance format (Bilenko et al., 2020, pp. 52-53). A distinctive feature of the model compared to the flipped classroom is the structure of the educational process technology, where the instructor not only explains the material before practical tasks but also assists in the preparation and completion of practical assignments. Thus, the method is suitable for low-motivated student groups who are capable of working independently.

The present model of blended learning involves the use of topics and subjects that require the acquisition of standard skills and competencies, which can be accessed for independent study without the aid of an instructor (for example, in the IT field, where students, after an explanation of the fundamentals, can independently practice problem-solving).

From a didactic perspective, implementing this model requires modern electronic educational resources that offer various formats and levels of task complexity, enabling students to consolidate their skills at their own pace and level.

Implementation of this model requires communication between the teacher and the student. It can increase motivation and ensure timely assessment of the material being studied. Modern automated technological solutions can be used to assess some materials, while for tasks requiring personal interaction, it is recommended to conduct control and measurement activities in person (Blinov & Sergeev, 2021, pp. 17-18).

- *Flipped Classroom Model*

The "Flipped Classroom" model represents a didactic antithesis to the Face-to-Face Driver. Implementation of the model begins with students conducting independent studies of materials in an online format and continues with the application of acquired knowledge in face-to-face sessions (Campillo-Ferrer & Miralles-Martínez, 2021). To date, this model is considered the most well-known and methodically elaborated model of blended learning, which is increasingly being utilised in the field of technical vocational education and training in Russia (Ericyan, 2020). The primary emphasis of this model is on technology (Tomas et al., 2019) and its application in educational activities, extending beyond traditional instructional formats (Yıldız et al., 2022).

The advantage of this model from a didactic perspective lies in its emphasis on consolidating educational material and foundational professional qualifications. The flipped classroom model, given the contemporary level of technological development, allows for the satisfaction of key didactic principles in educational cycle construction: the material is presented accessibly, variably, visually, and is substantively comprehensive (Baig & Yadegaridehkordi, 2023).

The flipped classroom model enables teachers to reduce their workload and focus on developing the necessary competencies for acquiring professional knowledge (Jiang et al., 2022; Karjanto & Acelajado, 2022). From a didactic perspective, the optimal achievement of learning objectives involves repeated engagement with theoretical material (sequence: self-study – explanation in the classroom – reinforcement during practical sessions), thereby influencing both the level of material mastery and the motivational component of the educational process (Mardiha et al., 2023).

However, this model is more suitable for students who have self-organisation skills and a reflective attitude towards learning (understanding difficulties, recording questions, etc.). In turn, for students who experience difficulties with learning, the process can lead to a loss of motivation and a decline in their mastery of the material (Blinov & Sergeev, 2021, pp. 18-19).

- *Hybrid Flexible Learning (HyFlex)*

The HyFlex model combines hybrid and flexible forms of learning, allowing students to "attend the same combination of face-to-face and online classes" (Lohmann et al., 2021). HyFlex was first mentioned in a paper by B. Beatty (2019), who emphasised the importance of rethinking the didactic approach in hybrid learning. However, C.J. Bonk and C.R. Graham (Cho, 2011) are the authors of this term. Research shows that the HyFlex model is often associated with thematic blocks in scientific works: blended learning, hybrid learning, and e-learning, which indicates the model's popularity and versatility in application (Eduljee et al., 2022).

Within the HyFlex framework, learners become active participants in the educational process, autonomously selecting the learning format (synchronous online, synchronous face-to-face, or

asynchronous). There is currently a debate regarding the precise definition of HyFlex, balancing between the equation of blended and hybrid learning and the distinction between these concepts, leaning towards the idea that the task of hybrid learning is to create a 'seamless' and interactive digital environment for learners and to involve both teachers and students in it actively (Barannikov et al., 2023). However, S. Atkinson (2023) notes that HyFlex is "an approach to curriculum design that allows for the choice of place and time for individualised learning."

The HyFlex model is based on consultative interactions between teachers and learners through digital educational platforms, as well as self-directed engagement with materials via electronic educational resources.

From a didactic standpoint, the organisation of the educational process involves a combination of educational technologies within the framework of the studied discipline, regardless of its implementation format (online or in-person). Educational material is presented on digital educational platforms in a visual, understandable, and accessible format. Access to the material is not restricted by location or time frames (except for the time allocated for studying the material within the discipline, as regulated by the educational organisation's rules) (Voronina, 2023, p. 7).

HyFlex is implemented within a unified conceptual approach, featuring consistent educational material content and methodological forms of explanation in a blended mode (in-person or online). A distinctive feature of this model is the possibility of reusing educational materials in various formats (Pusenkova, 2023), as well as the equality of final knowledge and skills, regardless of the chosen educational format (Barannikov et al., 2023). HyFlex may also involve the development of educational materials tailored to different contexts, given the heterogeneity of educational contexts (Bennett et al., 2020; Goodyear, 2020).

An auxiliary tool in implementing the HyFlex model is digital educational platforms (Trentin, 2015; Wong et al., 2023), which encompass knowledge bases, assessment materials, interactive communication tools, planning and notification tools, analytical instruments for monitoring student performance, as well as personal accounts for participants in the educational process (teachers and students) (Voronina, 2023, p. 7).

The implementation of this model necessitates consideration of the level of technological and digital literacy among both teachers and students. It requires adaptive adjustments to pedagogical methodologies and the regulation of social interactions within the framework of HyFlex implementation (Wong et al., 2023). Recent evidence suggests that hybrid formats help to achieve better results in developing digital literacy and mastering writing and time management skills (Crawford et al., 2014). For novice teachers, implementing the HyFlex model successfully in their educational process may be more challenging. However, implementing this model requires independent work and the need to learn materials on one's own. In this regard, it is necessary to re-evaluate traditional teacher training programmes, which will include modern technologies and teaching methods (Miller & Baham, 2018; Raes et al., 2020; Chehimi & Alameddine, 2022; Tanguay & Many, 2022; Amirova et al., 2023).

- LESSON LEVEL

At the lesson level within the blended learning model, the integration and balance of face-to-face and online instructional formats are considered within the framework of a single session.

- *Blended lesson*

The "blended lesson" model represents a didactic combination within a single instructional session involving a sequence of online and face-to-face learning. An example of such learning is the "Station Rotation" model (Larsari et al., 2023), which consists of three zones: F2F (Face to Face), where students work directly with the teacher; CM (Computer Mediated), where students study the material using information technologies; and SS (Self - Study), where students work individually or in groups to complete practical tasks.

The convenience of this model lies in its ability to eliminate the need to coordinate its use in the educational process with administrative units. Moreover, the model allows for variety in the instructional session and repeated reinforcement of material through its use in different tasks within a single instructional session. During these lessons, students are permitted to personalise their learning process by choosing different tasks and levels of support from the teacher, thereby improving the quality of learning thanks to the dynamism, density and diversity of the material presented.

The "blended lesson" model is better suited for general subjects in vocational education and training organisations, as well as for interdisciplinary utilisation that incorporates digital technologies. However, implementing this model is labour-intensive for teachers, as it requires developing a lesson plan and selecting the necessary materials and electronic resources. Furthermore, the use of the model should alternate with other models to avoid diminishing the positive impact and student engagement in the educational process. Last but not least, the learning space should provide the opportunity to vary the lesson as needed (for example, using two classrooms or reformatting an existing classroom to meet educational needs) (Blinov & Sergeev, 2021, pp. 20-21).

- LEARNING TECHNOLOGY LEVEL

At the learning technology level in the blended learning model, the stages of the educational process are examined, which are not rigidly tied to the traditional classroom-based system and can be implemented in both face-to-face and online formats.

- *Blended Project / Blended Study*

The "blended project" model involves rotating various project or research stages (such as individual or group projects, coursework, etc.) performed by learners within the educational process. From a didactic perspective, the most effective approach involves integrating online and face-to-face formats at different stages of the educational process: online formats are suitable for information search, organisation, and analysis, monitoring intermediate results, and communication between learners and teacher trainers; face-to-face formats are conducive to project initiation, conducting field research, assembling project groups, and presenting project outcomes. The combination of formats is chosen based on specific situations and educational objectives.

The versatility of the blended project model allows for the utilisation of project-based research activities, as well as practical sessions for professional qualification and the implementation of additional professional education utilising project-based learning.

From a didactic standpoint, this model facilitates the development of project, research, and digital competencies, enhances engagement and motivation in the educational process, increases student autonomy, and broadens their experience in project and research work. Furthermore, this model enables the individualisation and personalisation of the educational process (Blinov & Sergeev, 2021, pp. 21-22).

The successful implementation of the model relies on students' autonomy levels, a balanced group composition for collaborative work, precise planning of implementation stages, quality feedback, and adherence to fundamental pedagogical principles in organising project and research work (Sergeev, 2010).

To summarise, no research has been conducted to date on the combination of different blended learning models within a single discipline. To enhance the effectiveness of the educational process, researchers recommend employing a single model throughout the learning process to prevent confusion when using various didactic approaches. However, a testing scheme of various models throughout the academic period may also be employed, provided there is comprehensive preparation from both the instructor and students for the implementation of blended learning (Blinov & Sergeev, 2021, p. 19).

2.4.2 Distance Education Technologies

Pedagogical discourse often conflates distance educational technologies with identical concepts, although this usage is inaccurate (Lebedeva, 2011, p. 19). Researchers and authors have not yet established unified terminology in the literature to describe distance educational technologies; only legislative documents currently define the concept. Learning utilising distance educational technologies involves educational activities implemented through information and telecommunication networks, such as the Internet, i.e., virtually, without the need for students and teachers to be physically present in the exact location (Federal Law No. 273, 2012/2023) or involving partially mediated interaction between the learner and the educator (Resolution No. 1678, 2023).

Alongside the normatively accepted definition, terms such as distance learning, distance education, and internet-based learning are used to describe the characteristics of remote learning that utilise modern information and communication technologies (Lebedeva et al., 2010, p. 9). Teachers can use distance educational technologies in both traditional teaching processes and remote formats. The fundamental idea behind the use of distance educational technologies is to create an accessible educational environment for learners, regardless of their place of residence or location (Barbashina & Gulyaevskaya, 2019).

From the standpoint of understanding the term "technology," the most insightful interpretation was put forth by Edward de Bono, who characterised it as "the process of producing something useful based on the application of knowledge," highlighting technology's key function as "the application of theory into practice" (De Bono, 1993).

Distance educational technologies constitute a complex and integrated structure comprising distance educational resources (products, resources, services, platforms) and didactic methodologies and approaches for addressing pedagogical objectives. While these key components are closely interrelated, they do not form a unified whole, as the utilisation of distance educational technologies always involves a distinction between the actions of the educator and the technology employed (Blinov & Sergeev, 2023). In this context, the term "technology" is interpreted, following the work of De Bono (1993), as the implementation of theory into practice—that is, the realisation of pedagogical intentions through information systems. Distance learning technologies (DLT) may be employed both within fully online instructional environments and as integral components of face-to-face or blended learning formats.

Historically, distance education technologies have been divided into three types: case technology, internet technology, and network technology (Concept of informatisation of the education sector

of the Russian Federation, 1998; Lebedeva et al., 2010, p. 26-32; Andreev & Soldatkin, 2013; Konovalov & Ilyina, 2023; Gavrilov, 2024). However, some research also identifies a fourth type - technology based on an information learning environment (Zaitseva, 2003, p. 147; Lebedeva, 2011, p. 17) (Appendix C):

Case Technology

Case technology is a set of educational and methodological complexes (lectures, methodological guidelines, reinforcement tasks) linked into a single whole. It is implemented through comprehensive training programs that detail the educational process and include instructional and practice-oriented materials, as well as audio and video content accompanying each lecture, laboratory-based practical sessions, electronic textbooks, and specialised software.

A key didactic feature of this approach is the learners' independent engagement with printed and multimedia instructional materials, which are delivered in the form of "cases." In face-to-face settings, the implementation of case-based learning involves orientation lectures, seminars, training sessions, and simulation-based activities, as well as consultation and assessment formats. Special emphasis is placed on group work facilitated by a tutor, who provides ongoing pedagogical support and guides the learner's development process.

The educational resources are characterised by a strong focus on learners' practical engagement, action-oriented and developmental task design, high levels of interactivity, and continuous content updating. These features collectively ensure a thorough understanding of educational content within both vocational and pedagogical training contexts (Ilyina et al., 2023). The implementation of this form of distance learning is supported by computer networks, modern communication tools (e.g., videoconferencing, chat discussions), electronic libraries, databases, and digital administrative systems (Lebedeva et al, 2010, pp. 26-29).

Internet-Based Technology

Internet-based technology refers to the use of software tools to facilitate instructional delivery and knowledge assessment via the Internet. It is implemented through electronic instructional packages hosted within the unified information system of an educational institution, as well as through training modules designed for independent practical work, digital textbooks, online seminars, chat forums, email, and other technological solutions. Educational materials are made available for self-directed study in a virtual learning environment.

A defining feature of this approach is the opportunity for real-time interaction with instructors, along with the administration of formative and summative assessments through Internet-based platforms. This form of distance education is enabled by hybrid technologies that integrate electronic learning resources and instructional software, all of which are accessible online (Gavrilov, 2024).

Network-Based Technology

Network-based technology refers to an instructional approach that utilises satellite communication and Internet connectivity to provide access to educational materials—such as e-books, video lectures, and other learning resources—regardless of geographic location, provided an Internet connection is available. This technology delivers a standardised set of assignments across all subjects, developed in alignment with officially approved national educational standards.

Knowledge assessment is conducted through an electronic testing system, which includes real-time lecture-based quizzes, individualised computer-based training, modular control testing, written examinations, and final examination tests based on course completion. The instructional design follows a modular structure, dividing each discipline into self-contained units, each accompanied by specific forms of assessment.

Within this framework, learners study course materials independently in an asynchronous format, supplemented by classroom-based elements, including introductory and modular lectures, virtual tutoring sessions, individual and group training activities, modular consultations, and online assessments conducted via the Internet (Lebedeva et al, 2010, pp. 29-31).

Technology Based on An Information-Rich Learning Environment

Technology based on an information-rich learning environment relies on a hardware-software model of the subject domain, enriched by specific instructional strategies and teaching methods. It is implemented through open-source software that enables modifications and extensions to the existing educational infrastructure, including distributed databases, virtual libraries, and electronic learning materials.

From a didactic perspective, this approach comprises a set of instructional resources that teachers can use to construct tailored learning content suitable for both in-person and online delivery formats. A distinguishing feature is the individualised learning process, which is grounded in models of learners' cognitive activity. Knowledge acquisition occurs through the resolution of content-driven tasks developed within the framework of constructivist cognitive science.

These information-based learning technologies represent highly structured, intelligent, and adaptive instructional environments. The learning trajectory, student participation formats, and progression pathways are programmatically defined and executed sequentially, all aimed at achieving articulated educational objectives (Barbashina & Gulyaevskaya, 2019; Gavrilov, 2024).

Implementation Models of Educational Processes Using Distance Education Technologies

Depending on educational goals and implementation conditions, six models for implementing the educational process using distance education technologies are identified. These models have been in existence for over 35 years (Polat et al., 2004, pp. 80-82; Boronenko et al., 2017; Gil & Morozov, 2019; Krasnobaeva-Chernaya & Borodenko, 2024; Pavlova, 2024; Nikoforova, 2024). In this study, the development of modern technologies and their application in the educational process will be presented, along with an updated description and consideration of current trends.

- *Self-Study Education*

This model aims to provide learners who, for various reasons, cannot attend classes with the opportunity to acquire knowledge in its entirety. A didactic feature of the presented model is the self-directed study of the material and preparation for exams, with periodic consultation with a teacher in either face-to-face or online formats (Knowles et al., 2014). The use of this model is recommended for theoretical subjects that do not require specialised equipment and can be implemented at any level of education, from elementary school to higher education. For teachers, this model is applied in cases where there is a production-related necessity for presence at the workplace and the inability to attend classes in a face-to-face format (Blaschke, 2012).

- *Education in The Context of An Educational Institution*

The presented model is implemented through the utilisation of information technologies, including their latest forms. A didactic feature of this model is the learners' study of the material within the framework of distance education, presented in the form of a system utilising case technology as its foundation. The use of the model is recommended for teachers who possess contemporary knowledge of technology usage and their subject area (Bilenko et al., 2020). Teachers could apply this model within the scope of additional professional education or professional retraining, and it is intended for teachers who, for specific reasons, cannot attend face-to-face classes (Podobed & Maron, 2003).

- *Network or Cluster Learning*

Networked learning encompasses a diverse range of educational disciplines or programs developed collaboratively by teachers from various educational institutions. Each educational organisation designs a specialised course that is integrated into the overall curriculum and recognised by all participating educational institutions within the network. The didactic feature of this model lies in organising the educational process in the form of a modular structure, with educational materials provided in electronic format, facilitating rapid adaptation to evolving professional landscapes (Tretyakova, 2018; Apukhtina & Malorossiyanova, 2021).

The networked implementation of educational programs is regulated by Article 15 of Federal Law No. 273, "On Education in the Russian Federation" (Federal Law No. 273, 2012/2023). The utilisation of this model may be challenging due to regulatory constraints and the resource-intensive nature of implementing the educational process. However, it also offers the opportunity to accumulate the best practices of educational institutions and employers participating in the networked collaboration cluster (Agency for Strategic Initiatives, 2017). Teachers can implement the model by providing access to various modules in separate educational institutions, with subsequent documentation to confirm the level of knowledge acquisition (Gladkova & Solomennikova, 2022).

- *Education in Specialised Educational Institutions*

This model enables the organisation of the educational process within specialised institutions that exclusively offer distance learning formats and do not employ other forms of educational organisation. A didactic feature of the model is the independent learning of students utilising instructional materials, specialised literature, audio and video materials, chat platforms, as well as other technological and software solutions. Video conferences using accessible programs, such as Zoom, Telegram, and Webex, are widely employed in the educational process (Mayer & Fiorella, 2021). A distinguishing characteristic of this model is its emphasis on course creation using multimedia tools (Nikou & Economides, 2018). However, educational institutions often not only develop multimedia courses but also conduct assessments in specialised disciplines (e.g., engineering). Educational institutions that implement specific courses or disciplines in a distance format or entirely organise activities in the form of distance or open learning may utilise this model. Educational resources are provided for various levels of educational programs, catering to all categories of pedagogical staff (Gladkova & Solomennikova, 2022).

- *Learning Utilising Autonomous Learning Systems*

Autonomous learning systems encompass education through television or radio programs, digital educational resources, and printed materials. The didactic feature of this model lies in its emphasis on self-directed learning, delivering educational content through mass media, the Internet, and its interactivity. Initially, paper-based distributions were part of the model's implementation;

however, electronic equivalents have now entirely replaced them. Since the 2000s, and particularly after 2020, this model has been evolving into more digitised formats while maintaining its authentic origins (Kabalnov et al., 2007). For teaching staff, the emphasis is on self-directed learning and the acquisition of knowledge through mass media channels, including social networks, Telegram channels, television, newspapers, magazines, and online resources such as YouTube, TED Talks, and others.

- *Education in a Virtual Learning Environment*

The term "virtual educational environment" refers to the integrated information and educational space created through the integration of traditional informational resources and computer technologies (Lubkov, 2006). It encompasses databases, virtual libraries, electronic educational and methodological complexes, as well as adapted and expanded didactic methods (Lobachev & Soldatkin, 2002). This model is characterised by its convenience and universality of application for both learners and teachers. Alongside technological progress, the concept expands and complements technological innovations, including simulators, games, social networks, VR and AR technologies, AI, and GenAI. According to the findings of the research on governmental use of AI in education, only China, Finland, Georgia, Qatar, Spain, Thailand, and Turkey are developing training programs for teachers on AI usage, and only Singapore is creating an online repository for teachers on the utilisation of ChatGPT. The research data suggests that despite the development and widespread use of virtual educational spaces, most teachers lack knowledge in utilising modern technologies, including GenAI (Miao, F. (with Giannini, S., & Holmes, W.), 2023, p. 26).

Didactic features: the ability to design individual educational trajectories, organise bulk access to educational courses and disciplines, or study a single educational module or subject, the application of interactive methods to enhance the effectiveness of the educational process, increase the assimilation of educational materials, and overall academic performance (Anoshina et al., 2023). VR enables learning in a fully modelled environment identical to the natural one (Milgram & Kishino, 1994; Tom Dieck et al., 2021), allowing the simulation of practical situations from the professional field (Hu-Au & Lee, 2018; Spilski et al., 2019; Zender et al., 2020; Mulders, 2020; Zhan et al., 2022). AR enables the augmentation of physical space with interactive virtual information (Azuma, 1997), allowing for the simulation of equipment operation (Knowles, 1984; Babu et al., 2018; Kim et al., 2020). AI enables the creation of an assessment system, the real-time monitoring of the educational process (Niemi, 2021), and the application of interactive tools for knowledge formation and exchange (Waring, 2019; Fischer et al., 2020). AI enables the individualisation of the educational process through the capabilities of machine learning (Stone, P. & 16 Study Panel members, 2016; Timms, 2016; Chen et al., 2020; Roschelle et al., 2020), networks, and online intelligent education systems (intelligent tutoring systems (ITS)) (Niemi et al., 2023).

For teachers: the opportunity for flexible and adaptive learning tailored to the needs and interests of pedagogical staff. One example implemented within the presented model is the use of virtual laboratories as tools for engineering pedagogy. Their application spectrum ranges from preparing for solving real-world problems through conducting laboratory work as an alternative in the absence of materials and equipment to distance and self-directed learning (Trukhin, 2003; Anoshina, 2019).

Summary
From all the aforementioned, distance educational technologies can be utilised both in the implementation of distance and electronic education, as well as in traditional formats of educational activities. The examined didactic peculiarities of using each type and model of distance educational technologies suggest that each model can be employed depending on the

objectives of preparing teachers for the technical vocational education and training system and the conditions of educational process implementation. It is essential to recognise that program implementation is not limited to the framework of a single educational institution and can be realised within the scope of networked educational programs, enabling the creation of more adaptive and contextually relevant training programs for technical and vocational education and training teachers. Despite several evident advantages, it is also crucial to use various formats cautiously to avoid overloading with a specific type or method, which may lead to a loss of educational quality.

CHAPTER 3: METHODOLOGY AND RESEARCH DESIGN

Currently, there is a significant lack of comprehensive research on the training of TVET engineering teachers that covers a thorough analysis of the online learning process, including both the perspective of teacher trainers through online courses for TVET engineering teachers as well as the perspective of the TVET engineering teachers themselves who have experience in studying via online courses. The literature review has revealed a shortage of specific key variables in the study of TVET engineering educator training, which could serve as a foundation for conducting research and a deeper exploration of this topic. Most existing studies focus on isolated aspects of educator and/or TVET engineering teachers' training or address general pedagogical issues (Grollmann & Rauner, 2007; Kuhn et al., 2016; Asgari et al., 2021; Hassan & Bin Ismail, 2022; Zhao & Xue, 2022; Caves & McDonald, 2023).

This chapter outlines the steps taken as part of this study, which aims to conduct comprehensive research on training TVET engineering teachers through online courses. This study aims to identify the key factors that determine the perceived effectiveness of online courses for training TVET engineering teachers. This research objective falls within the scope of exploratory investigations (explorative Untersuchungen) in the field of empirical social research (Diekmann, 2007; Diekmann, 2020, p. 33).

The choice of this research type is guided by the insufficient prior examination of the topic and the lack of an established instrument for identifying factors that influence the effectiveness of online courses for TVET engineering teachers, particularly those relevant to technical and digital disciplines. In their respective works, Diekmann, Creswell, and Plano Clark emphasise that research should begin with a qualitative analysis of the topic through "expert interviews" based on the results obtained and proceed to the development of structured quantitative surveys (Diekmann, 2020, p. 34; Creswell & Plano Clark, 2017, p. 77).

In the context of this research project, a mixed-method research design will be employed—specifically, an exploratory sequential design. Within this framework, a qualitative study will first be conducted using standardised, in-person, open-ended, in-depth interviews with experts aimed at formulating hypotheses. These hypotheses will subsequently be tested through a quantitative study (a large-scale survey using a questionnaire), which will be quantitatively validated in the next stage (Creswell & Plano Clark, 2017, p.60). The process can be visualised as follows (adapted from Creswell & Plano Clark, 2011):

$$\text{QUAL} \rightarrow \text{development} \rightarrow \text{quan} = \text{validate exploratory dimensions by developing and testing an instrument}$$

This type of analysis enables the collection and examination of quantitative and qualitative data within a single study (Creswell et al., 2005; Dawadi et al., 2021). Based on the results of a small-sample qualitative investigation, key indicators can be identified and subsequently tested on a larger quantitative sample (Creswell & Plano Clark, 2017, p. 86).

The exploratory sequential research design employs a stepwise synchronisation, allowing for a deeper understanding of the experiences of teacher trainers who train TVET engineering teachers through online courses, as well as a broader interpretation of the generalised quantitative findings (Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 1998, 2010; Creswell & Plano Clark, 2017, p. 53). This study places particular emphasis on the development and validation of a quantitative instrument, reflecting an overall prioritisation of quantitative data over qualitative data.

The study was conducted in three consecutive phases: the first involved an exploration of the phenomenon (the perspectives of teacher trainers who teach TVET engineering teachers via online courses); the second focused on instrument development to verify the findings; and the third comprised the measurement of the phenomenon. (Figure 1.1)

3.1 Empirical Part 1: Interviews

At the first stage of the empirical study, it was decided to conduct expert interviews with teacher trainers who, over the past three years, have had practical experience in at least five educational programs for TVET engineering teachers delivered online or through distance learning technologies. The works of Seidman, I. (2006, 2019), Rubin, H. J., & Rubin, I. S. (2012), Flick, U. (Flick, Kardorff & Steinke, 2004), and Patton, M. Q. (2002) discuss various typologies of qualitative research that may be applied for analysing interview results. For the qualitative part of this study, the Interview Approach will be employed—specifically, a traditional research interview using Interview Instrumentation based on standardised open-ended questions as described by Patton, M. Q (Patton, 2002, p. 638; Patton, 2014). The selected interview type follows Johnson, R. Burke's definition: a standardised in-person, open-ended, in-depth interview, which involves a predefined interview protocol with a strict sequence of open-ended questions and is more structured than other approaches (Rubin & Rubin, 2012; Johnson & Christensen, 2014; Patton, 2014). This approach to conducting interviews was chosen due to the need to create conditions that are as uniform as possible and to obtain answers to standardised questions in order to obtain the optimal number of such answers while minimising the influence of the interviewer (Hyman & National Opinion Research Center, 1954). The interview is conducted according to protocol and follows a "strictly prescribed format" (Bornat, 2004). Furthermore, the use of standardised questions enhances the quality, reliability, and validity of the information obtained and increases the comparability of responses (Singleton & Straits, 2012).

3.1.1 Development of The Interviews

Diekmann emphasises that a particular research design is preceded by preliminary knowledge, which helps guide the study in the appropriate direction to achieve its objectives (Diekmann, 2020, p. 34). In the present study, a theoretical foundation was established through an analysis of the development of the professional education system in Russia, an examination of online learning practices in Russia, and a review of pedagogical theories relevant to the training of TVET engineering teachers via online courses.

During the process of identifying experts involved in the training of TVET engineering teachers through online courses, it was observed that there are no relevant scholars or practising specialists in Russia within this research domain who could serve as a preliminary validation group for the developed interview protocol, as the topic is both new and not widely explored (Magnusson & Marecek, 2015, p. 27).

During the process of identifying experts involved in the training of TVET engineering teachers through online courses, it was observed that there are no relevant scholars or practicing specialists in Russia within this research domain who could serve as a preliminary validation group for the developed interview protocol, as the topic is both new and not widely explored (Bogner, Littig, & Menz, 2009; Meuser & Nagel, 2009, pp. 25-27; Rubin & Rubin, 2012, pp. 82-85).

Consequently, it was decided to conduct a pilot test of the interview protocol with the first three respondents and, if necessary, revise the protocol for subsequent expert interviews. Pilot testing of the interview is a critical step that allows for the identification of potential structural and logical issues within the protocol (Patton, 2002, pp. 244-246; Creswell, 2012, pp. 165-167). For pilot

testing, respondents were selected from teacher trainers who deliver training programs for TVET engineering teachers via online courses and are geographically located in different parts of the country, including the Central Federal District, the Southern Federal District, and the Siberian Federal District. [1]

The pilot face-to-face interviews were conducted via digital tools (VK video calls, Yandex Telemost, and others). Each pilot interview was fully aligned with the conditions of the planned expert interviews and covered the following thematic blocks:

1. Objectives and Goals of Online Training
2. Challenges in Delivering Online Training
3. Instructional Methods and Pedagogical Techniques
4. Evaluation and Assessment of Training Impact
5. Technological Tools and Their Role in Enhancing Learning Effectiveness
6. Support Systems and Learning Resources
7. Course Customisation and Adaptation to Learner Needs
8. Strategies for Learner Engagement and Interaction
9. Opportunities for Continuous Professional Development (CPD)
10. Factors Influencing the Adoption of Online Learning
11. Practical Implementation of Online Educational Components
12. Teacher–Learner Interaction and Communication
13. Ethical Considerations in Online Education
14. Knowledge and Skills Transfer in Online Settings
15. Innovations and Recommendations for Improvement

Based on the identified thematic blocks, specific questions were developed and included in the pilot interview protocol (Appendix D).

As a result of the pilot testing, the interview questions were trialled, the order of question delivery was adjusted, and clarifying modifications were made to questions that could be interpreted differently depending on the context. The outcome of the pilot testing was a finalised interview protocol containing questions aligned with the objectives of the present study (Nyumba et al., 2018) and covering the previously identified 15 thematic sections (Appendix E).

The interview questions relate to the foundations of the literature review, the conceptual frameworks of learning theories for adult learners that are relevant to the training of teachers through online learning, and incorporate key analytical frameworks for distance education technologies and online learning in the Russian context.

3.1.2 Realisation

Conditions of origin

The interview is one of the most widely used data sources when a researcher aims to study specific phenomena in the field of education (Johnson, 2014; Plano Clark & Creswell, 2015) and obtain more spontaneous, meaningful, and in-depth responses (Johnson & Christensen, 2012). A fundamental criterion for effective qualitative research is an understanding of the process being studied (a certain level of expertise in the field) by all participants involved (Merriam, 2009; Tisdell, 2025). For this reason, this study involved teacher trainers who are current authors or teacher trainers of online engineering-pedagogical courses for TVET engineering teachers.

[1] 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.

Qualified sample participants were defined as practising teacher trainers who:
– have worked with adult learners for no less than five years;
– participate in professional development and retraining programs for teachers, as well as in the training of teachers for the vocational education system in the fields of engineering and pedagogy;
– possess either a formal degree in pedagogy or engineering and/or professional retraining in these fields;
– have over three years of teaching experience;
– have taught in more than five online programs for TVET engineering teachers in the vocational education system over the past three years;
– fall within the age range of 25 to 60 years;
– reside within the territory of the Russian Federation.

For the pilot testing of the interview questions, three respondents were selected who met the criteria mentioned above and represented different Federal Districts (the Central Federal District, the Southern Federal District, and the Far Eastern Federal District). The fulfilment of these restrictions allowed us to adjust the questions considering the territorial peculiarities of different parts of the country. For the finalised interview questions, respondents were selected from all eight Federal Districts of the Russian Federation: The Central, the Northwestern, the Southern, the North Caucasian, the Volga, the Ural, the Siberian, and the Far Eastern Federal Districts.

Respondents were recruited through social networks, academic publication databases, and professional communities. The total outreach to potential participants amounted to approximately 15,000 individuals across key social media platforms in the Russian Federation. Additionally, information about the search for respondents was sent to 30 educational institutions involved in the online training of TVET engineering teachers. In all communication channels, announcements about the search for participants included a link to a short screening questionnaire designed to determine whether the individual met the selection criteria. A total of 42 individuals expressed interest in participating in the qualitative study, of whom 15 did not meet the eligibility criteria.

Each potential candidate received a personal invitation via email containing a detailed description of the study, its phases, and the terms of participation in the interview. In total, 27 personal invitations were sent to qualifying respondents; 13 confirmed their participation, two discontinued communication shortly after agreeing to participate, and 11 participated in the interviews at the scheduled time.

Of these, three respondents expressed willingness to participate in the pilot interviews, and eight respondents agreed to take part in the main stage—the expert interviews. It is essential to note that, due to the minor substantive changes made to the interview questions regarding question wording, the results of the pilot interviews were also utilised for further qualitative analysis. The sample of eleven participants is considered representative of this type of research method, as by the eighth interview (including three pilot and five primary interviews), a level of information sufficiency had already been reached: the data were repetitive, and no new relevant insights into the research topic were emerging (Merriam, 2009; Tisdell, 2025). Nevertheless, it was decided to conduct three additional interviews to ensure data saturation and to confirm the adequacy and completeness of the information collected.

Each interview participant was informed about the purpose of the study, had the opportunity to review the interview questions in advance, and was notified that the video call would be recorded, followed by anonymisation and transcription for analytical purposes.

Participation in the interviews—both during the pilot and main stages—was voluntary and without compensation. Respondents were informed about how the collected data would be used and where

the results would be disseminated. All participants were informed of their right to withdraw from the study at any time and provided with detailed information regarding confidentiality protocols and the handling of their data.

The assurance of complete confidentiality enabled participants to openly share their personal and professional experiences, which contributed to the effective collection of information on the training of TVET engineering teachers through online courses.

Conducting the qualitative study

To conduct the standardised in-person, open-ended, in-depth interviews, an online interview format was chosen using video conferencing systems, such as Yandex. Telemost and Telegram. The virtual interview format helped reduce the amount of time required for both the interviewer and the interviewee for travel and preparation. Moreover, it helps to increase respondents' willingness to participate in the study because they can choose the time and place that suits them best. Last but not least, selecting a comfortable environment helps the interviewees be more open and relaxed during the conversation.

The duration of the interviews ranged from 30 to 90 minutes, depending on the pace of responses and the level of detail provided. Each interview was recorded using the built-in video recording features of the software, as well as with a voice recorder, to minimise the risk of data loss. The recorded sessions were transcribed using Charla-AI, an AI-based audio and video transcription service. After receiving the transcript, the text was checked for errors and anonymised by assigning a random number. It was then sent to respondents for review and any necessary changes. Such verification allows the materials obtained to be more accurate and reliable (Creswell & Poth, 2018). Each expert was given 14 days to review the transcript and suggest edits. In the absence of a response, the transcript was considered accurate and proceeded to the analysis stage (Koelsch, 2013; Birt et al., 2016).

To ensure the reliability and validity of the collected data, all interviews were conducted personally by the author of this research project, using the method of bracketing, which involves intentionally setting aside personal experiences and preconceived assumptions related to the research problem (Chan et al., 2013). This approach minimised inconsistencies in the formulation of questions and the interpretation of responses while also allowing the researcher to maintain neutrality and avoid leading participants toward specific viewpoints (Flowerday & Schraw, 2000).

All interviews followed an identical structure and sequence of questions. In addition to audio and video recordings, notes were also taken, which helped to delve deeper into the context of each expert and note personal observations. All work was conducted in Russian and subsequently translated into English.

The credibility of the study is established through its validity and reliability (Curtin & Fossey, 2007). The validity of the interview results was ensured through pilot testing and refinement of the interview questions (Raffe, 2021). The final version of the interview protocol included only approved questions that can minimise bias and focus exclusively on obtaining information relevant to the research objectives and aligned with the overall research design. The reliability of the data was achieved through the rigorous selection of respondents who met the established criteria and voluntarily agreed to participate in the interviews (Shenton, 2004). All interviews were conducted in a neutral tone, with no reactions to participants' responses, and with careful separation of the researcher's perspective from that of the participants.

The use of these combined methodological approaches ensured the effectiveness of the interviews and allowed for the collection of data sufficient for the following stages of the study. The interpretation and analysis of the results obtained are presented in detail in the study to increase the transparency of the research and provide an algorithm for the collection, analysis, and further use of data. This approach helps to improve the reliability of the study (Creswell & Creswell, 2018).

Throughout the qualitative research, field notes were kept to capture detailed reflections on the research process, insights into the topic, and additional themes that emerged during the interviews or follow-up communication with experts and may be helpful for future studies.

3.1.3 Analysing the qualitative study

There are various approaches to analysing data by conducting qualitative research using the algorithm. In this study, data analysis was carried out in several stages: familiarisation with the data (Compiling), coding the data (Disassembling procedure), grouping the data into themes (Reassembling procedure), identifying thematic blocks (Interpreting), and generating a report (Concluding) (Yin, 2016). The primary objective of analysing the data collected through expert interviews is to identify shared meanings that align with the research objectives (Mayer, 2013, p. 47).

Procedure for analysing the qualitative study

All interview transcripts were translated from Russian into English using a double-translation process. The first step was to translate all the material with the help of AI tools, such as DeepL and GPT. The second step is to review every translation manually to avoid misunderstandings and translation errors. However, the entire analytical process described below was conducted using both versions (Russian and English) in parallel to minimise the loss of meaning and potential omission of important information during translation. To analyse the transcripts, thematic coding was applied to identify themes in the data that could form the basis for subsequent quantitative analysis through a questionnaire targeting TVET engineering teachers who had completed online courses. The coding process followed a structured method based on Moustakas' (1994) approach, which is commonly used for inductive data analysis through deep immersion in the transcripts (Hall et al., 2016). Before the coding process, each interview transcript was read twice, and key concepts were identified and noted. The next step involved applying the method of horizontalisation, meaning that each statement was assigned a descriptive label, ensuring equal attention was paid to every response. Based on this material, the data were reduced and filtered to extract shared indicators of participant experience and the most frequently used descriptions in their responses. For each selected statement, the researcher evaluated the significance of its content and decided whether to use it as an abstracted category or in its original textual form. In the following phase, the identified indicators were grouped by merging them into broader thematic labels (Creswell, 2013; Smith et al., 2022).

Thematic tags are then verified for accuracy, analysing the full text of the transcript and checking that they correspond to the interviewees' words. The determined themes are then used to construct questionnaire sections and questions for further quantitative research (Creswell & Plano Clark, 2018; Saldaña, 2021).

The choice of a phenomenological analysis method enabled the study to focus on understanding participants' personal experiences and to explore their perceptions and interpretations in greater depth within the context of their professional activities. The method of horizontalisation enabled detailed and balanced analysis of all parts of the data, reducing bias and subjectivity. Since this

study requires identifying the deeper meanings that experts use in their work when training TVET engineering teachers and integrating theoretical knowledge with practical skills, this combination of research methods is the most appropriate and best suited to the research objectives.

Results of the qualitative study

This section presents the findings of the qualitative analysis conducted through interviews with teacher trainers involved in online teaching for TVET engineering teachers. The interviews were coded manually, followed by verification using ATLAS.ti software to ensure the accuracy and relevance of the findings.

The qualitative analysis began with a thorough review of the interview results. The interview transcripts included the content of the conversations but excluded the evaluation of paralinguistic elements (intonation, speech tempo, pauses, etc.) (Mayring, 2016). The exclusion of paralinguistic features was justified by the lack of technical capacity for a detailed analysis of non-verbal components and the limited time resources, which did not allow for the inclusion of this additional level of complexity. The absence of paralinguistic elements may have led to the loss of specific nuances in interpreting statements, such as irony and hesitation. However, the primary focus of the analysis was on the meaning of the interviews' transcripts. In cases where the interpretation was unclear, video recordings were used for double-checking and clarifying the statement. This process helped to minimise the risk of misunderstandings about the meaning of the fragments and provided the study with more precise results.

To ensure the greater accuracy of the results, all interview transcripts were initially coded manually and then cross-checked using ATLAS.ti to eliminate potential omissions and ensure the findings were closely aligned with the research objectives. The English versions of the transcripts were uploaded into ATLAS.ti. A separate file was created for each interview. Subsequently, using the built-in AI Coding (+Intention) tool in ATLAS.ti, the transcripts were automatically processed and coded. The AI Coding process included the step of defining a clear and concise research goal. It was recorded as follows: «Research Goal: Evaluate the factors determining the effectiveness of online courses for preparing TVET engineering teachers in the professional education system and assess how these factors influence teachers' professional development and teaching efficacy. Research question: What are the key factors that determine the effectiveness of online courses for preparing TVET engineering teachers in the professional education system? » Following this step, AI Coding in ATLAS.ti generated five questions tailored to the initial research goal. Since all interviews had been conducted using a pre-established set of questions, the results of the AI-generated Related Questions and Category Codes were cross-checked, and the questions were adjusted to match the exact wording used during the interviews.

Additionally, the AI-generated category labels were renamed to align with the actual question formulations. Each question was assigned a category code—i.e., a "theme" or "subject"—that encompassed several more specific codes, allowing for refinement and improved coherence of the AI Coding results. In the next stage, the previously identified codes from manual coding were entered into the same document (hand-coding) and then compared with the outcomes of the automated coding. As a result of the comparison, a third level of codes was created, which included both analyses and best answered the research questions. It is essential to note that to standardise the assessment, all code categories were formed in response to the given questions; only at the stage of comparing and grouping the codes were transformed into broader thematic blocks. Detailed coding results are presented in Appendix F.

As a result of the analysis, key codes were identified and grouped into nine themes that were most frequently addressed during the interviews: Course Effectiveness Factors, Problems, Course

Goals, Teaching Methods and Techniques, Technology Integration, Engagement and Interaction, Ethical Considerations, Assessment Tools, and Hands-on Activities. However, many of these themes appeared to be interrelated and overlapping, which required further validation and consolidation to enable more precise and substantiated conclusions. This was accomplished using the six-step method of interview text analysis proposed by Mühlfeld et al. (1981).

Firstly, the analysis of the interview transcripts began with the identification of fragments that correspond to potential responses to the interview questions. Secondly, the interview transcripts were categorised into several sections. Thirdly, the internal logic between text fragments from the interview is established. All findings were then documented, and the fragments were analysed in detail to ensure a deep understanding of the material and avoid overlooking any important information. The step involving the construction of internal logical connections and the assignment of specific roles to each text segment was omitted in this study, as the primary focus was on validating the existing analysis rather than building new logical relationships. Thanks to the pre-structured interview design and predefined questions, as well as the coding and categorisation already in place, the underlying logic of the interviews had been sufficiently established, minimising any loss due to the omission of this step. The fifth step involved evaluating the data through the comparison and contrast of textual fragments.

Once all fragments with similar meanings were grouped and contradictions were resolved, the analysis combined overlapping themes into single categories. The process involved examining fragments that conflicted or offered multiple interpretations of the same topic, often reflecting differing expert perspectives on key effectiveness factors, teaching methods, and digital proficiency. For example, some participants highlighted the threats of using technology in the educational process, while others believed that technology brings their courses to the next level. Such differences in opinion are carefully analysed and categorised within the existing categories. In-depth analysis helped prevent potential distinctions and provided the rationale for merging topics. Moreover, another reason to consolidate the themes was that some highlighted topics had similar meanings, and the best strategy was to make the larger categories for them. Conflicting opinions on teaching methods and technology use, for instance, were grouped in a way that highlighted key insights and avoided duplication.

Ultimately, a set of interconnected themes was identified, such as Teaching Methods and Techniques and Engagement and Interaction, which were merged into a broader category: Teaching Methods and Engagement. In total, three overarching categories were defined as a result of the analysis:

- The category Course Design and Evaluation incorporated the original themes of Course Effectiveness Factors, Course Goals, Assessment Tools, Problems, and Ethical Considerations, as they all pertain to course evaluation, structure, potential challenges, and ethical aspects of the educational process.
- Teaching Methods and Engagement brought together the themes of Teaching Methods and Techniques, Engagement and Interaction, and Hands-on Activities, focusing on how teachers engage learners and apply various instructional methods.
- Technology Integration encompasses topics related to the implementation of technologies, including "Technology Integration" and "Ethical Considerations," which focus on the importance of utilising digital tools and adhering to ethical standards.

The rationale for selecting these categories lies in their coverage of the main aspects mentioned by the experts in the interviews when discussing the effectiveness of online courses for training TVET engineering teachers. The sixth and final step involved evaluating the outcomes and comparing them with the earlier analysis (Mayer, 2013, pp. 47-51).

The three broad categories of Course Design and Evaluation, Teaching Methods and Engagement, and Technology Integration not only structured the analysis but also provided a more profound understanding of the key factors that influence the effectiveness of online courses for training TVET engineering teachers.

Before moving on to the results of the qualitative analysis, it is essential to clarify the key academic concepts used in this study: engagement, interaction, and technology integration—in order to avoid misinterpretation and to ensure greater precision in the interpretation of the research findings regarding the effectiveness of online courses for training TVET engineering teachers.

"Engagement" refers to students' active participation in their learning process, including interaction with educational content, participation in professional experiences that simulate real teaching situations, and the use of a variety of teaching strategies that help develop skills for creating motivating and engaging curricula and teaching approaches (Seo & Gibbons, 2019).

"Interaction" refers to the process of exchanging information and ideas between participants in the educational process, i.e. the teacher, student and content, to acquire pedagogical or necessary technical skills in the context of training TVET engineering teachers.

As early as 1989, Michael Grahame Moore identified three types of interaction:

- Student–Content Interaction: the process by which learners engage with educational material through reading, completing tasks, and evaluating their work.
- Student-Teacher Interaction: the relationship between student and instructor, reflected in well-designed instructional materials and built upon feedback, discussion, consultation, and support.
- Student–Student Interaction: interaction among students through group discussions, collaborative projects, or other forms of teamwork, provided there is a sufficient level of self-regulation typical of adult learners (Moore, 1989).

"Technology" integration refers to the process of incorporating digital tools and resources into the educational process in order to master digital platforms and technical tools, as well as to develop the ability to select and apply appropriate technological and technical solutions in teaching practice. It also involves adapting these tools to the specific nature of professional disciplines, with an emphasis on hands-on application in the context of preparing TVET engineering teachers (Mishra & Koehler, 2006).

During the coding phase, key categories were identified that reflect the practical embodiment of these concepts in real-world educational practice. The following section presents an analysis of the categories that synthesise the qualitative data and serve as the foundation for hypothesis development and further quantitative investigation.

Course Design and Evaluation

The category "Course Design and Evaluation" is dedicated to a comprehensive analysis of the factors influencing the design and evaluation of online courses for TVET engineering teachers. Within this category, the study explores the determinants of effectiveness in online courses for TVET engineering teachers, the challenges that arise, the intended goals of educational program development, the assessment tools employed, and ethical considerations that may impact the learning process.

While the factors contributing to course effectiveness were not directly addressed in the interviews, experts repeatedly emphasised the importance of specific components that, if absent, hinder the successful implementation of educational programs in digital environments.

The first issue highlighted was the lack of a clearly defined course focus and the delivery of generalised content to a diverse group of course participants from the TVET engineering education sector:

> *E1: "The first problem is that we do not differentiate our audience according to the functional roles of TVET engineering teachers, which vary. We encounter those who are effectively teaching and are responsible for general professional disciplines—I emphasise—or specialised disciplines, focusing on theoretical education. Even within these categories, there is a difference between specialised and general professional roles. The goals and tasks of these courses they teach are different systems of tasks, and, of course, different approaches to their preparation are required."*
>
> *E3: "They need to be differentiated by certain groups and already in the context of these groups consider the tasks of engineering-pedagogical education."*
>
> *E4: "An effective course is tailored to a specific subject matter."*
>
> *E8: "Online course should be very short and deep… there should be one theme, one course."*

It was repeatedly noted that TVET engineering teachers often join the courses unprepared for the level of content provided or come from unrelated subject areas—for example, teacher trainers of humanities disciplines enrolling in courses that include engineering modules. Such teachers find it more challenging to master engineering topics and modules, leading to a rapid loss of interest, which in turn negatively impacts the overall effectiveness of the educational process:

> *E1: "Providing higher qualifications both technically, engineering qualifications, and pedagogical qualifications. Moreover, I must admit that engineering is primary. It is possible to make an engineer into a teacher, but not vice versa. We must all understand this."*
>
> *E9: "For me, a person must have some kind of professional education, full-time, in order to be able to work with distance learning later."*
>
> *E3: "The basic level of competence literacy of the teacher is crucial to understand the material and readiness to take the most of it."*
>
> *E1: "I advocate that vocational education teachers should have higher qualifications."*

The experts placed particular emphasis on the presence of motivation and engagement, as well as on the conditions that facilitate the achievement of intended learning outcomes:

> *E3: "The presence of free time and motivation to study."*
>
> *E4: "Material and technical resources should be at the teacher's workplace that can allow them to study during work time. The teacher shall be given time resources for training."*
>
> *E9: "Plus, the problem and positive factor is still a setup for results and emotional involvement in the course."*

E10: "Engagement, interest, the number of participants who actively engage in performing those practical tasks."

Experts (E4, E5, E8, E11) indirectly mentioned a preference for online learning over face-to-face formats, justifying it by reduced time commitments, greater flexibility in scheduling, and significant economic advantages (such as lower travel costs, less time away from work, etc.):

E4: "Online courses help address the social issue of teachers being detached from their professional activities."

However, some experts noted that not all competencies and skills can be developed exclusively through online courses. They emphasised the need to incorporate blended learning formats—for example, blended learning, defined as: «Any formal education program in which a student learns at least in part through online learning, with some element of student control over time, place, path, and/or pace» (INEE, 2024; UNESCO-UNEVOC, 2025):

E1: "We select for distance courses those questions that do not require direct, so to speak, practical work in the classroom because analysing a lesson plan, choosing a technology—everything can be discussed online."

E3: "It will be some blended learning, a mix of online and face-to-face formats. For specialised knowledge, especially in technical fields, a combination of blended learning with hands-on practice in the workplace is ideal. This approach allows students to study the basics online independently, then try what they have learned through real-world practice, securing they fully understand the material."

E3: "Replacing hands-on workshops and lab work with online education is challenging because it requires tactile and visual experiences that are crucial for mastering practical skills, especially in fields like met alworking and welding. While online courses and simulators can supplement learning, they cannot fully replace the need for on-site, hands-on training with real equipment."

E6: "Online courses are effective when there is a need to incorporate hybrid forms of learning. Some disciplines, not all, but some, still need to be studied, to be mastered in person, especially where there are some workshops or lab work."

E7: "Studying and learning with blended learning (practical skills development with the help of simulators), but they should develop something in a real production environment, just to try it on."

E11: "We have often tried to create LMS courses that include the development of skills like communication, giving appropriate assignments, for example, asking to write down 15 variations of entering a classroom. This is because teachers often stumble over such simple things, mainly relying on their life experience and the methods they were taught, which they transfer directly into the classroom."

Online learning is more often chosen for theoretical subjects or for those that allow the demonstration of processes using digital tools necessary for study, with the clarification that all materials should be applicable by learners independently in practice:

E4: "Online training for engineer-teachers can only cover pedagogical education; practical experience must be gained on-site at the enterprise."

E7: "That is, he made some product himself, independently using the material that you give."

A significant portion of the interviews focused on the challenges and difficulties teachers face in implementing online learning. A key issue identified was communication, particularly related to time zone differences and territorial disparities. Online courses are open to all interested participants (not only engineering teachers) from any region of the country, which creates a heterogeneous environment in which contextual challenges and misunderstandings frequently arise:

E1: "There were courses we had in different cities, different regions, people who were not familiar, we could not introduce them to how to get close; it is simply impossible when there is no direct communication. However, when it comes to more complex issues, such as communicative ones related to reflection, professional self-control, and other functionally important, so to speak, activity-related pedagogical competencies, there is, of course, a problem here. It is poorly conveyed through online means. Even in an online environment, live communication in class, people trust each other more than when remote."

E2: "The second problem is that we initially announced a program for anyone who wants to study. Anyone went, then we realised, no, there still must be people with technical education."

E6: "There is no live communication, no atmosphere where we can share opinions, have a conversation, as it happens in face-to-face classes. There is no sense of community."

E9: "If you are a pedagogue and you do not have an engineering background, courses will not help you at all. For some reason, people think that online education is not so responsible; you do not have to prepare for it."

Another significant issue is the lack of discipline and organisational-technical challenges associated with online courses. Distance learning is often perceived as less important than face-to-face education, which leads to a lower level of responsibility, both on the part of teacher trainers when preparing materials and on the part of learners when studying them. Moreover, many teachers lack the necessary equipment at home to conduct or participate in classes, making learning feasible only during working hours and with access to institutional resources. Experts also noted that participation in training against one's will often results in conflict, refusal to complete assignments, and a lack of engagement in group work:

E2: "We encountered non-compliant discipline. They tell us that they will do tasks, and they do not do anything."

E4: "I had always found it extremely frustrating when teachers of general education subjects attended professional development courses for vocational teacher trainers, as they would disrupt discipline and lacked motivation for learning."

E4: "It is necessary to establish behavioural guidelines for meetings, as people often behave terribly during online courses."

E5: "They are not engaged; I cannot see their cameras and do not know what is happening on their end. Moreover, the results are unclear because it is not always obvious how I can assess them."

E7: "TVET engineering teachers go for training, not by their own will."... "Chat arguments, swearing, inappropriate language, a participant's camera turning on at the wrong time, them not engaging in what was required, which was completely unethical and unpleasant, involuntary microphone activation at an inappropriate moment."

E9: "The organisational-technical problems and a specificity of perception of materials."

E9: "Lacks the tools to simply show the application of the subject matter in practice, like digital tools."

E10: "The main problem is the formal approach. There is room for some carelessness in material selection and conducting classes. Also, formal relations from the side of those who attend."

In discussions with experts regarding the goals of developing online courses and the reasons TVET engineering teachers participate in such training, it was noted that online learning is aimed not only at acquiring new knowledge but also at addressing gaps in foundational (basic) education:

E1: "Not only mastering new material but also overcoming gaps in knowledge, skills, and anything else. I believe that courses, especially for TVET engineering teachers*, should be comprehensive. They should combine knowledge related to breakthroughs in technology, mechanical engineering, food production, and molecular production in space. However, a person must understand how the industry in which they work is developing. The second point is, of course, the enhancement of pedagogical knowledge, which is not always an enhancement; sometimes, it is treatment for a stale pedagogical view."*

E3: "Teachers who have come to learn and improve their qualifications."

E9: "They will get acquainted with various teaching methods."

Moreover, the goal of any online learning program primarily depends on what TVET engineering teachers themselves expect to gain from the course. Eighty percent of the experts emphasised that one of the key stages in the development of online courses is the analysis of the target audience and its needs, as well as the assessment of potential learners in order to adjust the course content accordingly:

E1: "Firstly, we need to define who these people are—those already working, individuals with engineering education and work experience who have come to work in professional educational organisations. Pedagogical training is more productive when we divide the audience and create targeted courses for those who teach theory, those who organise instructional practice, and those who organise industrial practice."

E3: "It is important to understand the audience, its generation and use appropriate teaching methods."

E4: "The key interest here is to select a course topic that is engaging for everyone."

E5: "We constantly conduct a needs analysis at the beginning of the training to assess what learners already know and what they do not, followed by a trial lesson. After that, we compare the results and develop the program accordingly."

E9: "You need to understand with whom you work... age category, firstly, and how involvement, immersion in all this."

E11: "Online course must be relevant to them, and they must need this material specifically."

It was also mentioned that online courses contribute to professional development by saving time, thereby facilitating more efficient learning:

> *E8: "The purpose of online courses, as I understand it, is to save time because it is complicated to go somewhere now; for example, offline courses either involve business trips or taking time off to go somewhere and sit there. The main goal of online courses is professional development via time savings."*

Rapid technological development and the emergence of new digital tools require teachers to develop their skills constantly, and experts noted that one of the key objectives of online courses is to teach teachers to adapt to changing conditions by acquiring the basic set of competencies necessary for this:

> *E1: "There is a critical parameter—increasing pedagogical motivation itself. A person begins to feel more confident, understands that they have been given important tools with which they can solve complex tasks surrounding them."*
>
> *E5: "After the training, teachers will perform their work better."*
>
> *E7: "Most often, the goals were to transfer practical tools, such as program design, development of specific lessons, and project activities."*
>
> *E4: "If an engineer-teacher is delivering a lecture online, they must also be skilled in presenting themselves effectively."*
>
> *E10: "The primary goal is the readiness of future teachers to engage in professional activities under various conditions… Modern teachers must be proficient in all technologies to carry out their professional duties."*

An interesting fact that was noted during the analysis of the transcripts was that all experts unanimously confirmed the need for continued professional development for teachers. Experts E1, E3, E4, E8, E10, and E11 emphasised the importance of undergoing training at least twice a year. In contrast, respondents E2, E5, E6, E7, and E9 stated that TVET engineering teachers must continually work on their professional growth, with online courses serving as a tool for achieving pedagogical professionalism.

The analysis of the interview transcripts also revealed that there are no significant differences among experts in their approaches to knowledge assessment. The evaluation process typically begins with establishing an understanding of the learners' initial level—namely, what level of knowledge participants possess when entering the educational programs. This assessment is carried out either during diagnostic testing or during the first point of contact with prospective learners, and it can also be implemented during the initial hours of the training program:

> *E4: "Diagnostic testing for knowledge, for example, of regulatory documentation on specialisation."*
>
> *E7: "I did diagnostic testing."*

It is important to note that entrance tests also serve as a benchmark for understanding the starting level of knowledge and comparing it with the level of knowledge after completing the programme. Studying the delta can be one of the factors that allow us to evaluate the effectiveness of online learning:

> *E1: "We see the delta—what a person came with and what they left with. This is a direct result-based assessment."*

The assessment of knowledge levels during the learning process is carried out through various tests, learner interaction, and the implementation of rating-based incentive systems:

> *E1: "We have more of a pass-fail scale rather than a five-point scale."*
>
> *E4: "Control of the material mastered involves a specific thematic topic and how the instructor utilises various techniques, methods, and technologies to assess the level of understanding and mastery."*
>
> *E5: "The transfer of knowledge from online to practice is assessed through observation, supervision, or site visits—whatever you choose to call it—where you go and see what has been applied."*
>
> *E5: "Tests that learners complete and check lessons once a month."*
>
> *E6: "We have a rating system and more punitive measures. That is, if you have a low rating, two times a semester, a checkpoint, you did not pass, you have more problems."*
>
> *E8: "They go through the general material, take the final test, and some average cuts."*

An essential element of assessment—though not directly related to knowledge—significantly influences the overall effectiveness of learning: the evaluation of learners' psychological and emotional state. The audience of teaching professionals often exhibits signs of professional deformation and experiences difficulty transitioning into the role of a "learner":

> E7: "Any educator needs to first bring them into a student state at the program entry stage."

However, to truly understand TVET engineering teachers and their condition at the outset of their engagement with online courses, it is necessary to maintain "live" contact and continuous interaction with them:

> *E1: "Try to understand teachers' attitudes through conversations, through simple diagnostic tasks… Diagnostics of difficulties, burnout, and stagnation."*
>
> *E10: "Question-answer sessions, hints, consultations, and instant feedback, where it is not the system but rather the instructor providing a subjective evaluation based on established criteria."*

When discussing ethical issues, the experts noted that online courses represent an entire system of both formal and informal ethical norms:

> *E1: "You turned on the recording, you recorded video, and this is already such an ethical moment; it is like a published manuscript."*

Discussions with experts on ethical aspects that could impact the effectiveness of online learning revealed that many TVET engineering teachers experience discomfort due to the lack of interaction with the audience (e.g. when participants keep their video cameras turned off), as well as due to the reluctance of some learners to demonstrate specific skills that are being developed during the training process:

> *E6: "Those very black screens that you see from students and material-technical provision."*

> *E10: "If a person does not demonstrate how they work but is ready to discuss the difficulties that arise in their professional teaching activity, then this recording is optional."*

However, the most significant resistance to online learning on the part of students lies in cultural and national characteristics, as well as possible inclusive limitations, when it is necessary to competently form groups of students, preventing discomfort and their "dropout" from the educational process:

> *E3: "In online education, ethical issues can arise, such as resistance to video surveillance during exams due to cultural or religious beliefs or challenges in group work involving individuals with disabilities. These situations highlight the need for sensitivity and adaptability in educational practices to accommodate diverse needs and perspectives."*

> *E10: "If a learner who is being trained and will be a future TVET engineering teacher has any health restrictions that do not hinder their professional teaching activity but do hinder the quality display of recorded material, then a solution is sought. Permission is obtained from other learners to review someone else's session so that the individual understands how it went. Thus, they conduct the session without recording it and come out with a self-analysis of this session to discuss some nuances. Our main task is not control but ensuring quality."*

Considering various potential ethical challenges, it is also important to pay attention to creating a supportive learning environment and try to minimise the effect of external factors on the retention rate:

> *E5: "It is crucial to make students comfortable during the learning process and create a supportive learning environment for them, especially when we are working with adult learners. This could have a positive influence on the retention rate."*

The analysis of the "Course Design and Evaluation" category demonstrated the complexity and diversity of factors that influence the perceived effectiveness of online courses for TVET engineering teachers. The lack of a clearly defined educational course curriculum and the provision of universal material for a diverse audience means that some of the teachers being trained are unable to master the material due to a lack of sufficient knowledge and skills. In contrast, others find the training uninteresting because the material is too simple for them. This situation contributes to a decline in motivation and engagement, negatively impacting the overall quality of the educational process. The diversity of the audience necessitates the development of online courses that account for its heterogeneity to prevent a decline in learning effectiveness. While online courses offer several advantages—such as saving time and resources—they cannot fully replace face-to-face instruction when it comes to developing practical skills. Experts repeatedly emphasised that blended learning is the most effective format for training TVET engineering teachers. Technical difficulties, communication challenges, disciplinary issues, and organisational problems lower the overall effectiveness of the educational program and require targeted attention. Assessment was also identified as a critical aspect. It includes not only the evaluation of knowledge

and progress during the course but also the early identification of teachers' readiness for training and other indirect factors that influence the effectiveness of the educational process.

Teaching Methods and Engagement

The category "Teaching Methods and Engagement" focuses on the application of pedagogical practices and the combination of theoretical instruction with hands-on skill development in training TVET engineering teachers through online courses. This category explores key teaching methods and techniques, the organisation of practical activities, as well as strategies for engaging learners and effective formats of interaction with them.

Contemporary pedagogy is becoming increasingly complex, requiring TVET engineering teachers to possess technological literacy and to apply a variety of teaching algorithms and methodologies. Many experts highlighted the importance of integrating theoretical content with hands-on practice in online courses. They also pointed out that educational programmes must be regularly revised and adapted to reflect evolving external demands and conditions:

> *E1: "Indeed, pedagogy becomes a complex, imaginative activity that requires knowledge of technologies, specific algorithms, and teaching techniques."*
>
> *E4: "Pedagogical technologies should be superimposed, adapted to production technologies through various models, simulators, which are available in the educational institution."*

While a strong pedagogical foundation was considered essential for TVET engineering teachers, knowledge of methodology—encompassing all aspects of pedagogy, including strategies for content delivery and the creation of problem-based learning scenarios—emerged as one of the critical factors for an effective distance education process:

> *E1: "Therefore, these distance courses rely more on methodological knowledge when we teach them planning, control, of course, achievement analytics, and so on. Here, we are talking about basic pedagogical skills, the ability to design educational program documentation correctly, and so on."*
>
> *E9: "Methodology is more important than pedagogy because methodology includes pedagogy in one way or another. Pedagogy does not deal with material presentation, with material exposition."*

To make educational programmes effective in a distance learning format, it is important to use diverse, active learning methods — for example, group work, elements of gamification, and visual materials. Such techniques help keep learners engaged, support the development of practical skills, and improve how well the material is remembered:

> *E3: "The method of creating problem situations proves itself the most. These are group methods where roles are distributed within the team, including production roles and roles in solving some of their complex pedagogical tasks."*
>
> *E6: "I like to use some group learning formats…Firstly, gamification themes personally for me as a teacher have been used for quite some time already."*
>
> *E7: «Digital visual tools and gamification (gamification just worked that men compete with each other, ratings, so there it worked great, but when it comes to the educational environment, they do not really want to compete)."*

However, the use of modern interactive methods and practices does not replace the application of fundamental pedagogical approaches that have been employed for many years:

> *E1: "I am certainly a supporter of andragogy; I am a supporter of learning and self-education."*
>
> *E6: "You need to use certain didactic principles, well-known ones, from simple to complex and visualisation."*
>
> *E7: "Going through knowledge stages, skills, practical experiences."*
>
> *E11: "We try to specify, applying methods of anticipatory learning in its original sense and anticipatory professional preparation."*

It is important to emphasise that the use of new pedagogical technologies, approaches, and solutions is not a universal remedy and should be applied contextually, guided primarily by the goal of delivering maximum educational value rather than by the desire to incorporate as many tools as possible within a single program:

> *E1: "We strive to have two plans in our courses. One plan moves forward, mastering new techniques and technologies informed by psychological, methodological, and pedagogical theories. On the other hand, we stay grounded and pay attention to and help solve the tasks that are here, now, today."*
>
> *E6: "The main thing is to structure the session, to lead it step by step from goal setting to reflection."*

Pedagogical methods and techniques enhance the learning process, making it more accessible and applicable in practice. However, the most outstanding results are consistently observed among those TVET engineering teachers who receive well-structured assignments and already have practical experience. Such learners can immediately apply the acquired knowledge during the training process and return with feedback to discuss challenges, mistakes, and other issues related to implementing the information in their teaching practice:

> *E1: "The most successful audience is the audience of teachers, masters who are currently practising during the course…Before the session, a specific assignment is given that needs to be attempted, relying on one's experience and any sources to accomplish it. Moreover, the session is structured as a review and discussion of errors and findings to improve the product that was initially created ultimately. Therefore, we believe the most important thing is to have an educational task that improves as it is performed, resulting in the process of such distance discussion."*
>
> *E5: "Through assignments, meaning the task needs to be formulated in a way that prompts the learner to go and complete it."*
>
> *E9: "If I am talking about methods and techniques, it means that methods and techniques should go methods and techniques applied to their material, on their material."*

Many experts emphasised the importance of mutual feedback. The experts noted that its presence within the educational process enhances learners' comprehension of the material and provides teacher trainers with the opportunity to adjust the learning process in real-time:

E1: "Feedback from real activities, we suggest discussing what we teach with other people and trying to gauge their reactions."

E3: "There is feedback, reviews, responses – all the things that help us."

E5: "Surveys with feedback and strict deadlines after each meeting increase productivity of the course."

E6: "Often there is no feedback from students, from faculty, and this is the real problem."

E7: "You need an adequate feedback collection system so as not to bore, but at the same time not to miss the most important thing. I use standardised feedback with closed answers, where you can read analytics and summarise. Moreover, I always work with live feedback, textual."

E8: "A person must have something tangible as a result of an online course and also feedback; if they have a question, they should somehow answer this question, get an answer immediately, and not from a chatbot. They need feedback from the teacher; they should take a photo or record a video of what did not work out with this particular issue and send it to get feedback."

When discussing practical training, experts emphasised the importance of using practice-oriented and problem-based approaches in preparing TVET engineering teachers. According to the experts, the most effective type of instruction is that which focuses on solving real-world problems and developing professional skills and competencies. Assignments that involve analysing real cases, problematic situations, and examples from the learners' professional practice—along with approaches to their resolution—enable learners to simultaneously absorb theoretical knowledge and apply it in their teaching practice:

E1: "We adhere to an activity and practice-oriented approach. It is not just about imparting information; it is more closely aligned with problem-based learning. It is also essential for the course to be connected to real activities. Most often, this is done not at the level of methods or content, but at a personal level."

E1: "We show that we have the opportunity to change individual work to group work, project-based learning, so we apply and are not afraid of anything, use collaborative learning, flipped classrooms, and so on. Moreover, attitudes change. It is not just a well-dictated explanation for the record about what a flipped classroom is, or some meeting, or who knows what else. We have about 60 different tricks up our sleeve."

E6: "The main tool is industrial practices, during which students go to real colleges and teach real disciplines. We try to work out everything that we gave ourselves."

E11: "We also teach applying the knowledge and skills acquired in real life to establish contacts with people, to refine oneself, one's face, body in everyday communication."

Working on assignments within these approaches involves both the development of skills in the classroom and the application of knowledge through laboratory and practical work:

E4: "TVET engineering teachers develop skills and professional competencies through laboratory and practical sessions…Practice-orientedness depends on the number of

laboratories and workshops, educational production practices, and the design of courses and diplomas. Those are the things that focus on the formation of professional competencies. Practice orientation depends on the number of laboratories and practical, educational production practices, courses and diploma designs. In other words, those things that are aimed at the formation of professional competencies."

E6: "Not just to complete the project and attach it to the portal, but also defend their project, demonstrate the results of their work."

E10: "It is crucial to establish boundaries right away, clearly: when the practical work submitted by the learners will be reviewed by the teacher, when the practical work that is performed directly in the presence of the teacher will be evaluated, entered into the records, and so on—all the documents."

Experts have repeatedly emphasised the importance of preserving traditional pedagogical approaches in online courses while also highlighting the need to incorporate modern teaching practices simultaneously and integrate them with up-to-date digital tools.

E3: "All these courses have a basic pedagogical knowledge or are in the field of digital literacy."

E10: "Everything new that appears is just called something new, but in fact, it is experience accumulated over generations. The more I work, the more engineering and pedagogical personnel I produce, and the more I understand that the established system of engineering and pedagogical education used to be the most qualitative. It just needs to be filled with modern content."

When discussing teaching methods and technologies, particular attention was given to tools for learner engagement and interaction. In working with TVET engineering teachers, only minor differences distinguish courses designed for them from those intended for other learner groups. Experts noted that TVET engineering teachers often enter training programs without a genuine interest, resulting in initially low levels of engagement and motivation. For this reason, the first factor identified by experts as essential to making online learning effective for this group was the implementation of active learning and engagement methods. These methods included team-based activities, project-based learning, brainstorming sessions, opportunities for hands-on tasks, and interactive lectures that facilitate continuous communication among participants:

E1: "We constantly make brief stops so that each listener can express what they have acquired, what they have gained, what they have simply felt. Everyone can talk about their difficulties, and together, we find ways to overcome them. We pay attention to their practical difficulties and help them overcome them. Sometimes, we leave time just for group discussions, but there is a task that each listener prepares some material about certain obstacles."

E5: "Workshops and masterminds in terms of interaction between participants…More practical sessions, meetings, and brainstorming, where we, like bees, share ideas…One-to-one meetings with teacher trainers."

E6: "We used brainstorming sessions and more complex, more detailed assignments for students who need a higher level of knowledge."

E7: "Trying to keep hands busy… even if it is a lecture, for example, an online lecture, it should be an interactive lecture with constant communication with the listeners."

E8: "There are generally tools that help maintain attention and engage students, for instance, creating a community inside."

E9: "I try to show them on fingers what it is, with examples, and then open Excel and do it all manually in Excel. I mean, you understand how to create a situation of success in the simplest task."

In addition to the examples mentioned above, various interactive formats can also be identified as practical means of maintaining engagement and increasing learner motivation—for instance, competitions, quizzes, collaborative projects, and active interaction among participants:

E2: "We made a competition based on the material they learned."

E4: "We try to implement a talent pool development system as an engagement tool in our courses. Certification and competitive movement. Participation in various competitions of professional mastery as a pedagogical engineer."

E5: "These quick warm-up exercises, such as posting something, writing on the board, conducting a survey, completing a request, or creating your presentation, all help to boost engagement. We start a meeting with Kahoot, for example, and other warm-up exercises."

E6: "We engage students in various competitions, experiments, and scientific research. We also have tools when there is an opportunity to edit something together, add information, use something, and some links."

E9: "When you give some material or ask for material, or I tell you today about this, and tomorrow you tell me about that. Moreover, I have questions for you. To answer them, first, ask yourself many questions…To play out this situation."

Although digital tools are an integral part of online education, experts consistently point out that meaningful interaction and an individualised approach are equally important when teaching TVET engineering teachers. Opportunities for direct contact with teacher trainers and tailored support were frequently mentioned as key to maintaining learner engagement and motivation:

E4: "It is important to have face-to-face interaction with the instructor. Moreover, at the end of each course, I always provide a list of recommended literature and specific online courses."

E7: "I directly track so that they immediately review everything with me… if they make mistakes, something does not work out, so that I hear about it so that I help them work it out."

E8: "Within our online course, there is always an offline seminar."

E9: "You need to be constantly in touch… throughout the day, by email, in chat."

E10: "If you tell people about the difficulties you encounter in your professional activities using modern technologies, including communication and interactive technologies, and if you sincerely explain to people that this online course is aimed not only at transmitting

knowledge but also at exchanging experience, and primarily at gaining vital, necessary, up-to-date information on the training of TVET engineering teachers, then the interest from the learners increases."

E11: "Have an opportunity to interact periodically face-to-face (teacher-student) to see each other's perspectives and understand how interested and satisfied both sides are in this interaction."

The size of the learner group also plays an important role. The experts noted that in large groups, there is always the possibility of "going unnoticed," which reduces individual effectiveness. At the same time, experts expressed a negative view toward fully individualised formats in the training of TVET engineering teachers and the development of teaching skills, as such settings fail to create a sense of group dynamics. The ideal group size was identified as between 5 and 10 participants, a range that enables ongoing communication between the instructor and learners and fosters a supportive environment for practising pedagogical skills:

E4: "When there are even 200 people online, even 150 people, there is always the possibility of hiding out. It all depends on the individual, their motivation, and their desire to develop."

E9: "With only face-to-face, we will not create a classroom situation and so on. It will be just nodding, a heart-to-heart conversation for two. Fifteen people are already a lot because you need to allow each one to participate. Consider using small groups. Like 5-10 people."

Experts discussed the issue of maintaining attention with particular interest because it requires the use of various tools, such as videos, graphic inserts, interactive tasks, and rotating between different types of activities. Integrating these elements into the educational process allows teacher trainers to engage multiple modes of information perception, thereby ensuring that the content reaches the widest possible range of learners:

E6: "If it is just a lecture text posted, or it is just, say, a talking head that just speaks, that is one thing, but when some graphics back it up, some illustrations, maybe short videos with examples, demonstrating something, of course, this much more engages in learning this content."

E8: "Lectures are recorded, they watch, and in the offline seminar, they prepare questions. I outlined these questions for them, along with the relevant textbook pages. So logically, they had to watch the stream and read additional literature on those pages and textbooks. I wrote them questions, and they came to the online seminar. Everything should have gaming, interactive and visual elements."

E9: "Does every 15 minutes to distract to some videos, like with children, read, play, draw, play. Then you use sound, then you use a picture, then you use writing. Thus, you involve these three types of memory: visual, sensory, and auditory, in the educational process."

The analysis of the "Teaching Methods and Engagement" category showed that successful training of TVET engineering teachers through online learning requires a combination of theoretical knowledge and practical activities, the reasonable use of modern technologies, and consideration of specific educational objectives.

Experts noted that while modern interactive tools can enrich the learning experience, they should not displace established teaching practices. To sustain attention and keep learners engaged, they stressed the need to use a variety of methods—especially those that connect theory with practical

activities, such as practice-oriented and problem-based learning approaches. The experts also highlighted the necessity of personal interaction with learners and the use of individualised approaches in the teaching process. According to experts, effective interaction can only be achieved in groups of up to 10 participants. The use of various pedagogical methods should serve the achievement of specific educational objectives rather than being implemented merely for the sake of innovation.

Technology Integration

The category "Technology Integration" focuses on the use of technology in organising training processes for TVET engineering teachers. This category examines key technological solutions, forms of structured educational activities, and tools that improve the effectiveness of online courses for the targeted learner group.

The experts had mixed feelings about discussing technologies and their use in education. Most of them agreed that technology can be both beneficial and, at times, a hindrance to the assimilation of educational content. From the experts' point of view, technology is a tool that can be used to improve the perceived effectiveness of learning, but it should be chosen with caution. Since online courses themselves contain technological solutions, the integration of new tools into the structure of an online course must be approached thoughtfully:

> *E1: "Technology is just a means—a means we must put in the hands of those who truly want to make a difference, engage, and more. We not only list technologies but also equip teachers with them. It is important not to move into some purely theoretical sphere and try to pump up with modern technologies."*

> *E3: "It is necessary to use the tools that today's modern youth use (all possible platforms, tools, all possible groups, some messengers). Tailoring approaches to different age groups and integrating practical tools directly into online (digital) platforms can help bridge this gap in adaptation to the new technologies."*

> *E7: "You always need to choose the optimal amount of these tools, not overload, not overdo it."*

> *E10: "Most importantly, moderation in everything, ensuring that both sides, both the one teaching and the one learning, understand and speak in the same informational context."*

When discussing the thoughtful application of technology in education, experts emphasised the importance of providing practical experience through the use of additional technological tools—such as virtual laboratories, simulators, and similar resources. Experts noted that it is not enough to demonstrate learning materials; it is equally important to offer opportunities for applying acquired knowledge in real-world contexts, including integration with production processes:

> *E2: "We integrate only necessary tools, such as multimedia tools and virtual labs."*

> *E3: "It is clear that we often use simulators and trainers and integrate them into the educational process; this would be possible, for example, with the use of online education, but for the most part, we still need the mastery of practical techniques of the direct audience, directly on the spot of practical training at the enterprise, so it is not always possible for us to master practical techniques through online learning."*

E4: "The development of professional competencies is possible through VR technology, for example, virtual tours to enterprises."

E6: "We do not have such a big experience of using artificial intelligence in education, although we make some separate attempts…but we use a chatbot with some basic questions and answers."

E10: "There are many educational platforms available today where experiments, laboratory work, practical classes, preparation for demonstration exams, and work with equipment on simulators can also be conducted. We use them. There is an opportunity to record the process, the real production process, show it in an online session, and dissect it in detail: what it is, how it works, where it is located, how to operate it, how to troubleshoot, what possible problems there might be, and so on."

The use of technology should be aligned with the needs and characteristics of the target learner audience. Given that a single group may include TVET engineering teachers of different age groups and with diverse backgrounds, it is essential to use technology to create an optimal environment that enables seamless integration of all learners into the educational process:

E1: "What is good about LMS courses is that everything can be demonstrated; you can record whatever you want and discuss what you saw."

E7: "Services for synchronous communication, a shared field, can help to develop a shared environment that allows practising different pedagogical skills."

E8: "When we talk about digital services, we constantly forget the importance of accessibility to library resources. People should have free access to the literature."

E9: "Some accessible application or something convenient, which everyone has installed on their PC without professional help."

Technological solutions, such as online platforms, facilitate the creation of a learning environment where learners complete tasks under the guidance of their teacher. This not only supports skill development but also enhances engagement and strengthens the teacher-learner connection:

E2: "A combination of theory and practice in one lesson. We sat down online and did exercises together, but at a distance."

E5: "On Miro, we often do exercises like writing something, commenting on others, giving a thumbs-up, or choosing a sticker. All of this immediately increases engagement."

E10: "When materials are developed, there is the opportunity to conduct practical sessions on the educational platform itself. Here, students do not just take assignments, complete them, and attach them; rather, they work directly on the platform, performing tasks immediately within it. This helps establish contact between the teacher and the students."

The analysis of the "Technology Integration" category demonstrated that the use of technology in training TVET engineering teachers can enhance the effectiveness of educational courses by enabling the practical application of theoretical knowledge through various digital tools. However, respondents note the need to use technological solutions with caution, perceiving them as auxiliary tools in the educational process and not overloading the curriculum with them. The use of various interactive tools allows the creation of a virtual environment in which close teacher-student

communication can be realised, along with the simultaneous practice of skills. Experts have confirmed that the choice of technological tools for online courses should be based on student requests, ensuring that the use and convenience of these tools are the same for all learners. Moreover, the most positive learning outcomes can be achieved by adopting a balanced approach to integrating technology into the educational process, complemented by traditional educational tools.

Summary

Summarising the analysis of the transcripts from expert interviews, it can be concluded that the identified factors determining the effectiveness of online courses for TVET engineering teachers should be based on a comprehensive approach that combines various tools, such as competent course design, effective teaching methods, and well-thought-out integration of technologies. These components should be aligned with clearly defined educational goals, support learner motivation and engagement, and provide opportunities for the practical application of knowledge. Although online courses are inherently a technological solution, the use of additional tools must be approached with caution—evaluating their overall contribution to the educational process in a way that supports both the theoretical and practical development of TVET engineering teachers.

3.1.4 Findings for Quantitative Research

Grounded in a comprehensive theoretical analysis, including pedagogical theories, historical developments in engineering teacher education, and typologies of online learning, a qualitative study was conducted using interviews with teacher trainers involved in the development and implementation of online courses for TVET engineering teachers. The findings of the theoretical and qualitative analyses together formed the basis for the formulation of hypotheses, which were subsequently tested through quantitative methods. The respondents confirmed key ideas related to the transfer of pedagogical theories into online education through their responses. For example, the humanistic approach emphasises the importance of creating comfortable learning conditions that help students achieve their educational goals. In the context of online courses, this theory is confirmed by experts who have spoken about the need to include practical examples and timely feedback for the successful implementation of educational programmes. The humanistic theory—encompassing a wide range of indicators from addressing individual learner needs to promoting active learning—serves as a foundational framework for constructing hypotheses that require further empirical investigation.

The importance of feedback and individualised instruction is also reflected in behaviorist theory. At the same time, cognitive theory emphasises the importance of learning through observation of others and the use of visual tools. The constructivist approach, in turn, provides a basis for incorporating synchronous formats into the educational process. Albert Bandura's social learning theory highlights the significance of interactive methods and hands-on practice for the effective training of TVET engineering teachers—an idea frequently mentioned by the respondents. Experts noted that the integration of digital technologies should be selective and aimed at preparing learners for life in a digital society. Digital didactics emphasises the use of the hermeneutic approach as a process of exchanging information and knowledge about technical and software-related aspects, which was confirmed by experts' opinions. In the context of training TVET engineering teachers, particular importance is attributed to the Pädagogischer Doppeldecker model, as well as to andragogy and heutagogy approaches. These are oriented toward the use of blended courses that integrate theory and practice, multimedia components, and platform-based solutions grounded in empirical methods and a flexible, outcome-oriented blended learning process. They also emphasise the need to combine educational activities with other professional responsibilities.

According to the respondents, the didactic features of training TVET engineering teachers should be based on a blended learning approach that includes both in-person sessions and online formats. Although the experts rarely mentioned specific methodological models by name, their descriptions of the learning process can be associated with approaches such as HyFlex, blended curricula, and face-to-face sessions. Respondents also repeatedly noted that a significant portion of the courses was aimed at developing pedagogical competencies and mastering interactive teaching methods rather than delivering foundational subject knowledge in a specific engineering discipline.

Based on the collected data, a consolidated analysis of factors was conducted, which led to the identification of three key categories that formed the foundation for hypothesis formulation to be tested in the next phase of the study:

- Course Design and Evaluation — encompasses course content adaptation, evaluation, and structure;
- Teaching Methods and Engagement — focuses on learner interaction and the use of interactive teaching methods;
- Technology Integration — examines the use of technological solutions in the educational process.

Based on the theoretical research foundations and the findings of the qualitative part of the study, five hypotheses have been formulated and will be tested in the subsequent quantitative phase:

1. Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses.

In this study, "perceived usefulness and effectiveness of courses" refers to the subjective perception of TVET engineering teachers who are taking the courses regarding the relevance of online learning to their professional needs, the achievement of their goals, and the practical value of the courses. Respondents' assessment of online courses is based on their experience and perception rather than on objective metrics.
Experts emphasised that tailoring courses to the professional experience and tasks of TVET engineering teachers plays a crucial role in how the course is perceived and its overall success.

> *E3: "It is crucial to understand the audience, its generation and use appropriate teaching methods. "*

> *E1: "Indeed, pedagogy becomes a complex, imaginative activity that requires knowledge of technologies, specific algorithms, and teaching techniques. "*

To test this hypothesis, it is necessary to gather insights into teacher trainers' experiences with online courses: their learning goals, course topic preferences, challenges encountered (to identify the need for adaptation), and how they would like programs to be customised to meet their needs. It is also essential to explore what additional features or improvements they would consider valuable, as well as what elements were lacking in their online learning experience.

The corresponding questions should help reveal how teachers interact with online courses and how they perceive these courses in relation to their professional needs and goals.

2. The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers

In this study, Traditional Teaching Methods are understood as forms of organising the learning process, implemented in a face-to-face format in a physical, educational space (classrooms, laboratories) and based on direct interaction between the teacher and students. The key characteristics of traditional teaching include frontal teaching (lectures), classroom seminars and workshops, the use of printed learning materials, and limited use of digital technologies. These methods involve rigidly fixed timetables, synchronised communication and face-to-face monitoring of learning progress.

In contrast, online learning functions with the help of digital platforms and telecommunications networks, which broaden the territory of educational program realisation far beyond the institute, as well as utilise different formats, multimedia resources, and forms of feedback.

Respondents identified the integration of theoretical online learning with workplace-based practical experience as one of the most effective approaches. In the context of this hypothesis, convenience refers to the perceived ease with which TVET engineering teachers can access, participate in, and benefit from blended learning formats. It encompasses flexibility in terms of time and location, adaptability to individual learning paces, and reduced logistical barriers such as travel or scheduling conflicts.

TVET engineering teachers frequently combine their teaching duties with continuous professional development. Blended learning formats help to integrate education into their schedule smoothly. That is why the convenience, flexibility, and adaptability of such formats could be the pillars of course engagement rates and overall satisfaction with the educational process.

It is important to note that experts emphasised the flexibility of the blended approach as a way to meet the diverse needs of learners through the balanced use of different formats to achieve the desired educational outcomes:

> *E3: "It will be some blended learning, a mix of online and face-to-face formats. For specialised knowledge, especially in technical fields, a combination of blended learning with hands-on practice in the workplace is ideal. This approach allows students to study the basics online independently, then try what they have learned through real-world practice, ensuring they fully understand the material."*
>
> *E4: "Online training for TVET engineering teachers can only cover pedagogical education; practical experience must be gained on-site at the enterprise. "*
>
> *E6: "Online courses are effective when there is a need to incorporate hybrid forms of learning. Some disciplines, although not all, still require in-person study and mastery, especially when workshops or lab work are involved."*

To test this hypothesis, it is necessary to determine the opinions of TVET engineering teachers regarding the online learning format they prefer and the problems they encounter during the learning process. It is essential to identify their individual needs for practical sessions and closer communication with teacher trainers and peers, determine which formats they prefer in online education, and identify which methods and tools they feel are lacking. Additionally, the study examines the essential skills required to teach online independently after training and identifies the improvements and additional features that TVET engineering teachers consider critical in online courses.

3. The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers

The respondents emphasised the importance of teamwork and interactive instructional strategies for increasing engagement in the learning process and improving educational outcomes for TVET engineering teachers:

E3: "The method of creating problem situations proves itself the most. These are group methods where roles are distributed within the team, including production roles and roles in solving some of their complex pedagogical tasks. "

E6: "I like to use some group learning formats…I like to use some group learning formats…Firstly, I have personally used gamification themes as a teacher for quite some time already."

To test this hypothesis, it is necessary to understand what resources are important to TVET engineering teachers in online courses and what tools have allowed them to immerse themselves more deeply in the educational process. It is also pivotal to explore different formats of effective active teaching methods, the role of interactive modules and multimedia materials in the educational process, as well as the importance of live communication in the online learning experience.

4. The integration of modern technologies (virtual laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness

The respondents noted that the use of technological tools should be intentional and appropriate. The overuse of various tools in the educational process should be avoided, as it does not yield the desired educational results. However, the use of technology itself increases the accessibility of education and the practical focus of teaching:

E1: "Technology is just a means—a means we must put in the hands of those who truly want to make a difference, engage, and more. We not only list technologies but also equip TVET engineering teachers with them. It is important not to move into a purely theoretical sphere and try to rely on modern technologies. "

E7: "You always need to choose the optimal amount of these tools, not overload, not overdo it. "

To test this hypothesis, it is necessary to understand the thematic needs of TVET engineering teachers and how comfortable they are with using digital tools and technologies in general (in order to understand the level of preparedness of teachers and the need for their training). It is essential to emphasise the benefits of utilising additional resources and technological solutions to enhance the online learning experience, as well as the potential of interactive technologies to facilitate a deeper immersion in online learning. The study should examine the level of technology integration in the educational process, its orientation towards addressing ethical issues, and the importance of digital literacy training in assessing the value of learning.

5. Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes

The experts emphasised the importance of timely, personalised feedback from teacher trainers. It was noted that such feedback strengthens learner motivation and enhances performance:

E8: "A person must have something tangible as a result of an online course and also feedback; if they have a question, they should somehow answer this question, get an answer immediately, and not from a chatbot. They need feedback from the teacher. To do this, they should take a photo or record a video of what didn't work out with this particular issue and send it to the teacher for feedback. "

To test this hypothesis, it is necessary to determine whether there is a lack of interaction between learners and teacher trainers and to identify the need for regular feedback. It is critical to evaluate whether communication with the instructor facilitates deeper engagement with the course content, the extent to which learners require individualised support, and how teacher trainers assess the effectiveness of personalised feedback and mentoring. Additionally, the analysis should examine whether high-quality feedback affects learners' satisfaction with online learning and contributes to an improved learning experience. Given that many experts highlight the critical role of feedback in the educational process, this hypothesis is one of the key ones to be tested.

Thus, the proposed hypotheses reflect key findings based on interviews and theoretical analysis, which are structured to provide a comprehensive examination of the factors influencing the perceived effectiveness of online courses for TVET engineering teachers.

To empirically test the hypotheses, a quantitative study in the form of a large-scale survey is proposed. The survey will be structured around the following thematic blocks (Appendix G):

- Online course experience (satisfaction of TVET engineering teachers with online courses and assessment of course adaptation to their specific needs);
- Selecting and evaluating participation in online courses (factors influencing the selection of an educational program, course completion, and the level of technological competence);
- Resources and technologies (preferences of TVET engineering teachers regarding the use of technological tools in the educational process);
- Engagement and interaction (examination of engagement strategies, communication effectiveness, and preferred learning methods);
- Practical exercises and evaluation (tools and methods used for practical training and the perceived effectiveness of interactive modules from the perspective of TVET engineering teachers);
- Experience in delivering online courses (independently, as a teacher) (teachers' experience with integrating online learning into their teaching practice, the challenges they encounter, and desired improvements);
- Overall satisfaction and recommendations (overall satisfaction with the online learning experience and suggestions for improving online courses).

This study will employ a mixed-methods approach to validate the hypotheses formulated based on the qualitative analysis of interviews with teacher trainers delivering online courses to TVET engineering teachers. To quantitatively test these hypotheses, a survey will be conducted among TVET engineering teachers who have participated in such courses. The survey will assess their perceptions and satisfaction levels, structured around the three key categories: Course Design and Evaluation, Teaching Methods and Engagement, and Technology Integration.

The results of the quantitative analysis will be compared with the qualitative data to confirm or refute the proposed hypotheses. This approach will provide a comprehensive understanding of the effectiveness of online courses for TVET engineering teachers.

3.1.5 Methodological Criticism

Methodological criticism is an integral part of this scientific research, as it enables the recognition and analysis of potential limitations that may affect the interpretation and reliability of the results. Comprehending the limitations helps increase the quality of the study by providing an accurate understanding of its conclusions and preventing possible mistakes in practical implementation. According to Ross and Bibler Zaidi (2019), describing the limitations of the research not only enhances its reliability but also strengthens the scientific community's confidence in the work's conclusions (Ross & Zaidi, 2019). This section discusses the main limitations of the study, analyses their impact on the results obtained, and suggests possible ways to minimise these limitations in the future.

One of the key limitations of this study is the sample size for the interviews. While data saturation was reached after eight interviews (Creswell, 2007) and confirmed with 12 additional participants, the sample remains limited in terms of institutional and regional diversity. Including teachers from a broader range of contexts could have added additional perspectives on the digital preparation of TVET engineering teachers without necessarily improving saturation.

Another limitation is that qualitative methods do not have strictly standardised indicators that can help assess the reliability and validity of the collected data. This makes the process of data interpretation and verification more complicated (Mayer, 2013). As Mayer (2013) notes, the inclusion of quotations in research results does not always allow for unambiguous conclusions about the significance of the data presented, as they can be interpreted differently depending on the researcher's context and analytical position. This is consistent with Spöhring's (1995, p. 159) view, which argues that each interview can be interpreted in multiple ways, emphasising the importance of transparency in the data collection and analysis process. In this study, transparency was ensured through an open and detailed description of all research stages, including data collection methods, participant selection criteria, and interview procedures. However, despite these measures, the problem of subjectivity in data interpretation remains, which can be a significant limitation (Flick, (cited in Mayer, 2013), 2016).

A crucial aspect influencing the reliability of research is the involvement of multiple researchers at various stages of the project. Mayring (2000) emphasises that to increase the reliability of qualitative research, it is necessary to involve multiple researchers at all stages of the work, which minimises bias and subjectivity in the analysis (Mayring, 2016, p. 124). However, this study did not include the participation of several researchers, which can be considered a limitation affecting the reliability of the results obtained. Johnson R. Burke also notes the difficulties in conducting qualitative and quantitative analyses by a single researcher, especially when using mixed methods (Johnson & Christensen, 2014, p. 652). In this study, the use of mixed methods could have led to certain limitations related to data integration and the interpretation of conflicting results (Johnson & Christensen, 2014, p. 653). This study conducted an in-depth thematic analysis to identify key patterns and trends in the data, helping minimise the risk of contradictions in interpretation.

The use of the 'horizontalisation' method helped not only to minimise bias but also to oversimplify complex knowledge. This could potentially reduce the depth of analysis. The process of selecting significant statements for analysis is subjective. In most cases, it reflects the researcher's experience and perspective, which can influence the study's results (Johnson & Christensen, 2014, p. 597).

Additionally, the limitations associated with the use of the standardised in-person, open-ended, in-depth interview format should be considered. This format of the interview defined the limits to the variability in question formulation, which can influence the conversation flow and the relevance

of the answers. However, the use of this format was warranted because it helps ensure consistent data collection and gather detailed, comprehensive responses (Patton, 2014, p. 643).

Summary

Methodological criticism enabled the identification of the study's strengths and weaknesses. The methods chosen for conducting qualitative research fully meet the objectives and goals of the study despite the identified limitations in their use. In the future, to improve the quality of research, it is recommended to increase the sample size, involve multiple independent researchers in the study, and employ additional measures to minimise subjectivity in data interpretation. The implementation of the proposed improvements in further developments will strengthen the methodological basis of the research and achieve a deeper understanding of the phenomenon under study.

3.2 Empirical Part 2: Questionnaire Survey

3.2.1 Development of the Questionnaire

For the next stage of the study, a questionnaire was developed as a tool to analyse the experience of TVET engineering teachers participating in online learning within the TVET system and to triangulate the collected data. The questionnaire is designed for quantitative analysis, aimed at testing the hypotheses formulated earlier.

The structure of the questionnaire was based on the results of the qualitative phase, during which interviews identified key factors influencing the perceived effectiveness of online courses, as well as specific features of their design and implementation by teachers working in the field of TVET The primary aim of the questionnaire is to conduct a comprehensive analysis of TVET engineering teachers' opinions on the factors that influence the perceived effectiveness of online courses, as well as to validate the hypotheses developed through theoretical analysis and expert interviews.

During the development of the questionnaire, eight thematic blocks were identified, each of which describes specific factors in detail that, when considered comprehensively, can significantly affect the effectiveness of online courses. The focus was on testing hypotheses from the qualitative stage of the research, covering key aspects such as course content adaptation, a balanced approach to blended learning formats, active teaching methods, the use of technology, and the importance of feedback. The primary goal of the quantitative analysis is to examine the impact of these factors on how TVET engineering teachers in the TVET system perceive the effectiveness of online courses from their perspective.

The questionnaire was structured into several thematic sections, featuring clear and accessible questions, allowing respondents to complete it within 15 minutes. Appendix G presents the rationale behind each hypothesis and the corresponding questions designed to test it. The questionnaire predominantly employed various question types, including multiple-choice questions (with or without an open-ended option), Likert scale items, and Closed-ended questions with the possibility of additional open responses. To gather more detailed feedback and suggestions, several open-ended questions were included, while closed-ended questions provided clear answers on specific aspects of the study. A detailed description of the questions and the measurement scales used is provided in Table 3.1.

Thus, the developed questionnaire serves as a well-justified instrument for quantitative analysis, enabling the verification of hypotheses and addressing potential gaps in the expert responses obtained during the interview phase.

Table 3.1 *Operationalisation and Measurement of Research Variables*

Thematic Blocks of The Survey	Question Topics	Operational Definition	Measurement	Question Number
Online courses experience	Motivation and Objectives	The goals and reasons for taking online courses.	Multiple-choice question with an open-ended option	Q1
	Course Selection and Topics	The topics and content chosen for online courses.	Multiple-choice question with an open-ended option	Q2
Selecting and evaluating participation in online courses	Challenges and Technical Issues	Identifying problems faced during courses.	Multiple-choice question with an open-ended option	Q3
	Support and Comfort Level	Assessing support quality and user comfort.	Likert scale Five-Point Scale	Q4
Resources and technologies	Resources and technologies	Key resources and technologies for online learning.	Likert scale Five-Point Scale	Q5- Q7
Engagement and interaction	Engagement and adaptation in online courses	Explore how effectively participants connect with course content and how well the courses are tailored to meet their individual educational needs and preferences.	Multiple-choice question with an open-ended option	Q8, Q9, Q10-11
Practical exercises and evaluation	Practical Application and Tools	Tools and methods for practice.	Likert scale Five-Point Scale	Q12
	Interactive Learning Experience	Engagement through interactive modules.	Likert scale Five-Point Scale	Q13
Experience in delivering online courses (independently, as an educator)	Improvements and Features	Desired enhancements for online courses.	Multiple-choice question with an open-ended option	Q14
Overall satisfaction and recommendations	Satisfaction and Feedback	Evaluating satisfaction with courses.	Open-ended question	Q15
	Professional Development and Skills	Impact of courses on skills.	Open-ended question	Q16
	Improvements and Recommendations	Desired changes and enhancements.	Open-ended question	Q17

3.2.2 Implementation

Pretest

After completing the final version of the questionnaire, which was linked to the research hypotheses and structured into thematic blocks, a pilot test was conducted to assess its accuracy, relevance and ease of completion. The primary purpose of the pilot testing was to identify potential issues with the perception and interpretation of questions, to verify the logical sequence of their arrangement, and to detect any possible technical and content-related shortcomings. Furthermore, the primary objective of additional testing is to verify the questionnaire's reliability and ensure that it encompasses all the necessary aspects of the hypotheses, thereby aiming to collect high-quality data for subsequent quantitative analysis.

The pilot test involved 10 respondents: five experts in online education for TVET engineering teachers with experience in course development and delivery and five TVET engineering teachers who had completed such courses. Participants were asked not only to complete the questionnaire but also to assess it using a 5-point Likert-type scale (1 = not relevant, 5 = highly relevant). The following criteria were evaluated:

- clarity and precision of wording,
- logical sequence of questions,
- ease of completion and optimal survey length,
- and comprehensiveness of thematic coverage.

Respondents were also allowed to leave open-ended feedback regarding possible improvements to the questionnaire (Appendix H).

The analysis of the pilot results showed that the questionnaire was considered logical, coherent, and comprehensive in covering the key aspects derived from the study's hypotheses. However, some suggestions for improvement were received. A few respondents noted the potential for ambiguous interpretations of specific questions, which necessitated clarification of wording to enhance understanding. Additionally, experts recommended adding minor structural adjustments to facilitate smoother transitions between thematic blocks. Some participants also suggested adding instructions for questions that required selecting multiple responses. Following these revisions, the updated version of the questionnaire was sent back to the same group of experts for a second round of validation.

To assess the reliability and validity of the questionnaire, the intraclass correlation coefficient (ICC) was calculated (LeBreton & Senter, 2008; Peñataro-Pintado et al., 2022) based on expert evaluations of 18 questions using the 5-point Likert scale. The ICC score was 0,81, indicating a high degree of consistency among expert ratings. The average relevance score across all questions was 4,3. Questions that received divergent expert ratings were further discussed and reviewed during the expert feedback session.

The results of the pilot testing confirmed that the final version of the questionnaire, after thorough refinement, is ready for deployment in the quantitative stage of the study. The corrections ensured the clarity and usability of the tool, thereby guaranteeing the collection of reliable and valid data for hypothesis testing and further analysis. The final version of the questionnaire distributed during the quantitative stage of the study is provided in Appendix I.

Implementation

- Sample definition

For the quantitative stage of the study, the target audience consisted of TVET engineering teachers who had participated in online professional development programs for vocational education teacher trainers within the past three years. The total number of teachers working in the TVET and VET systems in Russia is expected to be approximately 21,169 in 2024 (Federal Institute for Digital Transformation in Education, 2024). However, TVET engineering teachers represent only a small fraction of the overall target population of TVET teachers. Based on expert estimates obtained through consultations with directors of TVET and VET institutions, it is assumed that there are approximately two TVET engineering teachers per institution across 4,600 TVET and VET organisations. This results in an estimated total of about 9,200 TVET engineering teachers. It is important to note that no exact statistical data on this specific population is publicly available. Many TVET and VET institutions do not share this information for research purposes; therefore, these figures are based on publicly accessible sources. They may involve minor deviations from the actual numbers.

To be eligible to participate in the survey, respondents had to meet the following criteria:

- Be TVET engineering teachers,
- Have participated in at least one online professional development program within the past three years,
- Be aged 22 or older (no upper age limit was applied),
- Reside in the Russian Federation.

To calculate the required sample size, the classic Cochran formula (1977) was used, which considers a 95% confidence level and a 5% margin of error (based on Cochran, 1977).

$$n = \frac{Z^2 * p * (1 - p)}{E^2}$$

where:
Z — is the corresponding to the confidence level (for 95%: Z=1,96);
p — is the assumed proportion (0,5, to account for maximum variability);
E — is the margin of error (0,05 for 5%).

For this finite population of 9,200 individuals, the required sample size was calculated with a finite population correction (FPC) as follows (Cochran, 1977):

$$n_0 = \frac{(1{,}96)^2 * 0{,}5 * (1 - 0{,}5)}{(0{,}5^2)} = 384{,}16$$

$$n = \frac{n_0}{1 + \frac{n_{0-1}}{N}} = \frac{384{,}16}{1 + \frac{384{,}16 - 1}{9200}} = 369{,}85 \approx 370$$

Thus, to achieve a 95% confidence level with a 5% margin of error, the minimum required sample size was calculated to be 370 participants. However, during the study, 237 responses were collected, which is lower than the theoretically calculated value. Despite this, a sample size of 237 respondents can be considered sufficient for the following reasons:

- With a reduced sample size from 370 to 237, the margin of error increases to approximately 6,6%, which remains acceptable for educational research, especially in contexts where access to the target audience is limited. As noted by Creswell, a margin of error within 5–7% is acceptable for studies aimed at identifying general trends in education (Creswell, 2012). A sample of 237 provides a confidence level of approximately 90%, which is also deemed satisfactory in pedagogical research, particularly given the specificity of the target group.

- The TVET engineering educator population in Russia represents a specialised group, requiring different considerations when determining the sample size. In studies involving narrow target audiences, reduced sample sizes are acceptable and can still provide sufficient precision for analysing key patterns (Babbie, 2021). For specialised populations, a sample size of 200–300 may be enough to identify stable trends and draw well-founded conclusions.

- A crucial factor is the quality of the data collected. The study included TVET engineering teachers from various Federal Districts of the Russian Federation, ensuring geographical diversity and a variety of opinions, which is particularly important in research focusing on unique target groups, such as TVET engineering teachers. From the perspective of representativeness, the data collected from 237 respondents are sufficient to conduct analysis and draw conclusions regarding the factors influencing the effectiveness of online learning for TVET engineering teachers (Field, 2018, 2024).

- *Method of questionnaire distribution*

To conduct the survey, the Google Forms platform was utilised, offering broad access to the questionnaire and providing a convenient completion process for respondents residing in various regions across Russia. The use of an online form also ensured anonymity and confidentiality, which encouraged more sincere responses and the provision of true-to-life information (Cochran, 1977).

The distribution of the questionnaire was organised in two stages:

- First stage (June–September 2024)

The questionnaire was shared via social media (in professional groups and communities), generating a total of 8,458 views, and 750 email invitations were sent, encouraging recipients to complete the anonymous survey. These efforts resulted in 156 responses. The first stage occurred during the summer vacation period, which likely contributed to the lower response rate, as many respondents were on leave at the time.

- Second stage (September–October 2024):

In September, after the holiday period, posts were re-published in professional social media communities, generating an additional 7,629 views. A further 140 emails were sent, ultimately resulting in a total of 237 responses across both stages.

The use of Google Forms enabled cost-effective data collection, which was particularly important given the geographically dispersed target audience. The survey was available 24/7 and could be completed at the participant's convenience, which helped increase response rates. The guaranteed anonymity was particularly valuable in obtaining honest and open responses (Cochran, 1977).

- *Data collection*

The data collection period spanned from June to November 2024. The process encountered several challenges. Primarily, some potential respondents declined participation, citing concerns about the length of the questionnaire and doubts regarding anonymity. To increase interest in participation, a small incentive was offered—a free professional webinar and a complimentary copy of the author's book. This helped improve the response rate to some extent, but the main challenge remained: the difficulty in locating TVET engineering teachers who had participated in online

courses. Some potential participants either lacked such experience or were not interested in participating in the study.

To ensure the representativeness of the sample, targeted outreach was conducted through colleges and technical schools across all federal districts of Russia. This enabled the inclusion of teachers from diverse regions. Despite the difficulties, the final sample of 237 respondents represents a diverse audience and provides a sufficient amount of data to meet the research objectives. Thus, the implementation of the survey—targeting a sample of TVET engineering teachers and conducted using a multi-stage distribution strategy—resulted in the collection of representative data essential for subsequent analysis. It is essential to note that, through a rigorous selection process, refinement of questionnaire items, and the utilisation of diverse distribution channels, the necessary data variability was achieved. This, in turn, lays a solid foundation for moving on to the next stage of the study—evaluating and analysing the collected data.

3.2.3 Evaluation

The collection of factors influencing the effectiveness of online courses for TVET engineering teachers was conducted through the analysis of collected data using quantitative methods. The primary goal was to test the hypotheses related to the factors influencing the perception and effectiveness of online learning.

Procedure

1) Data processing procedure

To ensure the accuracy and reliability of the analysis, the collected data underwent thorough preparation and coding, which allowed the information to be converted into a format suitable for statistical analysis. The procedure consisted of several stages: verifying data for completeness and accuracy, coding categorical data, and coding qualitative data from open-ended questions.

2) Preparing data for analysis

In the first stage, a check was performed for missing values in the data tables. Missing entries were found only in open-ended questions (Questions 15, 16, 17, and 18), as well as in items where respondents could select the "Other" option and provide additional input. Since all mandatory questions were marked as required in Google Forms, most fields contained complete responses. To handle the missing data, it was decided to use imputation, where the most frequent response was used for categorical variables (Cohen et al., 2017). No questionnaires were excluded from the analysis, as all required fields were completed in full. As a result of the preparatory stage, all 237 questionnaires were retained for analysis.

The study included a data accuracy check. Inconsistencies and non-standard entries in textual responses were identified and standardised. For example, terms like "materials" and "lectures and presentations" were grouped under the unified label "educational materials." This process eliminated discrepancies and ensured consistency in data input. Additionally, a check for input errors was carried out using filters for each data column, which confirmed the absence of outliers or invalid values. After all corrections and data cleaning procedures were completed, a final dataset was compiled, containing complete, consistent, and error-free responses—ready for statistical analysis.

3) Data coding

After data cleaning, the coding stage was carried out to prepare the dataset for statistical analysis. The coding process involved transforming categorical variables and processing open-ended responses, as well as multiple-choice questions.

Data type definition

Categorical variables were present in the dataset, including questions that used Likert scale ratings. All open-ended responses were converted into a multiple-choice format to quantify the frequency of key themes.

Categorical data coding

For statistical analysis, the Likert scale responses were coded as follows:

- Not difficult at all — 1
- Slightly difficult — 2
- Moderately difficult — 3
- Quite difficult — 4
- Extremely difficult — 5

Additionally, the survey included Question 0, which was analysed separately and reflected respondents' age characteristics. For statistical processing, age was recoded into numeric values:

- Under 25 — 1
- 25–34 — 2
- 35–44 — 3
- 45–54 — 4
- 55–64 — 5
- 65 and older — 6

Coding of Open-Ended Responses and Multiple-Choice Questions

For processing open-ended questions, which yielded textual responses, an inductive coding method was applied—based on systematically identifying categories and codes from respondents' answers without a predefined framework (Charmaz, 2006). The analysis was conducted using QCAmap, [2] a specialised tool for qualitative content analysis. A project was created in the software, and the textual materials were uploaded as separate files for each question. In the first stage, core categories were formed by integrating inductively generated subcategories into broader groups, identifying recurring patterns among them. Once the coding was complete, the program automatically generated a frequency table of the coded categories (Mayring, 2019).

Following this initial coding phase, the data were exported to Excel for further editing and adaptation for statistical use. The Excel table included category identifiers, such as the research question number (e.g., "Q15") and the corresponding category number. This flexibility enabled the researcher to prepare the dataset for deeper quantitative analysis.

During the analysis, key categories were identified that reflected the main themes of the responses. For example, in response to the question, "What do you think was missing in the online course to make you fully satisfied with the learning outcomes?" the most frequently mentioned themes were "Materials and content accessibility" and "Practical applicability". For each identified category, a separate binary column was created, where a value of "1" indicated that the respondent mentioned the theme, and "0" stated that it was not mentioned. This allowed for a quantitative evaluation of how often different aspects were addressed (Seidman, 2019). Questions 15 and 18 were merged, as their responses addressed similar topics related to factors influencing the effectiveness of online courses, including suggestions for improvement and the integration of additional features into the educational process. The use of inductive coding enabled the researcher to extract meaningful

[2] available for free at: www.qcamap.org

categories and conduct content analysis to explore patterns (Mayring, 2022a; 2022b), thereby structuring the data and preparing it for further statistical analysis.

For multiple-choice questions, binary coding was applied (Creswell, 2009). Each response option was represented by a separate column, where a value of "1" indicated that the respondent had selected that option, and "0" indicated that it had not been selected. This method ensured a clear data structure ready for analysis. Questions using the Likert scale were processed with their original values preserved, as stated in the survey (e.g., from "1" — "very uncomfortable" to "5" — "very comfortable") (Yin, 2016). This maintained internal consistency and preserved the subjective evaluations of participants.

Thus, the application of an inductive approach for open-ended responses and binary coding for multiple-choice items ensured data standardisation and prepared the data for hypothesis testing and further statistical analysis.

Software Tools

To analyse the data and test the hypotheses in this study, the RStudio environment (version 4.4.3) with the R programming language was used (Wickham et al, 2023). This tool was chosen due to its open accessibility, ability to handle large datasets, and wide range of statistical and visualisation tools, which ensure both analytical accuracy and visual clarity.

The following packages and functions were applied in the study (Wickham et al., 2019; Wickham, 2019; Wickham & Hester, 2018; Wickham & Henry, 2019; Wickham & Bryan, 2019):

1) Data Preprocessing and Cleaning

At the data preparation stage, both Base R functions and specialised libraries were used:

- `base R`: `summary()`, `str()`, `table()`, `colMeans()` — to analyze data structure and calculate descriptive statistics.
- dplyr: `mutate()`, `filter()`, `select()`, `summarize()` — for data manipulation.
- tidyverse: A comprehensive toolkit for data cleaning and transformation.
- `na.omit()` — To remove missing values.

2) Statistical Analysis and Hypothesis Testing

To test the statistical significance of the findings, the following methods were applied:

- Chi-square test (χ^2) (`chisq.test()`) — for analysing differences between respondent groups.
- Wilcoxon test (`wilcox.test()`) — for comparing distributions in Likert scale data.
- Correlation analysis**:**
  - Spearman's rho (`cor.test(method = "spearman")`)— to assess rank-based associations.
  - Kendall's tau (`cor.test(method = "kendall")`) — for non-parametric correlation analysis.
- Cramer's V (`cramersV()`) — to measure effect size for significant χ^2 tests
- Fisher's exact test (`fisher.test()`) — for analysis of small sample categorical data.

3) Data Visualisation (Wickham et al., 2019)

- ggplot2: Used for creating various plots (`ggplot()`, `geom_bar()`, `geom_histogram()`, `coord_flip()`).
- RColorBrewer — Enhanced colour palette selection for improved graphic readability.

The use of these tools enabled a comprehensive statistical analysis, allowing the identification of significant patterns within the sample and an objective testing of hypotheses formulated during the qualitative phase of the study.

4) Data Analysis Process

This study involved a comprehensive quantitative analysis of the data, which included data preprocessing, descriptive statistics, statistical analysis to identify patterns and test hypotheses, and visualisation of key findings. The analysis was conducted using RStudio (version 4.4.3) with the aid of packages such as dplyr, ggplot2, and tidyverse, as well as other statistical tools.

The data analysis process consisted of the following stages:

1) Data Preprocessing

In the first stage, the following steps were carried out:

- Data structure verification

The functions `str(data)` (Figure 3.1) and `summary(data)` (Figure 3.2), were used to ensure the correct formatting of variables (numeric, categorical, binary).

```
tibble [237 × 143] (S3: tbl_df/tbl/data.frame)
 $ Q1_1  : num [1:237] 0 0 1 0 1 1 0 0 1 0 ...
 $ Q1_2  : num [1:237] 1 1 1 1 1 0 1 0 1 0 ...
 $ Q1_3  : num [1:237] 1 1 0 1 1 0 1 1 0 1 ...
 $ Q1_4  : num [1:237] 0 0 0 0 0 0 1 0 0 0 ...
 $ Q1_5  : num [1:237] 0 0 0 0 0 1 1 0 0 0 ...
 $ Q1_6  : num [1:237] 0 0 1 0 0 1 0 0 0 0 ...
 $ Q1_7  : num [1:237] 0 1 0 0 0 1 1 1 1 0 ...
 $ Q1_8  : num [1:237] 0 0 1 1 0 1 0 1 0 0 ...
 $ Q1_9  : num [1:237] 0 1 1 0 0 0 1 1 0 0 ...
```

Figure 3.1 *Questionnaire data structure*

```
> summary(R_17Q_Full)
      Q1_1             Q1_2             Q1_3             Q1_4       
 Min.   :0.0000   Min.   :0.0000   Min.   :0.0000   Min.   :0.0000  
 1st Qu.:0.0000   1st Qu.:1.0000   1st Qu.:0.0000   1st Qu.:0.0000  
 Median :1.0000   Median :1.0000   Median :0.0000   Median :0.0000  
 Mean   :0.5612   Mean   :0.7595   Mean   :0.4937   Mean   :0.3586  
 3rd Qu.:1.0000   3rd Qu.:1.0000   3rd Qu.:1.0000   3rd Qu.:1.0000  
 Max.   :1.0000   Max.   :1.0000   Max.   :1.0000   Max.   :1.0000  
      Q1_7             Q1_8             Q1_9            Q1_10       
 Min.   :0.0000   Min.   :0.0000   Min.   :0.0000   Min.   :0.0000  
 1st Qu.:0.0000   1st Qu.:0.0000   1st Qu.:0.0000   1st Qu.:0.0000  
 Median :0.0000   Median :0.0000   Median :0.0000   Median :0.0000  
 Mean   :0.4641   Mean   :0.3333   Mean   :0.2068   Mean   :0.1561  
 3rd Qu.:1.0000   3rd Qu.:1.0000   3rd Qu.:0.0000   3rd Qu.:0.0000  
 Max.   :1.0000   Max.   :1.0000   Max.   :1.0000   Max.   :1.0000  
```

Figure 3.2 *Questionnaire data summary*

- Detection and handling of missing values

The function `colSums(is.na(data))` was used to identify missing data. No missing values were found in the required questions. For categorical variables, mode imputation was applied by replacing missing values with the most frequent response. (Figure 3.3)

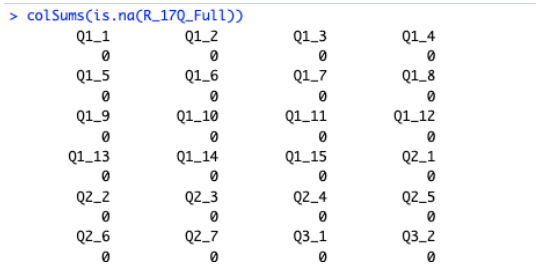

Figure 3.3 *Missing questionnaire data report*

- Binary variable coding (0 = not selected, 1 = selected) and Likert scale transformation were performed to prepare the data for further analysis.
- Creation of summary tables and merging datasets from different parts of the study were also conducted.

2) Descriptive Statistics and Frequency Analysis

To gain a general understanding of the data structure, the following were calculated:

- Means and standard deviations (`mean()` и `sd()`) for Likert-scale questions;
- Frequency distributions (`table()`) for each survey item;
- Visualisation of response distributions using histograms (`hist()`) and bar plots (`barplot()`) to illustrate respondents' preferences clearly.

Example: Analysis of responses regarding the importance of adapting online course content

```
summary_Q9 <- R_17Q_Full %>%
  summarise(across(starts_with("Q9_"), ~mean(. == 1) * 100)) %>%
  pivot_longer(cols = everything(), names_to = "Category", values_to =
"Percentage")

ggplot(summary_Q9, aes(x = reorder(Category, -Percentage), y = Percentage,
fill = Category == "Q9_7")) +
  geom_bar(stat = "identity", show.legend = FALSE) +
  coord_flip() +
  scale_fill_manual(values = c("TRUE" = "red", "FALSE" = "gray70"))
```

This analysis enabled the identification of key factors influencing the perception of online course effectiveness.

3) Statistical Analysis

For each hypothesis, relevant survey questions were selected, and appropriate statistical methods were applied:

3.1 Analysis of Differences in Response Distribution

- The Chi-Square Test was used to assess the significance of differences in respondents' preferences:

```
chisq.test(table(data$Gn_support > 0))
```

If p-value < 0,05, the differences are considered statistically significant.

- Cramer's V was used to evaluate effect size, indicating how strongly one response dominates:

```
cramersV(table(data$Q3_8, data$Q9_2))
```

High values (V ≥ 0,5) confirm the key role of the factor.

- Fisher's Exact Test (`fisher.test()`) — was applied when contingency tables contained small sample sizes (fewer than five observations in a cell):

```
fisher.test(table(data$Q3, data$Q9))
```

This test was beneficial for categorical data, where the standard chi-square test could be less accurate.

3.2 Correlation Analysis Between Variables

Correlation analysis was used to identify statistically significant relationships:

- Spearman's rank correlation (`cor.test(method = "spearman")`) for ordinal variables.
- Kendall's tau (`cor.test(method = "kendall")`) for nonparametric data.

```
cor.test(data$Gn_support, data$Age, method = "spearman")
```

3.3 Analysis of Likert Scale Data

- Wilcoxon Signed-Rank Test was used to assess whether responses significantly deviated from a neutral point on the Likert scale:

```
wilcox.test(data$Q5, mu = 3)
```

A p-value < 0,05 indicates a significant deviation from the neutral level.

- The Shapiro–Wilk Test (`shapiro.test()`) was applied to check for normality of distribution, determining whether to use parametric or nonparametric tests

```
shapiro.test(data$Q3_8)
```

The use of parametric tests was based on p-value < 0,05.

3.4 Cross-Tabulation and Dependency Analysis (Contingency Tables)

To explore relationships between demographic characteristics and respondents' preferences, cross-tabulations and dependency tests were conducted:

Example: Testing the relationship between age category and preferred learning format:

```
chi_test_Q14_Q1_13 <- chisq.test(table(data$Q14_4, data$Q1_13))
```

A p-value < 0,05 indicates significant differences between groups.

4) Results Visualization

To present the data clearly and accessibly, the following visual tools were used:

- Histograms (`hist()`) to show the distribution of responses;
- Bar plots (`barplot()`) or comparative analysis;
- Grouped variable plots using (`ggplot2`) to visualize relationships between factors.

Example: Plot showing the distribution of difficulties in online learning (Question Q3):

```
ggplot(summary_Q3, aes(x = reorder(Issue, -Percentage), y = Percentage, fill
= Issue == "Q3_8")) +
  geom_bar(stat = "identity", show.legend = FALSE) +
  coord_flip() +
  scale_fill_manual(values = c("TRUE" = "red", "FALSE" = "gray70"))
```

This plot provides a clear visual representation of the most pressing issues encountered by teachers in the context of online teaching.

The data analysis process included preprocessing, the calculation of descriptive statistics**,** quantitative data analysis**,** data visualisation, and the application of statistical tests to assess the significance of the results. This approach enabled a comprehensive and scientifically grounded analysis, ensuring the statistical reliability of the research findings.

3.2.4 Results

Hypothesis 1- Content Adaptation

To test the hypothesis "Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses", survey questions were selected that focused on respondents' opinions regarding the importance of course adaptation and their preferences for personalised learning. The data analysis aimed to assess the relevance of the need for course customisation and to identify key patterns in respondent preferences. The list of questions used to test this hypothesis is presented in Appendix J. The initial step in testing the hypothesis was to analyse respondents' answers regarding their main learning objectives. (Table 3.2)

Table 3.2 *Summary of Primary Goals of Online Learning*

Learning Goal	Number of Respondents	Percentage (%)
Practical Skills Development	133	56.12
Professional Qualification	180	75.95
Certificate/Degree Acquisition	117	49.37
Theoretical Knowledge	85	35.86
Career Growth	26	10.97
Research Opportunities	23	9.70
Pedagogical Innovations	110	46.41
Personal Interest	79	33.33
Time Efficiency	49	20.68
Cost Efficiency	37	15.61
Technical Skills	43	18.14
Pedagogical Practice	99	41.77
Flexible Schedule	109	45.99
Remote Access to Quality Education	52	21.94
Networking & Experience Exchange	67	28.27

The results of the Chi-squared test (χ^2 = 342.4, df = 14, p-value < 2.2e-16) confirm that the responses were not randomly distributed. The primary learning objective selected by the majority of respondents was professional development (75.9%), followed by the development of practical skills (56.1%) and obtaining certificates or diplomas (49.4%). It is also important to note that course selection is influenced by flexible scheduling opportunities (46%), which allow participants to combine work with acquiring new knowledge. Furthermore, respondents do not primarily view online education as an economic advantage but rather as a professionally driven and convenience-oriented option. (Figure 3.4)

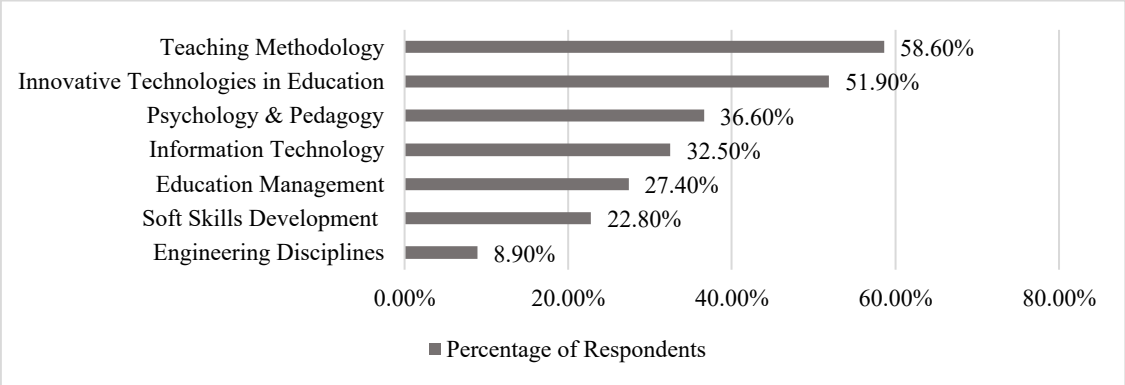

Figure 3.4 *Most Popular Online Course Topics*

Although the respondents were TVET engineering teachers, the most in-demand topics for online learning were unexpectedly Teaching Methodology (58.6%) and Innovative Technologies in Education (51.9%), while only 8.9% of respondents expressed interest in studying engineering skills online. The Chi-squared test (χ^2 = 120.84, df = 6, p-value < 2.2e-16) confirms that the response distribution is statistically significant, thus reflecting the current preferences of teachers. The following key step is analysing the challenges that TVET engineering teachers face when participating in online courses. (Figure 3.5)

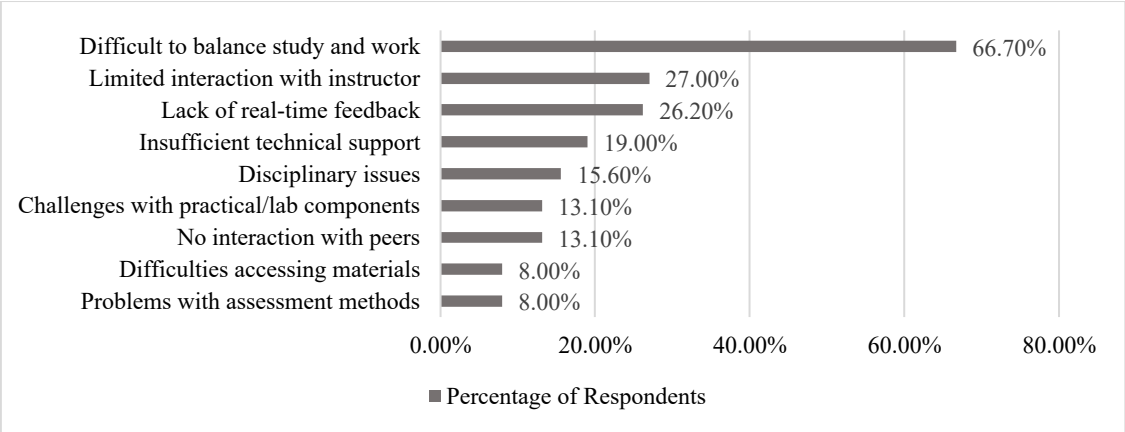

Figure 3.5 *Challenges Faced in Online Education*

The chart shows that 66.7% of respondents identified "difficult to balance study and work" as the key issue. The Chi-squared test (χ^2 = 286.1, df = 8, p-value < 2.2e-16) demonstrates statistical significance and confirms that the distribution is not random. A Z-test (p-value = 7.761e-13) further supports the notion that balancing study and work is a genuinely important challenge, not a result of random selection by respondents. The next step is to examine the tools and approaches respondents selected to adapt online learning to their individual needs as teachers. (Figure 3.6)

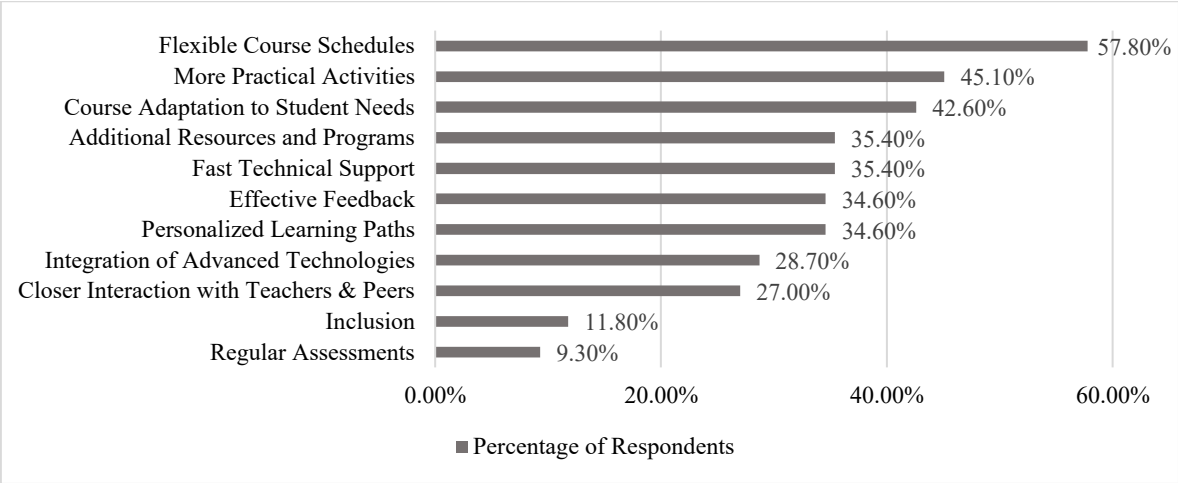

Figure 3.6 *Desired Adaptations in Online Programs*

The analysis showed that 42.6% of respondents selected course adaptation to learners' capabilities, placing it among the top three preferred tools. The most in-demand feature was the flexibility of scheduling (57.8%). The Chi-squared test ($\chi^2 = 139.41$, df = 10, p-value < 2.2e-16) confirms that the distribution is statistically significant and non-random. It is also important to note that the combined proportion of those who selected course adaptation to student needs and personalised learning pathways amounts to 77.2%, with statistical significance confirmed by a Z-test ($\chi^2 = 138.26$, df = 1, p-value < 2.2e-16). To gain deeper insight, the analysis examined the correlation between respondents who reported difficulty balancing study and work and those who preferred flexible scheduling. The result was r = 0.157, indicating a weak but statistically significant relationship (p-value = 0.0155). Other variables showed no significant correlation. Notably, 61.6% of respondents selected at least one option that supports the importance of adaptation tools in online education.

The next step involved analysing how important respondents consider the ability to adapt content to individual learning needs for effective online education. (Figure 3.7)

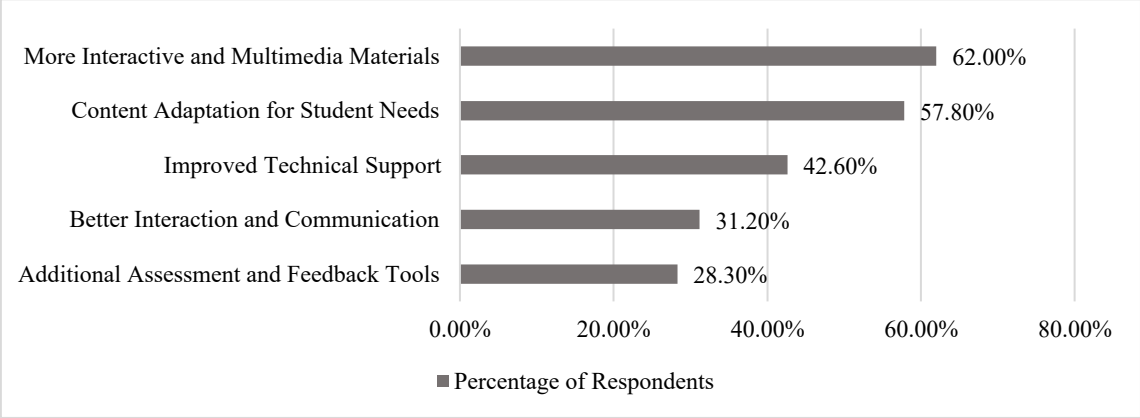

Figure 3.7 *Desired Improvements in Online Courses*

More than half of the respondents (57.8%) indicated that the ability to adapt course content to learner needs is an important improvement in online education. The Chi-squared test ($\chi^2 = 9.513$, df = 4, p-value = 4.563e-10) confirms that the responses were not random and that content adaptability is genuinely essential to teachers. To gain deeper insights, a Pearson's Chi-squared test with Yates' continuity correction was conducted between the item "Content Adaptation for Students' Needs" and all response options from previous questions. The results with statistically significant correlations are presented in the following Table 3.3.

Table 3.3 *Correlation Analysis*

Question	Correlation	p-value
Course Adaptation for Student Needs	0.2870683	0.000007093028
Personal Interest	0.2778962	0.000014160658
Additional Resources & Programs	0.2758262	0.000016496292
Pedagogical Innovations	0.1955279	0.002499218794
Difficult Work-Study Balance	0.1933191	0.002802425342
Information Technology	0.1913531	0.003099965067
Flexible Schedule	0.1884210	0.003597085298
Integration of Advanced Technologies	0.1830640	0.004694742457
Access to Quality Education	0.1639350	0.011486888043
Time Efficiency	0.1619181	0.012559866993
Certification/Diploma	0.1429812	0.027746670803
Cost Efficiency	0.1320917	0.042185529844

The analysis results showed that the most significant correlation was observed between course adaptation for students and the respondents' desire to see more adaptation tools in online learning ($r = 0.287$, $p < 0.00001$). This indicates that content adaptation is important to respondents, especially when tailored to each educator's specific needs. TVET engineering teachers who choose online learning out of personal interest ($r = 0.278$, $p = 0.00001$) are more likely to highlight the need for content adaptation, which may reflect a more conscious and flexible approach to learning. A significant correlation was also found between the desire for content adaptation and the need for additional resources and programs ($r = 0.276$, $p = 0.00002$), suggesting that respondents view course adaptation as part of a broader need for expanded learning materials. Content adaptation in online courses exhibits significant correlations with several key factors. Teachers interested in pedagogical innovations ($r = 0.196$, $p = 0.0025$) and information technologies ($r = 0.191$, $p = 0.0031$) are more likely to emphasise the importance of personalised learning. Additionally, the need for content adaptation is higher among those who struggle with balancing work and study ($r = 0.193$, $p = 0.0028$) and those who value flexible scheduling ($r = 0.188$, $p = 0.0036$), indicating the importance of an individualised pace of learning. A significant association was also found with the request for the integration of advanced technologies ($r = 0.183$, $p = 0.0047$), underscoring the role of technological solutions in personalising the educational process.

The next stage involved analysing what TVET engineering teachers feel is missing in online learning. (Figure 3.8)

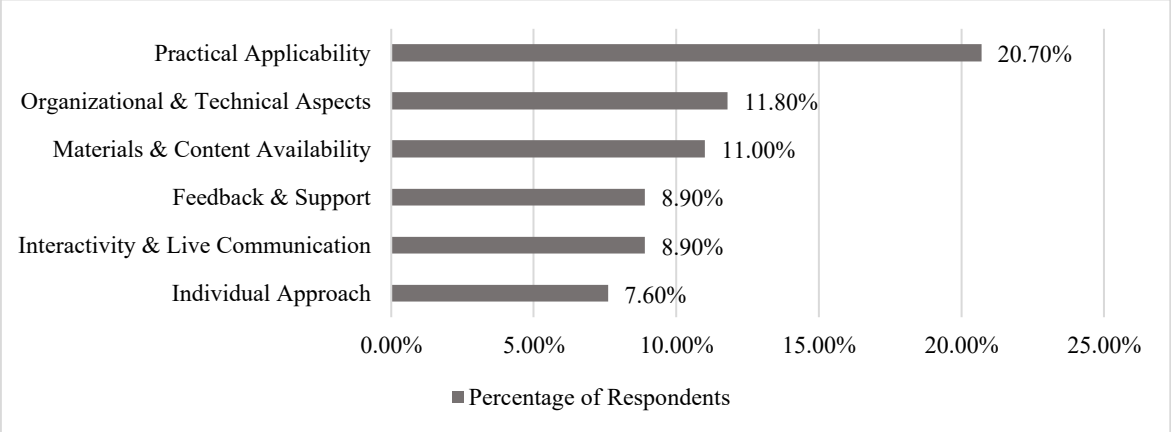

Figure 3.8 *Aspects Lacking in Online Courses*

It is essential to note that this question was presented in an open-ended format, allowing respondents to enter issues that genuinely concerned them. This is further supported by the Chi-squared test ($\chi^2 = 23.515$, df = 5, p-value = 0.000269). Although the individual approach (7.6%) was selected less frequently, its relevance should still be considered in the comprehensive evaluation of the hypothesis.

Summary

The research findings confirm the hypothesis that adapting online course content to the professional experience, educational needs, and tasks of TVET engineering teachers increases their perceived usefulness and effectiveness. The majority of respondents choose professional development (75.9%) and the development of practical skills (56.1%) as their primary goals, highlighting the need for a personalised approach to learning. The analysis highlighted that TVET engineering teachers prefer courses focused on teaching methodologies and innovative educational technologies over technical disciplines, which is a crucial consideration in course design. The main barrier to online learning was the difficulty in balancing study and work (66.7%), emphasising the critical need for flexible scheduling and personalised learning pathways. Correlation analysis revealed a significant relationship between course adaptation and the need for additional resources in online courses, the use of innovative technologies, and the flexibility of courses. Thus, the personalisation and adaptation of online course content to meet the needs of TVET engineering teachers are among the key factors that can help increase the perceived effectiveness of online courses.

Hypothesis 2 - Blended Learning Format

To test the hypothesis "The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers", a set of questions was selected to examine the preferences of TVET engineering teachers regarding learning formats. The analysis aims to determine the demand for a combination of traditional methods and digital tools and to identify the key factors influencing perceptions of convenience and effectiveness in blended learning. Special attention is given to assessing the accessibility and flexibility of this approach. The complete list of questions used in the analysis is provided in Appendix J. The first question considered in testing the hypothesis explores the problems and challenges teachers face when taking online courses. (Figure 3.9)

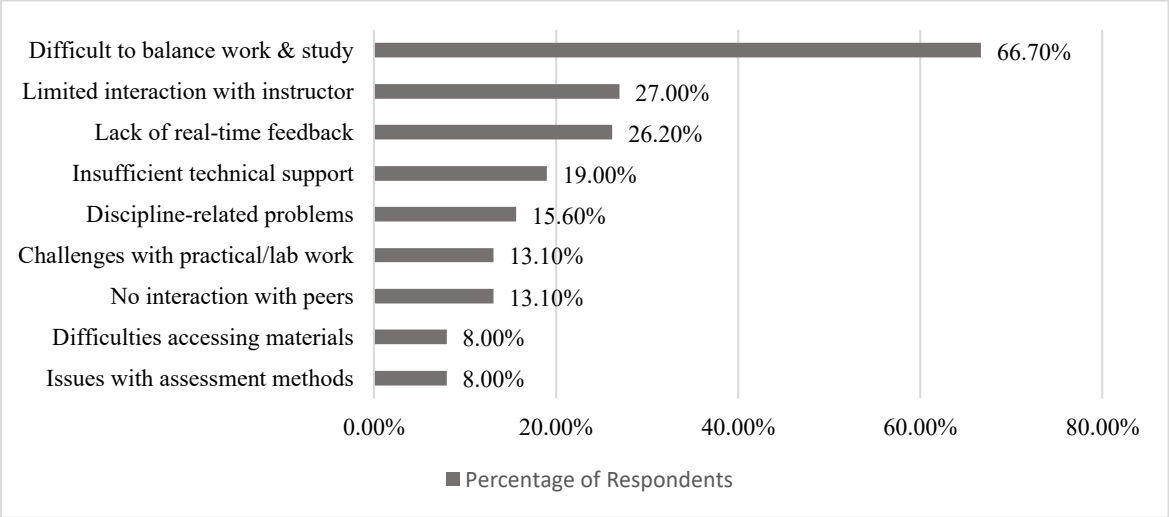

Figure 3.9 *Main Challenges in Online Learning*

The chi-squared test (χ^2 = 286.1, df = 8, p-value < 2.2e-16) confirmed statistically significant differences, indicating that the frequency of reported issues was not random but reflected the actual challenges experienced by respondents. The effect size, Cramer's V = 0.388, suggests a moderate association, confirming that while some issues occurred more frequently than others, the distribution was not extremely uneven.

The next question used to test this hypothesis examines respondents' opinions on the most important resources for effective teaching in an online learning context. The analysis revealed the three highest-rated tools: instructional materials (4.10), practical sessions (4.08), and multimedia materials (4.08). Other tools received average ratings of less than 4 (Figure 3.10).

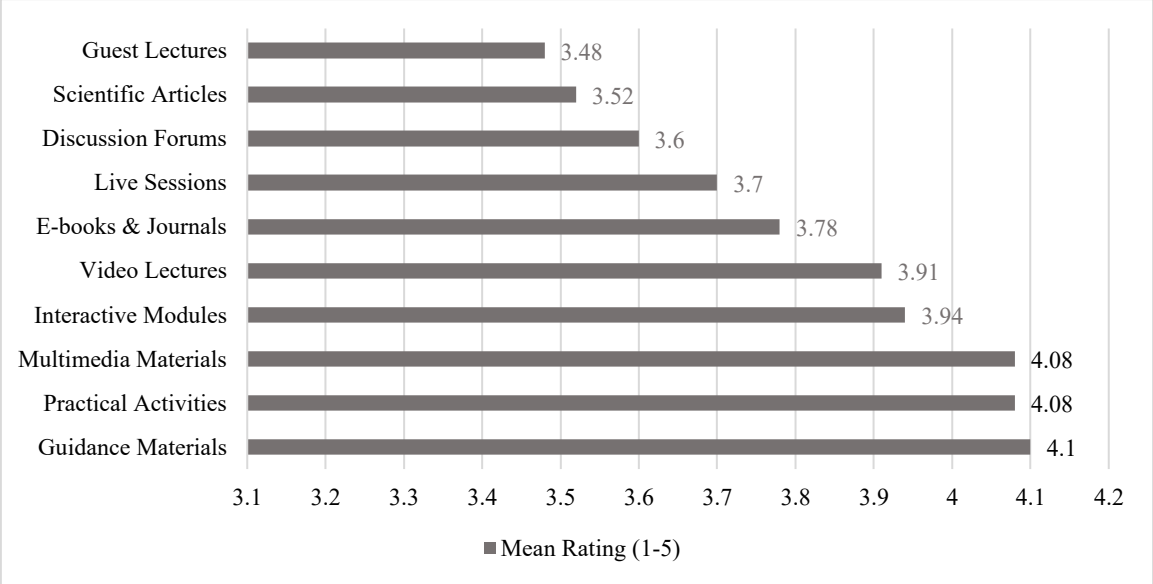

Figure 3.10 *Effectiveness of Online Learning Recourses*

The Wilcoxon test showed that all resources were rated significantly above the average level of effectiveness ($p < 0.05$), confirming that the selection of these tools was not random. Respondents generally evaluated most tools as effective, as all items scored above the neutral value of 3. The analysis of respondents' opinions on additional resources that could enhance their online learning experience showed that all listed resources, except peer review by fellow learners, were significantly different from the neutral value of 3 ($p < 0.05$). The highest-rated items were interactive textbooks (4.05) and instructional materials (4.04). (Figure 3.11)

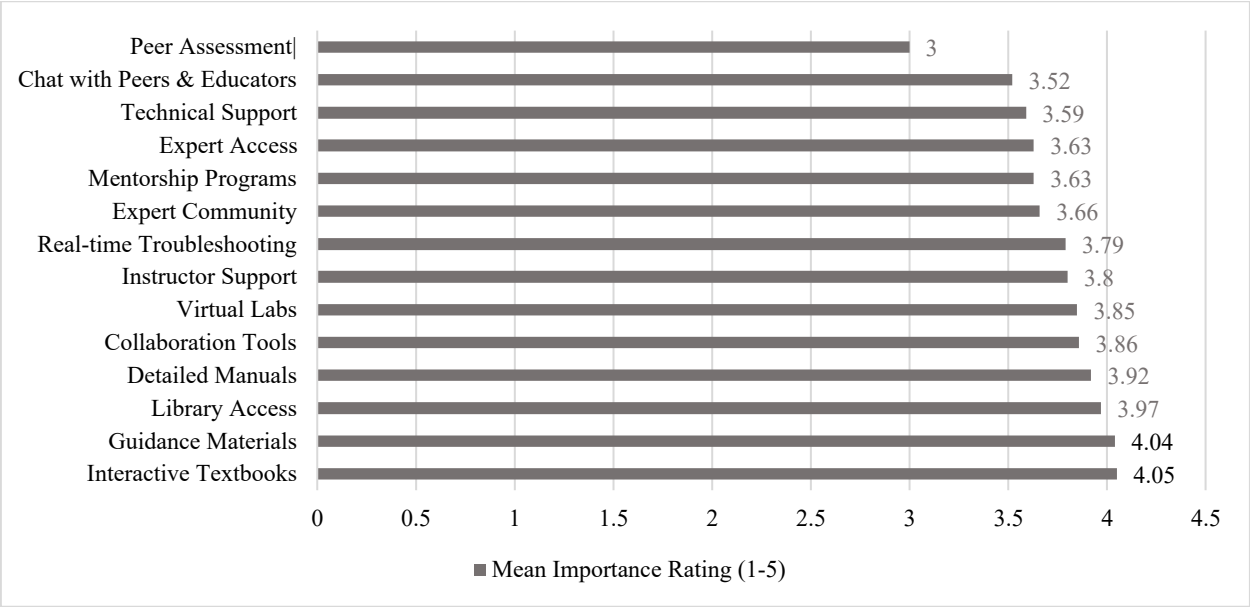

Figure 3.11 *Importance of Additional Resources in Online Learning*

The analysis of the methods chosen by respondents to adapt online programs to their teaching needs showed that course schedule flexibility (57.8%) is the most important factor in course effectiveness for the majority of TVET engineering teachers. (Table 3.4)

Table 3.4 *Number of Respondents Choosing Each Option*

Option	Respondents
Personalized learning paths	34.59%
Flexible course schedules	**57.8%**
More practical sessions	45.1%
Closer interaction with teachers & peers	27%
Fast technical support	35.4%
Adaptation to learner needs	42.6%
Effective feedback	34.5%
Integration of advanced technologies	28.6%
Inclusion	11.8%
Additional resources & programs	35.4%
Regular assessments	9.28%

The chi-squared test showed a statistically significant difference between the response options (χ^2 = 139.41, df = 10, p-value < 2.2e-16), where p-value < 0.05, indicating that the respondents' choices were not random and reflected the actual needs of teachers in the context of online learning. To assess how strongly one option dominates over the others, the effect size was calculated using Cramer's V = 0,127, which indicates a small but significant association between the distribution of responses and their frequency.

The analysis demonstrated that schedule flexibility is indeed an important factor, but its dominance is not overwhelming. Therefore, it is appropriate to examine several other options that respondents frequently selected. (Figure 3.12)

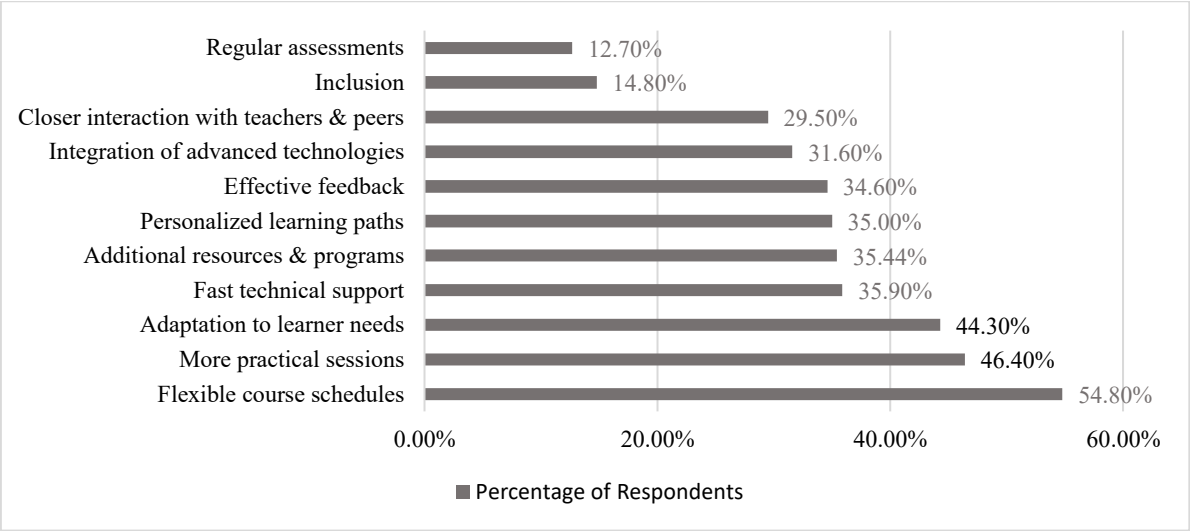

Figure 3.12 *Preferences for Adapting Online Programs*

The chart shows that over 100 responses were given in favour of the presence of practical sessions (46.4%) and adapting to learners' needs (44.3%). The main goal of the next question was to determine which learning method TVET engineering teachers prefer. The number of respondents who chose blended learning amounted to 58.6%. This option is not the most popular overall, but it represents a result well above the average level. (Table 3.5)

Table 3.5 *Number of Respondents Choosing Each Teaching Method*

Teaching Method	Number of Respondents
Synchronous Classes	16,8%
Asynchronous Classes	75,9%
Blended Learning	**58,6%**
Group Projects & Discussions	25,7%

The chi-squared test ($\chi^2 = 123.26$, df = 3, p-value < 2.2e-16) showed that the results are statistically significant and not a random choice by respondents, indicating substantial differences between the options. The Cramer's V value of 0.313 indicates a moderate effect size, suggesting that the differences between preferences are indeed meaningful and that the blended learning format plays a significant role.

However, alongside blended learning, a larger number of respondents preferred asynchronous formats despite the recognized importance of interaction, practical work, and other tools that were identified as important in other questions but were less accessible in asynchronous formats. In this regard, it was decided to analyze the relationship between age and preference for blended learning. (Figure 3.13)

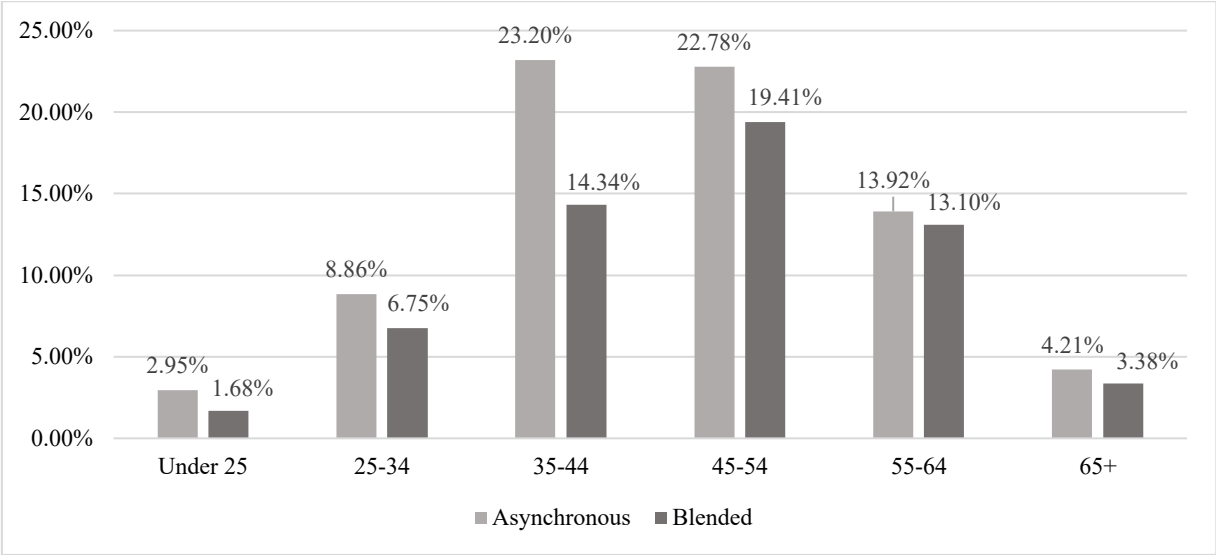

Figure 3.13 *Preferences for Asynchronous and Blended Learning by Age Group*

The histogram shows that the blended learning format is preferred by respondents in the 45–54 age group, and this preference appears to be evenly distributed among the 35–44 and 55–64 age groups. Regarding preferences for asynchronous learning, it is more frequently chosen by the 35–44 and 45–54 age groups. (Figure 3.14)

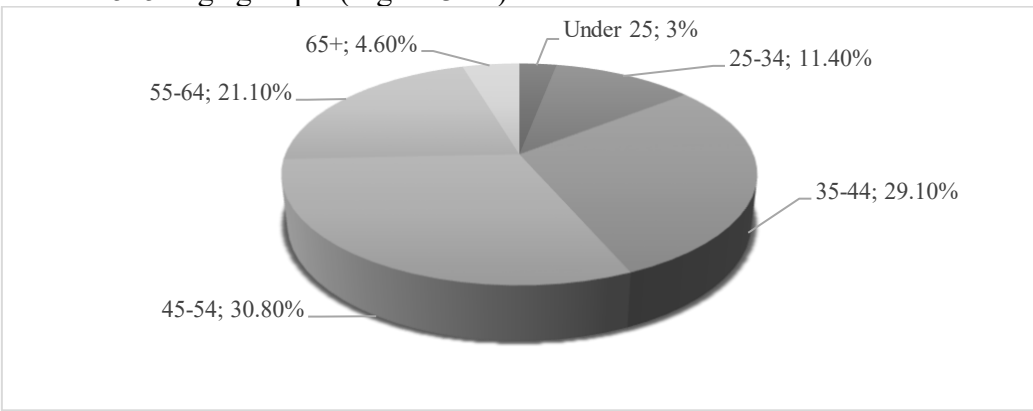

Figure 3.14 *Percentage of respondents by their age group*

The most active working-age group (35–54) slightly prefers asynchronous over blended learning. However, when testing for statistical significance between age and preferred learning format, Fisher's exact test revealed that neither asynchronous (p-value = 0.2732) nor synchronous (p-value = 0.5289) learning formats showed statistically significant associations with age. Cramer's V values for asynchronous (0.172) and synchronous (0.133) formats indicate a very weak association, suggesting that respondents across all age groups have relatively similar preferences for blended learning. Nonetheless, V values above 0.1 do not allow for firm conclusions regarding interdependence.

When discussing the use of blended learning formats, it is important to consider contextual factors that may indirectly influence the demand for a particular format. For this purpose, respondents were asked to identify the additional knowledge and skills they need in order to use virtual teaching methods confidently. (Table 3.6)

Table 3.6 *The most needed competencies and skills*

Skill	Number of Respondents	Percentage (%)
Digital Literacy & Platform Use	91	51.41
Pedagogical Methods & Didactics	41	23.16
Technical Skills	22	12.43
Soft Skills	13	7.34
Practical Skills	10	5.65

The results of the frequency analysis showed that digital literacy and working with platforms are the primary skills lacking among TVET engineering teachers, hindering their confident participation in online learning. The chi-squared test ($\chi^2 = 125.68$, df = 4, p-value < 2.2e-16) confirmed that the differences in responses are statistically significant and substantial, indicating that respondents did not select options at random but made conscious choices, emphasising the importance of digital literacy skills. The Cramer's V test (0.421) demonstrates a strong association, significantly dominating over other response options. These findings suggest that digital literacy and platform competency are key areas where teachers feel insecure when engaging in online education. The 51.41% of respondents doubt their full ability to learn through online courses.

The final question for testing the hypothesis focused on teachers' opinions regarding necessary improvements they would like to see in online courses. This was an open-ended question, meaning respondents could list multiple suggestions. The results of the frequency analysis are presented in Table 3.7.

Table 3.7 *Innovations and improvements*

Improvement / Innovation	Number of Respondents	Percentage (%)
Content Availability & Materials	32	13.5
Practical Application	23	9.70
Interactivity & Live Communication	38	16.0
Digital Literacy	24	10.1
Feedback & Support	30	12.7
Individual Approach	21	8.86

The most frequently mentioned improvement by respondents was "interactivity and live communication" (16.0%). However, the chi-squared test ($\chi^2 = 7.5$, df = 5, p-value = 0.186) indicates that the distribution of responses is not statistically significant. Cramer's V test (0.08) indicates a very weak association.

Summary

In summary, the blended learning format, which combines traditional methods and online tools, is a key factor in the convenience and effectiveness of online education for TVET engineering teachers. The most significant challenges that respondents faced during online courses were limited interaction with peers and teacher trainers, insufficient feedback, and difficulties in balancing work and study. This highlights the importance of using blended learning formats, as they enable learners to manage their workload and absorb material without compromising quality. Issues identified with the practical aspects of online courses may indicate the need for in-person laboratory and practical sessions, facilitating the integration of theoretical and applied knowledge in a blended learning environment.

Respondents evaluated practical sessions and multimedia materials equally highly, underlining the significance of combining digital tools and traditional methods in online courses. Instructional

materials, which received the highest rating, indicate that teachers need clear guidance and a structured learning framework that they can later implement independently at their workplace. Teachers also wanted meaningful interaction and collaboration during their learning process. This could be achieved with the help of interactive models, live sessions, discussion forums, and virtual labs. The analysis confirmed that the choice of learning format is not age-dependent and that both asynchronous and blended formats are in the highest demand. Respondents selected adaptation and flexibility as the most appropriate tools in their learning experience. Ultimately, combining structured content with interactive components enhances both convenience and effectiveness, supporting deeper learning and improved educational outcomes.

Therefore, the hypothesis that a blended learning format—combining traditional methods (e.g., instructional materials, mentoring, live communication) and online tools (e.g., virtual labs, interactive textbooks, digital platforms)—is a key factor in the convenience and effectiveness of courses for TVET engineering teachers is supported.

Hypothesis 3 - Active Learning Methods

The hypothesis "The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers" is tested using questions that reflect TVET engineering teachers' perceptions of active learning methods and their impact on engagement and educational outcomes. The analysis aims to identify which tools most effectively support interaction during the learning process. The complete list of questions used in the analysis is presented in Appendix J.

The first question aimed to test this hypothesis by examining respondents' opinions about the resources most important for effective teaching in the context of online education. A detailed analysis of this question was conducted during the testing of Hypothesis 2. This section focuses on the active learning methods that respondents rated highest. (Table 3.8)

Table 3.8 *Evaluations of Active Learning Resources*

Learning Resource	Mean Score
Interactive Modules	3.94
Practical Sessions	4.08
Discussion Forums	3.60
Live Sessions	3.70
Guest Lectures	3.48

The Wilcoxon test showed that all resources scored significantly above the average level of effectiveness ($p < 0,05$) and are statistically significant, disproving the randomness of the respondents' choices. The analysis demonstrated that all results exceed the neutral value of 3. The highest ratings were given to practical tasks and interactive modules.

The next question helps to understand the extent to which active learning methods allow for deeper immersion in an online course. Frequency analysis of the responses (Table 3.9) highlights the most popular tools for engaging in online courses: Live Q&A Sessions, Interactive Discussions, Simulations and Virtual Labs, Quizzes and Polls, Flipped Classroom, Collaborative Tools, and Case Studies and Practical Applications.

Table 3.9 *Distribution of Active Learning Tools*

Engagement Tool	Number of Respondents	Percentage
Interactive Discussions	96	40.51
Group Projects	65	27.43
Gamification	64	27.00
Peer Review & Feedback	31	13.08
Live Q&A Sessions	106	44.73
Flipped Classroom	78	32.91
Collaborative Tools	75	31.65
Case Studies & Practical Application	69	29.11
Role-Playing Games	66	27.85
Quizzes & Polls	79	33.33
Discussion Forums	56	23.63
Simulations & Virtual Labs	84	35.44

The chi-squared test (χ^2) confirmed that the differences in the choice of tools were not random (χ^2 = 92.987, df = 13, p-value = 3.74 × 10^ (-14)) and were statistically significant ($p < 0.05$). However, Cramer's V = 0.081 indicates a weak association and the absence of a dominant option that respondents would prefer. Therefore, it seems appropriate to group the most popular tools and identify three key categories of active learning methods preferred by TVET engineering teachers based on the survey results:

1. Live interaction and discussions, including live Q&A sessions (44.73%), interactive discussions (40.51%), and discussion forums (23.63%)
2. Practice-oriented methods, including simulations and virtual labs (35.44%), case studies and practical application (29.11%), and flipped classrooms (32.91%)
3. Game-based and interactive technologies, including gamification (27.00%), quizzes and polls (33.33%), and role-playing (27.85%)

Fisher's exact test returned a p-value of 0.3183 (> 0.05), indicating no statistically significant relationship between the respondents' age and their choice of learning methods.

The next step involved analysing the respondents' opinions on the effectiveness of active learning methods in online courses. The initial step involved conducting the Wilcoxon test for each tool, which showed that all tools—except for three—were statistically significant for the calculation. (Table 3.10)

Table 3.10 *Wilcoxon Test Results*

Method	P_Value	Significance
Virtual Labs	0.00000000346952099237	Significant
Software	0.00011842650103379767	Significant
Remote Experiments	0.00000000217914659210	Significant
Recorded Demonstrations	0.00001522366403351168	Significant
Real-time Control	**0.37864516612164894616**	**Not Significant**
Interactive Guides	0.00108079139346739820	Significant
Step-by-step Guides	0.00000000001260710271	Significant
Collaborative Work	**0.61648782579343364141**	**Not Significant**
Project-based Learning	0.01015320212484220608	Significant

Method	P_Value	Significance
Individual Feedback	0.00000038795417576917	Significant
Practical Application	0.0000000000002533246	Significant
Mentorship Support	**0.30576208340543503672**	**Not Significant**

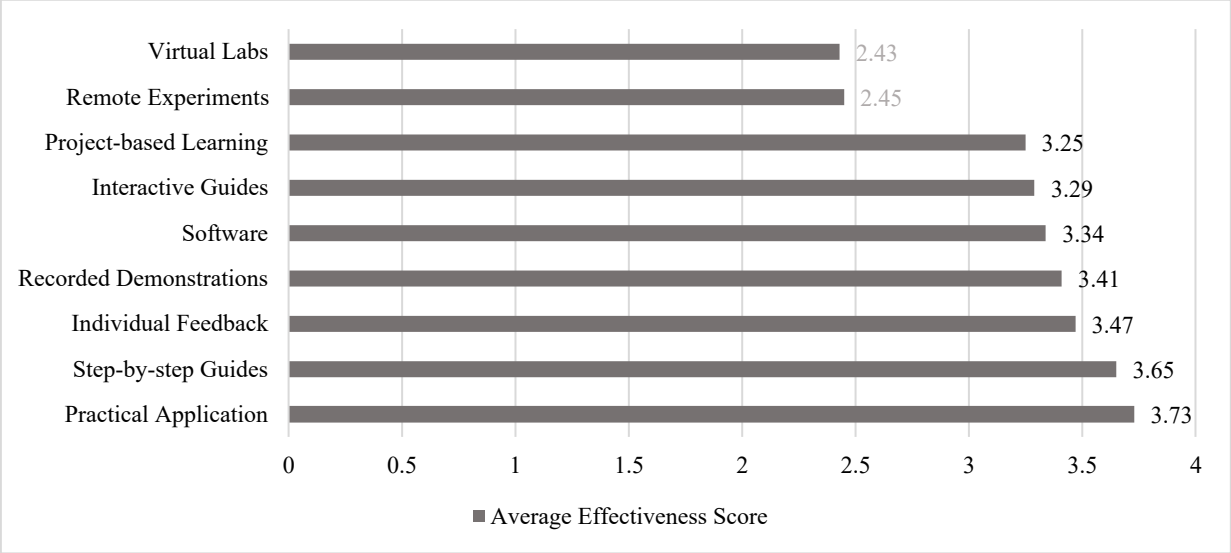

Figure 3.15 *Effectiveness of Statistically Significant Practical Learning Tools*

The analysis of Figure 3.15 shows that, according to respondents, the most effective tool is Practical Application (3.73). Step-by-step guides (3.65) and personalised feedback (3.47) are also among the most in-demand tools among teachers. Interactive Guides (3.29) and Project-based Learning (3,25) are not in the top five most highly rated options, yet they still have scores above average, indicating that while not a top priority, these active learning methods are still regarded as important.

Remote Experiments and Virtual Labs received the lowest scores. However, this does not mean they are less effective. Additional analysis showed that Virtual Labs were not used by 40.08% of respondents and Remote Experiments by 38.4%. Given that other scores are distributed quite evenly, these results more likely indicate that a significant portion of respondents did not have the opportunity to use them and, therefore, could not evaluate their effectiveness. These tools should not be considered ineffective but relatively underutilised and not widely available in online courses. Since Remote Experiments and Virtual Labs are important for TVET engineering teachers, an additional analysis was conducted to compare the groups that used these tools with those that did not, using the Wilcoxon rank-sum test. Respondents who used Virtual Labs rated them at 3.39 and Remote Experiments at 3.35, indicating that these tools are reasonably practical for those who have had the chance to use them. Furthermore, Virtual Labs (p-value < 2.2e-16) and Remote Experiments (p-value < 2.2e-16) both show statistically significant differences between the groups, confirming their effectiveness.

TVET engineering teachers rate Practical Application, Interactive Guides, Virtual Labs, and Remote Experiments as important active learning methods that contribute to improved educational outcomes. At the same time, Virtual Labs and Remote Experiments receive high ratings among users, but their overall availability remains limited.

When discussing active learning methods, it is also necessary to analyse respondents' views on the effectiveness of interactive modules. The average score is 3.79, with a standard deviation of 1.02. The distribution of responses is presented in Figure 3.16.

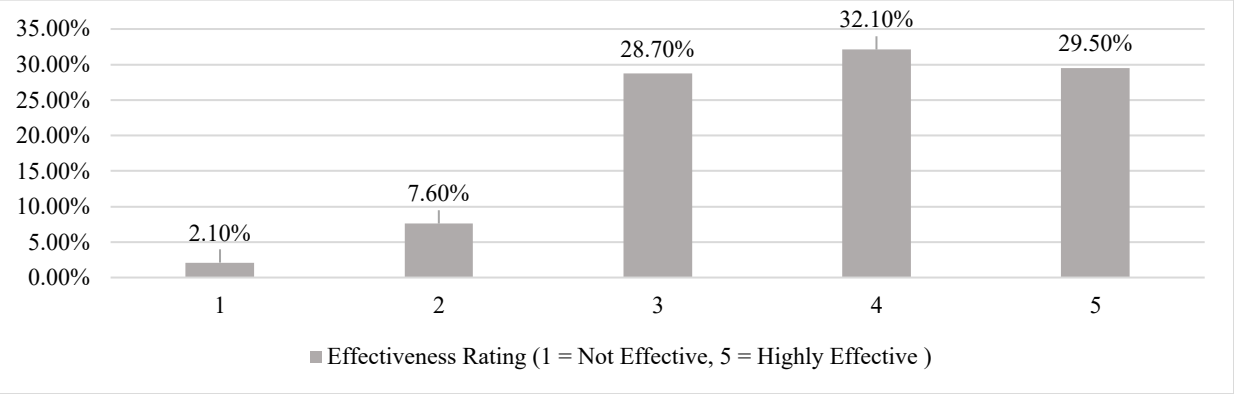

Figure 3.16 *Effectiveness of Interactive Modules*

The results of the Wilcoxon test (V = 12850, p-value < 2.2e-16) indicate that the distribution of responses significantly differs from the neutral value (3), confirming that the majority of respondents (61.61%) gave an upbeat assessment (4 or 5) to interactive modules.

An important aspect of the study is the analysis of additional features that TVET engineering teachers would like to see implemented in online courses. The frequency distribution is presented in Figure 3.17.

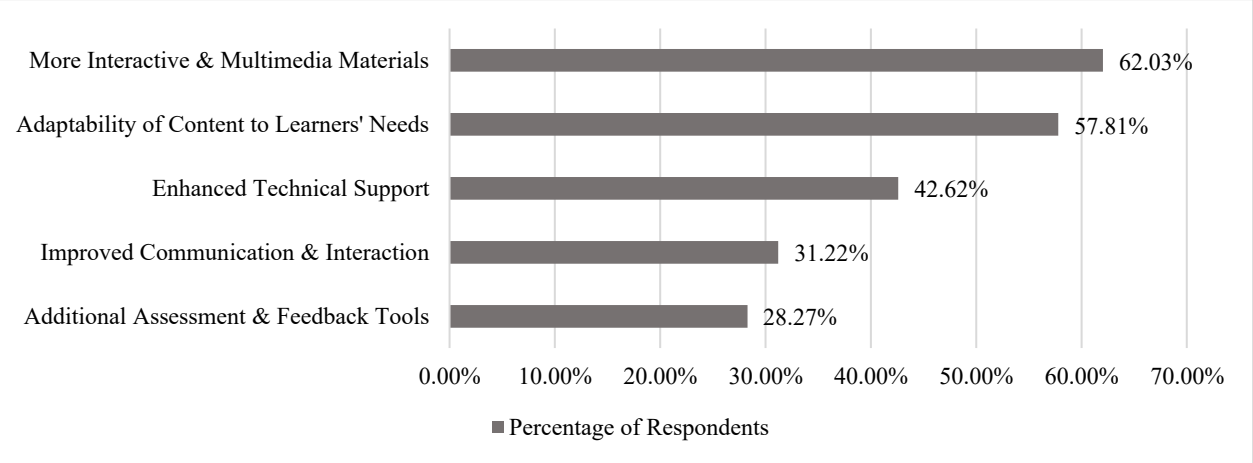

Figure 3.17 *Desired Improvements in Online Courses*

The figure shows that the majority of respondents prefer the inclusion of more interactive and multimedia materials (62%). The chi-squared test (χ^2 = 49.513, df = 4, p-value = 4.563e-10) indicates that the results are statistically significant (p-value < 0.05), and respondents selected this option consciously, demonstrating clear patterns in their preferences. Cramer's V effect size of 0.153 indicates a small but significant effect, confirming some variation among the selected options. The proportion Z-test for the "More Interactive & Multimedia Materials" option yielded statistically significant results (p-value = 1.598e-05) with a 95% confidence interval [0.3389; 0.4391], indicating that this option significantly outperforms the others.

To assess which teaching methods are most associated with respondents' preference for multimedia and interactive materials, a Spearman correlation analysis was conducted (Figure 3.18).

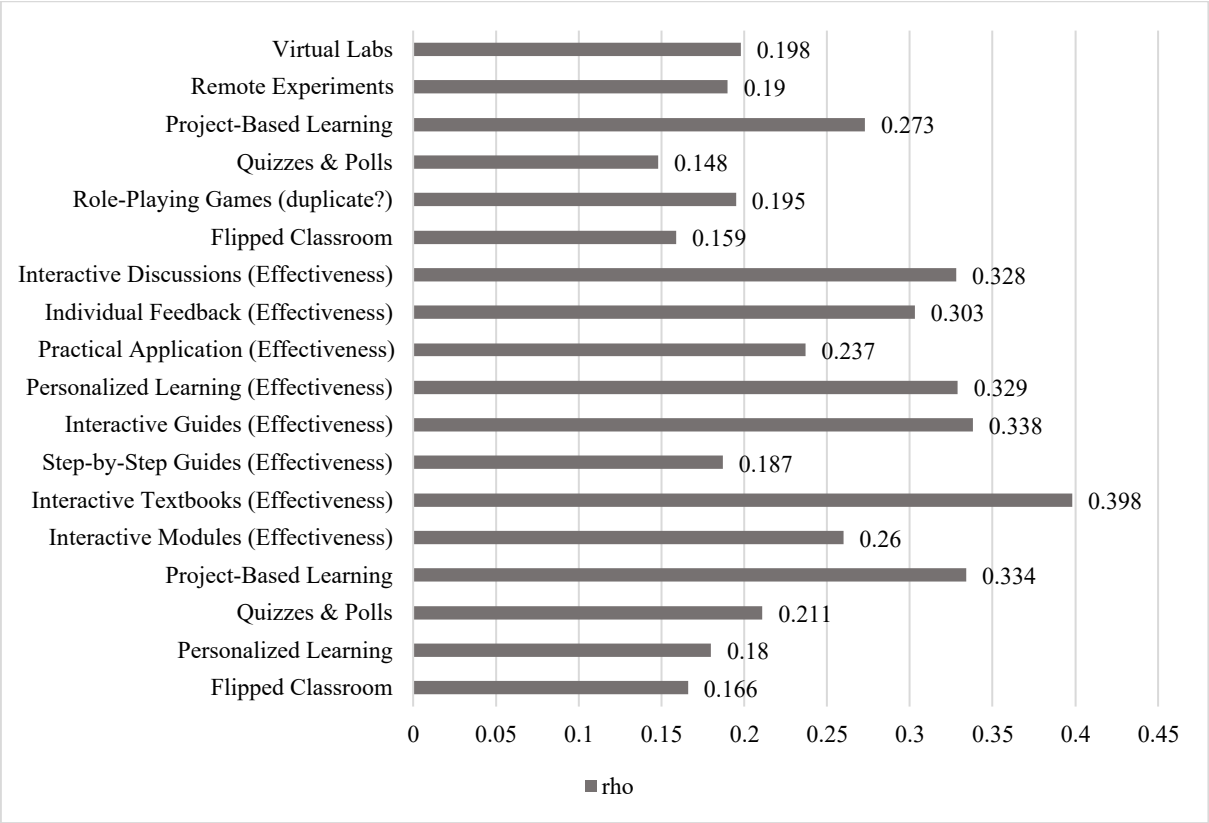

Figure 3.18 *Spearman correlation analysis*

TVET engineering teachers who utilise interactive and digital instructional strategies highlight the following methods as most effective when paired with technology-enhanced learning tools:

- Interactive Textbooks and Interactive Guides ($r \approx 0.34–0.40$) show the strongest positive correlations with perceived effectiveness, suggesting these resources are highly valued in tech-supported learning environments;
- Interactive Discussions, Personalised Learning, and Individual Feedback ($r \approx 0.30–0.33$) also demonstrate notable positive correlations, indicating that learner-centred and feedback-driven approaches align well with digital tools;
- Project-Based Learning and Practical Application ($r \approx 0.24–0.27$) reflect moderate associations, emphasising the role of multimedia in fostering applied and collaborative learning experiences.

Other instructional methods, including Virtual Labs, Flipped Classrooms, and Role-Playing Games, show weaker correlations ($r < 0.20$), suggesting their effectiveness may be less dependent on multimedia integration.

The next step in testing the hypothesis involved identifying which tools respondents felt were lacking in their online learning experience. (Figure 3.19)

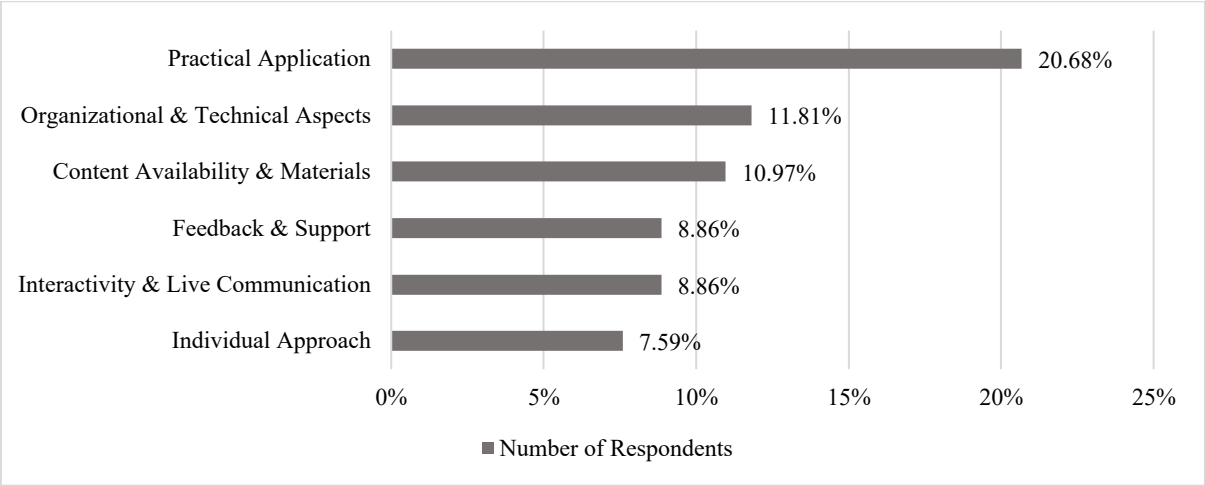

Figure 3.19 *Respondents' Selection for Missing Aspects in Online Courses*

The analysis results show that among respondents who answered this question, the majority identified Practical Application (20.68%) as one of the most critical missing components in the implementation of online learning. In this context, practical application refers to the ability to apply knowledge acquired through online courses. The following elements were most frequently mentioned: Organisational and Technical Aspects (11.81%) and Content Availability and Materials (10.97%). The chi-squared test ($\chi^2 = 23.515$, df = 5, p = 0.000269) confirms statistical significance and indicates that the responses reflect the respondents' actual needs. Cramer's V coefficient = 0.17 suggests a moderate relationship between the most frequently selected option and overall respondent preferences. The most significant concern identified by respondents is the lack of practical applicability, which supports the previously identified trend that TVET engineering teachers believe online learning should include more practical sessions, real-case scenarios, and lab work—thus, more active learning methods. Active learning methods (Interactivity & Live Communication and Feedback & Support at 8.86%) received relatively lower percentages, indicating that these elements may already be sufficiently present in the courses; however, their mention as areas of deficiency further confirms the importance of continued active engagement.

The final question, which was also discussed in Hypothesis 2, aimed to identify areas for improvement among teachers. Results showed that the most in-demand skill is Digital Literacy and Platform Use (51.41%), suggesting that the effective implementation of active learning methods in an online environment requires a higher level of digital competence from TVET engineering teachers.

Summary

To sum up, according to TVET engineering teachers, active teaching methods promote engagement in the educational process and enable the achievement of better results. Respondents highly rated active teaching methods, including practical classes, interactive modules, live discussions, simulations, virtual laboratories, and role-playing games, which confirms their effectiveness. The primary issue in online teacher training remains the lack of practical applicability of the material, which can be addressed by incorporating laboratory work, real-life case studies, and gamification of educational tasks into the educational process. Moreover, the analysis revealed a significant correlation between the use of multimedia tools and practical methods, which indicates the importance of their integration. Although most teachers surveyed support active teaching methods, the question of improving teachers' digital literacy for free inclusion in the learning process through online technologies remains. Based on the analysis, the hypothesis that active teaching methods increase the engagement and educational outcomes of TVET engineering teachers is confirmed.

Hypothesis 4 -Technology Integration

To test the hypothesis "The integration of modern technologies (virtual laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness", a set of questions was analysed to explore how TVET engineering teachers perceive modern educational technologies and how these technologies impact their professional development. Particular attention is paid to assessing the effectiveness of VR/AR, simulators and virtual laboratories in the process of acquiring practical skills. This analysis will help determine which technologies are in the highest demand and identify potential barriers to their application. The questions used for the analysis are listed in Appendix J.

To begin testing this hypothesis, an initial analysis was conducted on respondents' comfort levels in using various modern technologies (Figure 3.20).

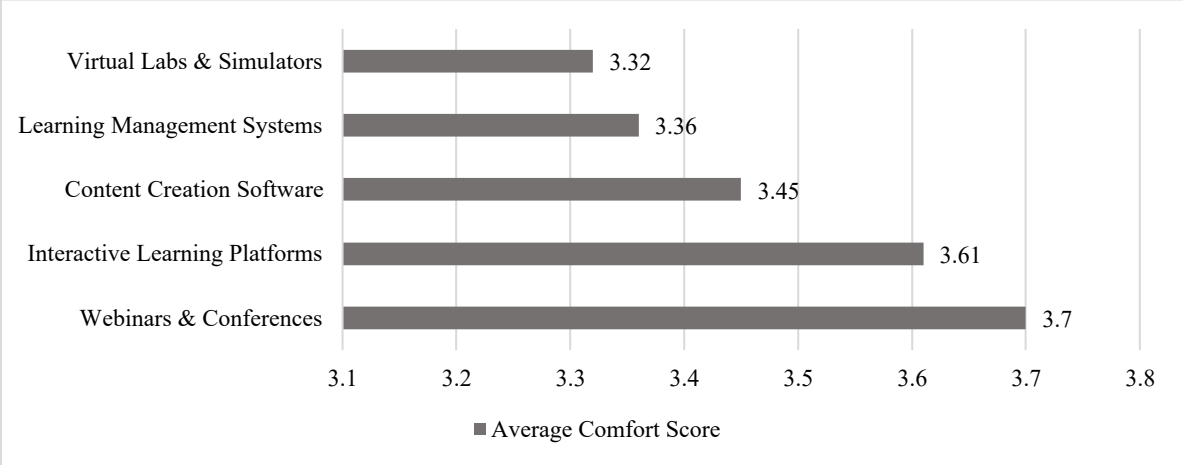

Figure 3.20 *Comfort Level with Digital Tools*

The most comfortable and familiar tools for TVET engineering teachers are webinars and video conferencing platforms. Interactive learning platforms also received high ratings from respondents. However, when considering advanced technologies, virtual laboratories and simulators were rated as the least comfortable, which may indicate their infrequent use in practice and limited availability among teachers. Despite this, none of the presented technologies were perceived as particularly difficult to use, as the average rating for all tools exceeded 3. The Wilcoxon signed-rank test showed a p-value of 0.0004, indicating that the mean rating of virtual laboratories and simulators is significantly different from the neutral score of 3. This suggests that although these tools received relatively lower ratings compared to others, respondents generally assessed their use in online learning positively.

The next step is to assess how highly respondents rate virtual laboratories and interactive textbooks as components that improve their learning experience in online courses (Figure 3.21).

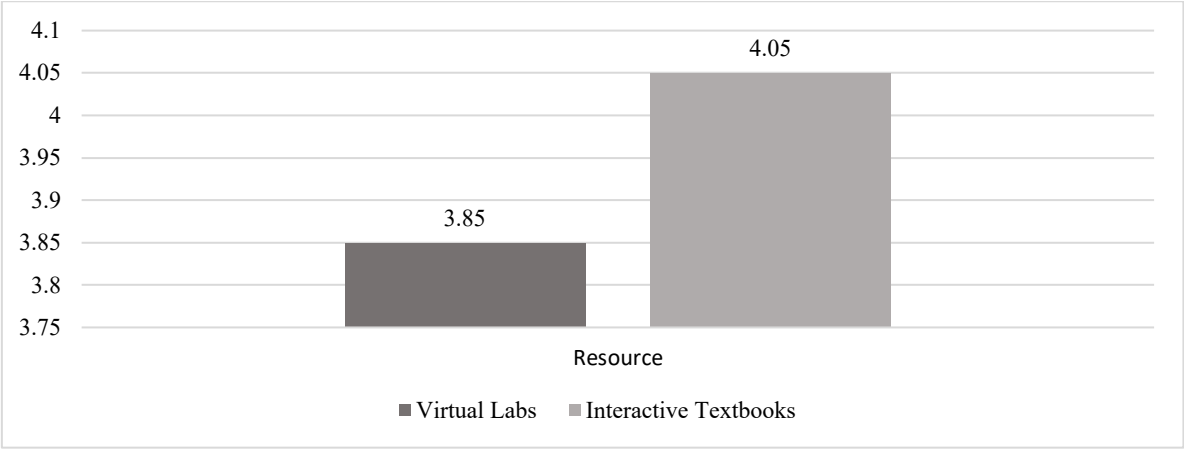

Figure 3.21 *Virtual Labs and Interactive Textbooks Importance (Average Importance Score)*

The results of the analysis indicate that interactive textbooks are rated higher (Mean = 4.05) than virtual laboratories (Mean = 3.85) by TVET engineering teachers. The Wilcoxon signed-rank test confirmed that both interactive textbooks (V = 17016, p-value < 2.2e-16) and virtual laboratories (V = 15020, p-value < 2.2e-16) scored significantly above the neutral value of 3, showing that the respondents' choices were deliberate. The standard deviation scores for interactive textbooks (SD = 1.11) and virtual laboratories (SD = 1.20) demonstrate that the latter have a slightly wider range of responses, which may indicate different levels of experience or accessibility of this tool for teachers. In this context, it appears appropriate to conduct a correlation analysis to examine whether the perceived importance of these tools is associated with how respondents who have already used them in practice assess their effectiveness (Figure 3.22).

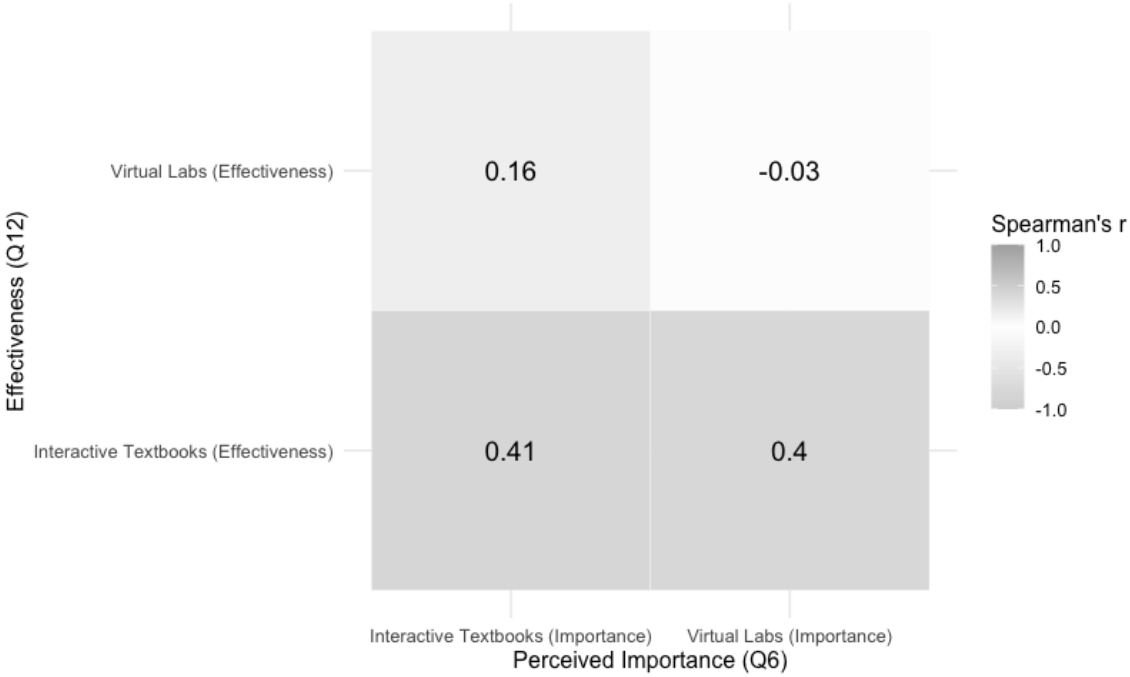

Figure 3.22 *Correlation between Perceived Importance and Effectiveness*

This heatmap illustrates the Spearman correlation between the perceived importance of using digital tools (Q6) and the actual perceived effectiveness after use (Q12) for Virtual Labs and Interactive Textbooks. A moderate positive correlation ($\rho = 0.41$) is observed for Interactive Textbooks, indicating that the more critical respondents consider this tool, the more effective it is perceived to be after use.

In contrast, the correlation for Virtual Labs is near zero ($\rho = -0.03$), suggesting that perceived importance and effectiveness are not meaningfully related for this tool.

Cross-correlations show that the perceived importance of one tool may be modestly related to the perceived effectiveness of another. However, these correlations (ρ = 0.16 to 0.40) are relatively low and should be interpreted with caution. Overall, these results suggest that respondents form clearer expectations about Interactive Textbooks than Virtual Labs, and that the alignment between expectations and experience is more substantial for the former.

The next step is to analyse teachers' preferences regarding their choice of advanced technologies that are important to add to online learning. (Figure 3.23).

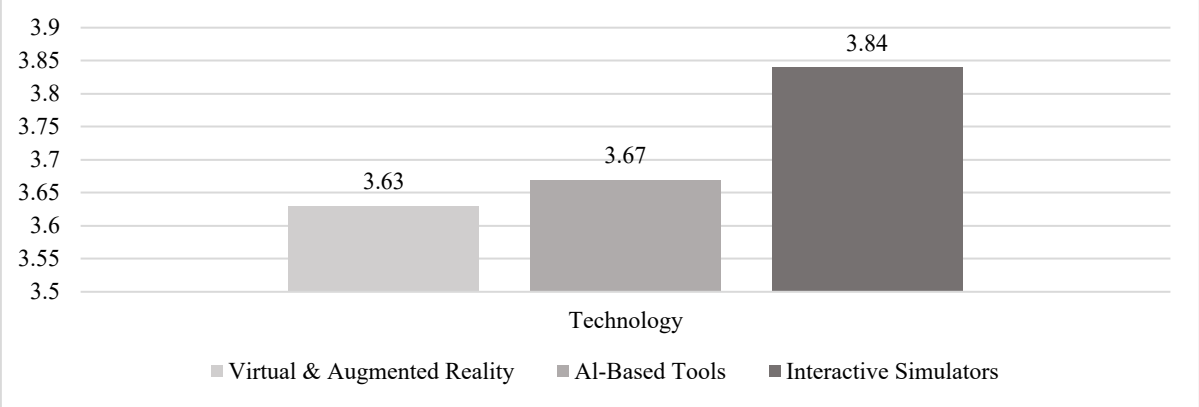

Figure 3.23 *Perceived Importance of Emerging Technologies in Online Learning*

According to the analysis, interactive simulations (Mean = 3.84, SD = 1.20) are the most desired tools for integration into online learning. However, all tools received average ratings above 3.5, which is further supported by the Wilcoxon signed-rank test ($p < 0.0001$), indicating their high perceived importance among respondents. All technologies demonstrated comparable standard deviations (~1.2–1.27), reflecting considerable variability in responses and indicating divergent evaluations among teachers. Nevertheless, the correlation analysis ($r = 0.031 / 0.021 / 0.00013$) and the Kruskal-Wallis chi-squared test (p-value > 0.05) confirmed that respondents' age does not significantly influence their choice of technological tools, which supports the applicability of uniform strategies across different age groups.

To further evaluate this, a Z-test was conducted to determine whether advanced technologies stand out compared to other options provided to respondents. The analysis showed that all three technologies significantly differed from one another ($p < 0.05$), with interactive simulations displaying the most pronounced distinction ($p = 2.51e-06$).

The subsequent analysis examined the extent to which simulations and virtual laboratories contribute to the immersion of TVET engineering teachers in online learning (Figure 3.24).

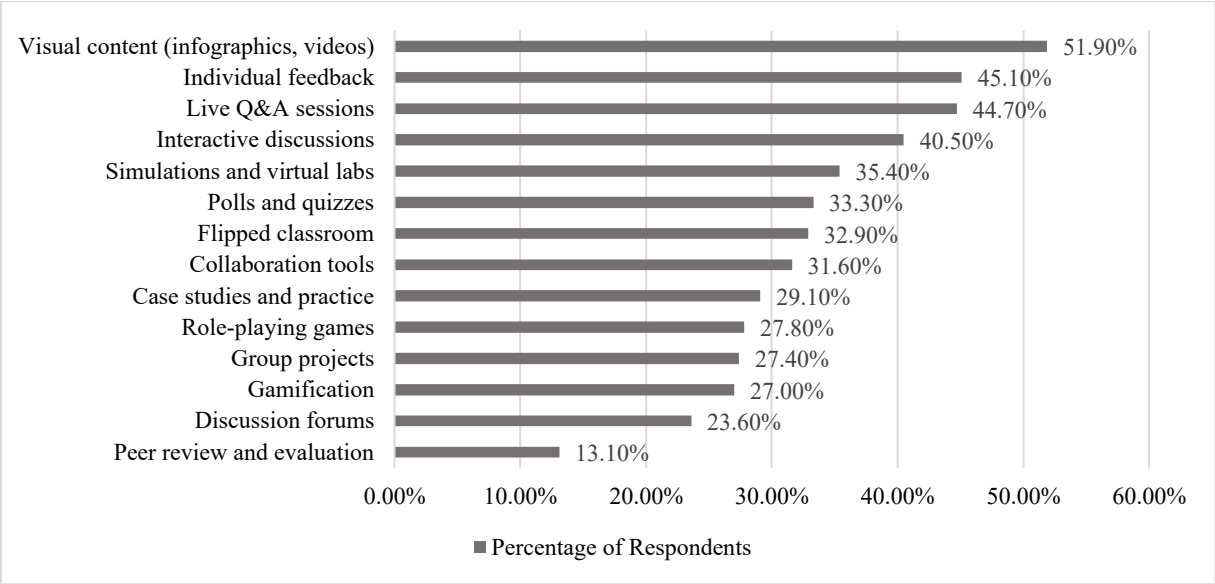

Figure 3.24 *Effectiveness of Online Learning Tools*

The analysis revealed that 35.4% of respondents selected simulations and virtual laboratories as tools that enhance engagement. However, the Wilcoxon signed-rank test indicated that it cannot be asserted (p-value > 0.05) that simulations and virtual laboratories are rated significantly higher than other tools by users. The Z-test showed that the frequency of choosing this tool as significant differs considerably from the random level ($p < 0.001$). However, the proportion itself (7.64%) is relatively small, indicating that this tool stands out but is not the undisputed leader among others.

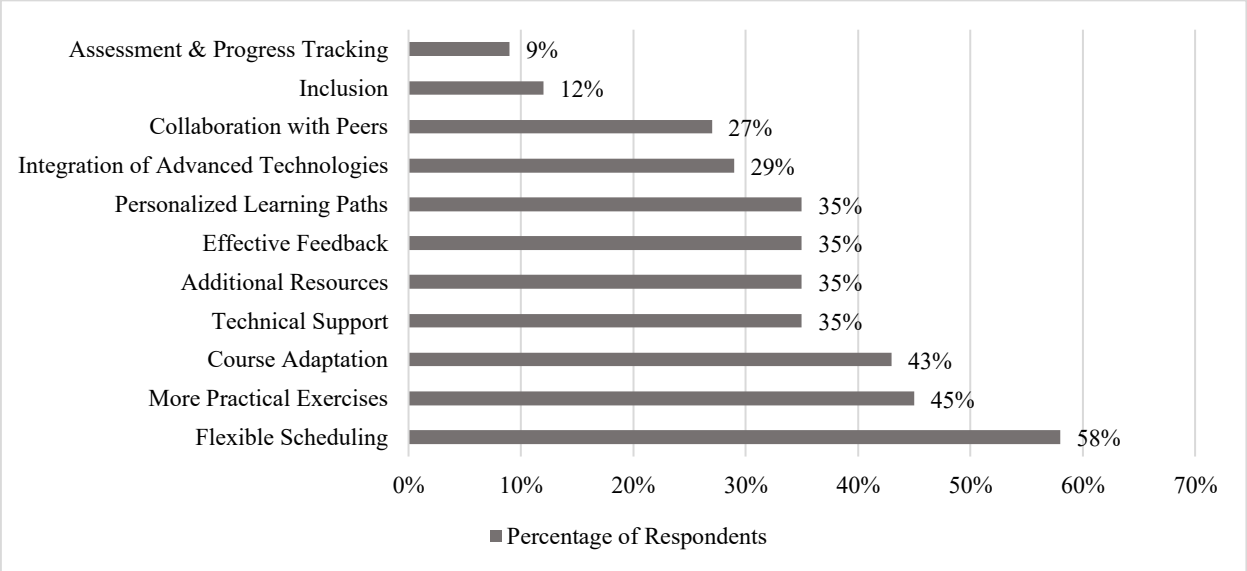

Figure 3.25 *Preferred adaptation instruments*

The analysis revealed that 29% of respondents considered the integration of advanced technologies a crucial tool for adapting online courses to the needs of TVET engineering teachers (Figure 3.25). The Wilcoxon test ($p = 0.9097$) indicates that teachers do not consider the integration of advanced technologies a key factor in course adaptation. However, the Z-test ($p < 2.2e\text{-}16$) demonstrates that the frequency of selecting this option significantly differs from a random distribution, suggesting its importance to respondents. The Chi-squared test ($\chi^2 = 139.41$, df = 10, p-value < 2.2e-16) further confirms the uneven distribution of response frequencies and their non-random selection.

When implementing advanced technologies, it is crucial to understand which ethical concerns teachers are most sensitive to. For this purpose, an analysis was conducted to identify the ethical issues that impact the online learning experience (Figure 3.26).

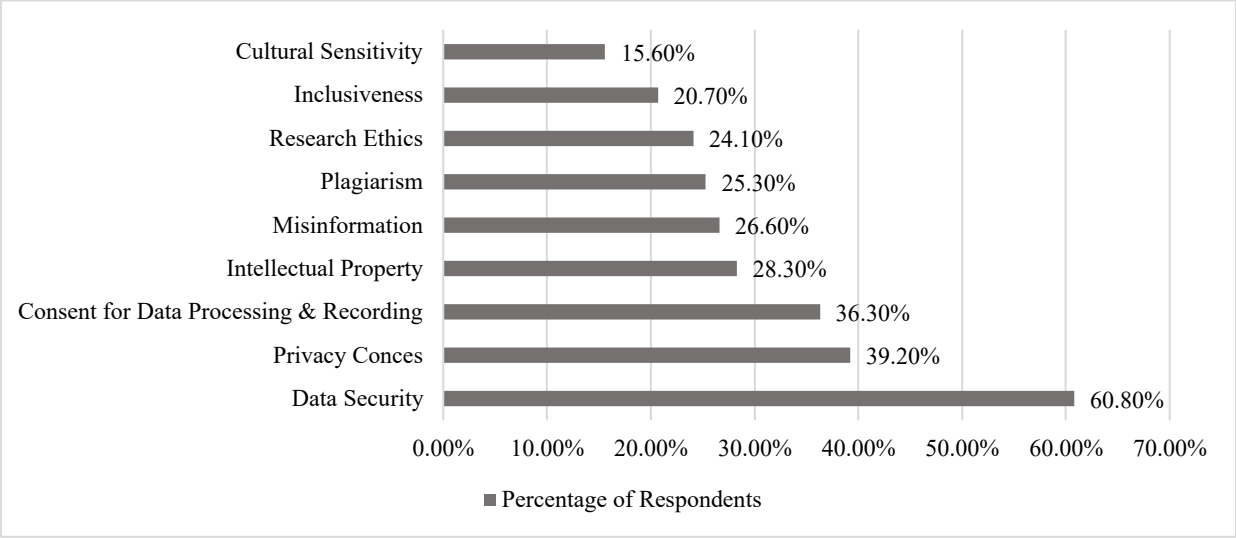

Figure 3.26 *Ethical Issues in Online Learning*

The analysis results revealed that the majority of respondents expressed concerns regarding data security (60.8%) and privacy concerns (39.2%). Data protection is perceived by respondents as the most critical issue when using technologies and implementing online learning. The Wilcoxon test for Data Security ($p < 2.2e{-}16$) and for Privacy Concerns ($p = 0.0038$) confirms the statistical significance of these options and their distinction from other potential ethical issues. The Z-test demonstrates the significant dominance of Data Security ($p < 2.2e{-}16$) over other options. The Chi-squared test ($\chi^2 = 110.34$, $p < 2.2e{-}16$) confirms that the distribution is not random and that Data Security is indeed considered the most important issue by respondents. It is also noteworthy that 70,89% of respondents selected at least one of the options related to the importance of data protection and privacy. This suggests that, in the context of using advanced technologies, Data Security is a key component of a comfortable and trusted online learning environment for TVET engineering teachers. However, it is also important to consider that 51.41% of respondents indicated a lack of digital literacy, which must be addressed in the design of online courses before the integration of complex modern technological solutions.

Summary

The findings of the study confirm the hypothesis that the integration of modern technologies (virtual laboratories, simulators, VR/AR) contributes to the development of professional skills among TVET engineering teachers and enhances the effectiveness of online learning. The analysis showed that familiar digital tools (such as webinars and interactive platforms) are perceived as more comfortable to use, while new technologies—although less familiar—are still positively evaluated. Correlation analysis revealed that the perceived importance of a technology is directly linked to its effectiveness in practice and that the combined use of interactive textbooks and virtual laboratories amplifies the educational effect. The main barrier to implementation remains the digital literacy of TVET engineering teachers. Additionally, the study highlights the importance of addressing ethical concerns, particularly in the area of data protection. Therefore, the successful integration of innovative technologies into online education requires not only the adoption of modern tools but also comprehensive user support through training, methodological adaptation, and cybersecurity assurance. Nonetheless, the presented analysis confirms that TVET engineering teachers did not consider the integration of advanced technologies as a priority. However, it remains a meaningful tool that can enhance the outcomes of online learning.

Hypothesis 5 – Teacher Trainers' Feedback

The verification of the hypothesis "Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes" is based on the analysis of questions related to the significance and quality of feedback within the educational process. The study aims to determine the extent to which regular and constructive feedback influences motivation, engagement, and learner satisfaction, as well as to assess the perceived importance of feedback in the context of online learning. A complete list of the questions used for the analysis is presented in Appendix J.

The hypothesis should first be examined by identifying whether there is a problem regarding the absence of feedback and interaction with the instructor during online learning. (Figure 3.27)

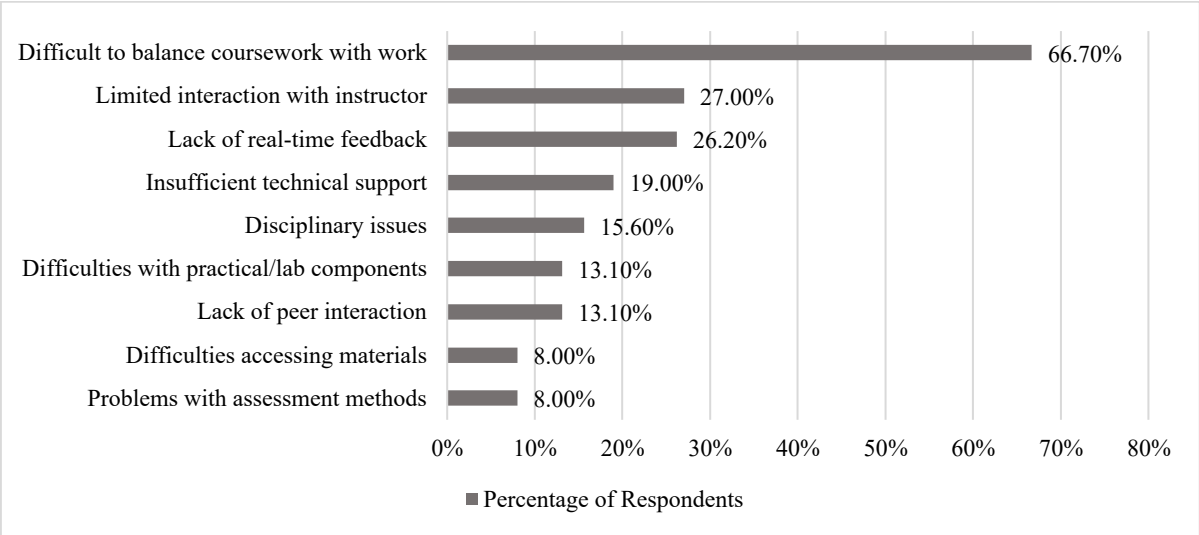

Figure 3.27 *Difficulties Encountered in Online Courses*

The results of the analysis show that a Lack of real-time feedback (26.2%) and Limited interaction with the instructor (27.0%) rank among the top three most frequently cited problems by respondents. Z-test results ($p = 0.0018$) indicate that these issues are statistically significant compared to other concerns, although they do not overwhelmingly dominate the others. Previously conducted chi-squared tests (χ^2, $p < 2.2e\text{-}16$) confirm that respondents selected their answers consciously, not at random. It is essential to highlight that 42.62% of respondents selected at least one option that supports the hypothesis.

A logical continuation of the analysis is the examination of additional resources that teachers would like to see integrated into online learning. (Figure 3.28)

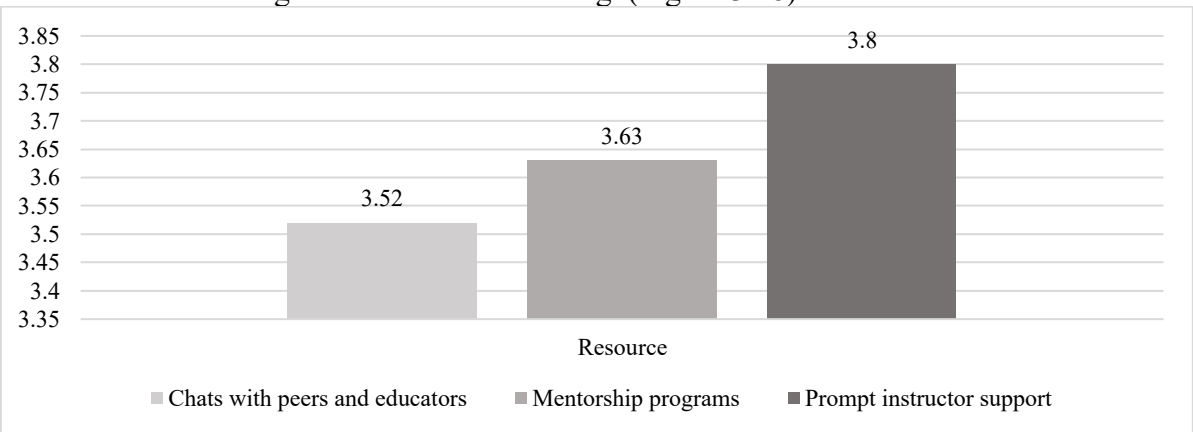

Figure 3.28 *Importance of Additional Learning Resources*

The analysis shows that prompt instructor support is one of the most highly rated elements (Mean = 3.80), indicating that feedback and communication with the instructor play a crucial role for learners. The Wilcoxon signed rank test revealed that:

- Chats with peers and teachers (V = 11.519, p-value = 4.241e-09)
- Mentorship programs (V = 12.456, p-value = 1.613e-11)
- Prompt instructor support (V = 14.534, p-value < 2.2e-16)

are all significantly above the neutral midpoint, suggesting that respondents meaningfully value these resources.

The Kruskal-Wallis test (χ^2 = 5.7539, df = 2, p-value = 0.05631) indicates that the differences between these options are not statistically significant, and the similar distribution of ratings suggests that respondents value all forms of interaction and support almost equally.

The next step in testing the hypothesis involves analysing whether individualised feedback is perceived as a tool that facilitates deeper engagement in online learning. (Figure 3.29)

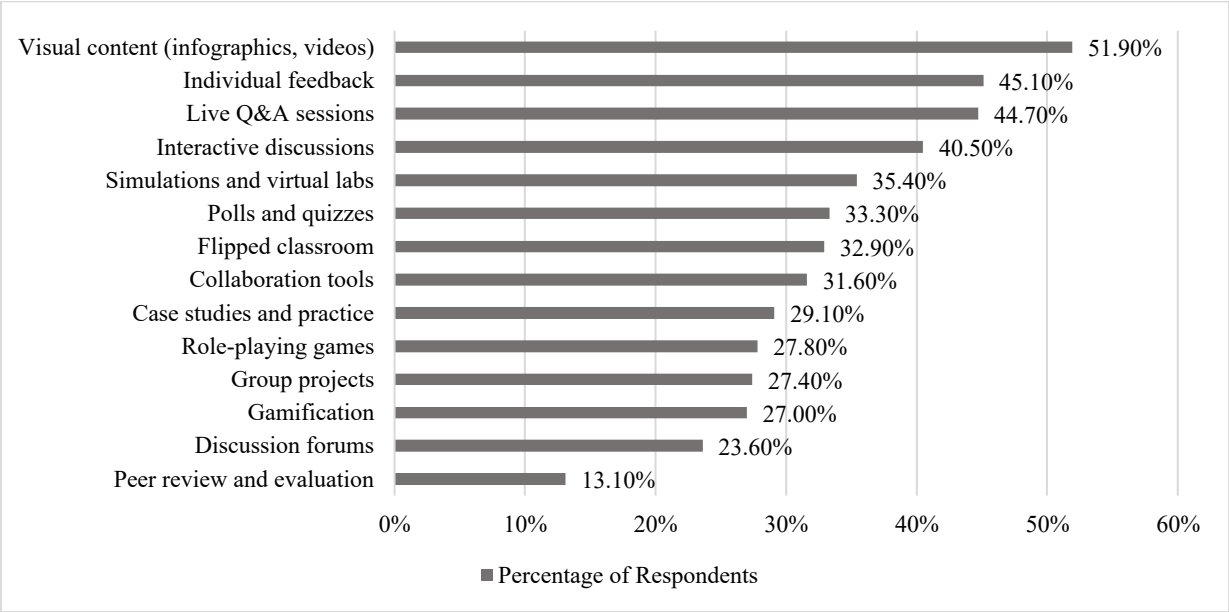

Figure 3.29 *Effectiveness of Online Learning Tools*

The analysis showed that Individual feedback (45.1%), Live Q&A sessions (44.7%), and the Flipped classroom (32.9%) were selected by respondents as options supporting the importance of instructor feedback for effective learning. The Z-sample test for equality of proportions with continuity correction confirmed that respondents significantly more often selected at least one of the identified tools compared to others (p-value < 2.2e-16) and did so consciously. 74.68% of respondents selected at least one of the three options that correlated with the importance of feedback in online learning. The interval (0.41; 0,58) indicates an extreme difference with 95% confidence that the actual difference between groups lies within this range. This confirms the significance of the selected tools. It is worth noting that 74.68% of respondents selected at least one option that supports the hypothesis.

The next step is to analyse how vital teachers consider the inclusion of feedback tools in meeting learners' needs. (Figure 3.30)

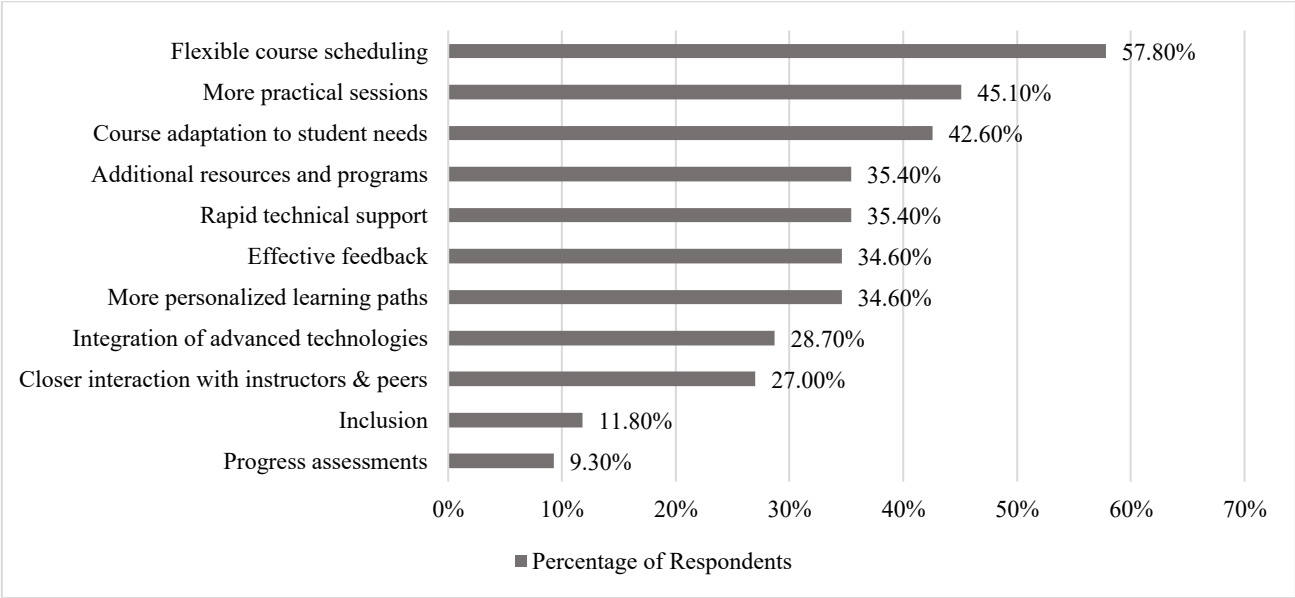

Figure 3.30 *Preferred Adaptation for Online Courses*

The analysis revealed that Effective feedback (34.6%) and Closer interaction with teacher trainers and peers (34.6%) were not randomly selected by respondents (p-value < 2.2e-16); however, they were not the most popular options teachers wanted to see in their training. The Z-test (p-value = 7.027e-07) indicated that these options differ significantly from the others. 47.26% of respondents selected at least one option supporting the importance of feedback in online courses. It is worth noting that 47.26% of respondents selected at least one option that supports the hypothesis.

The next question helps to understand how highly TVET engineering teachers evaluate feedback tools in online learning. (Figure 3.31)

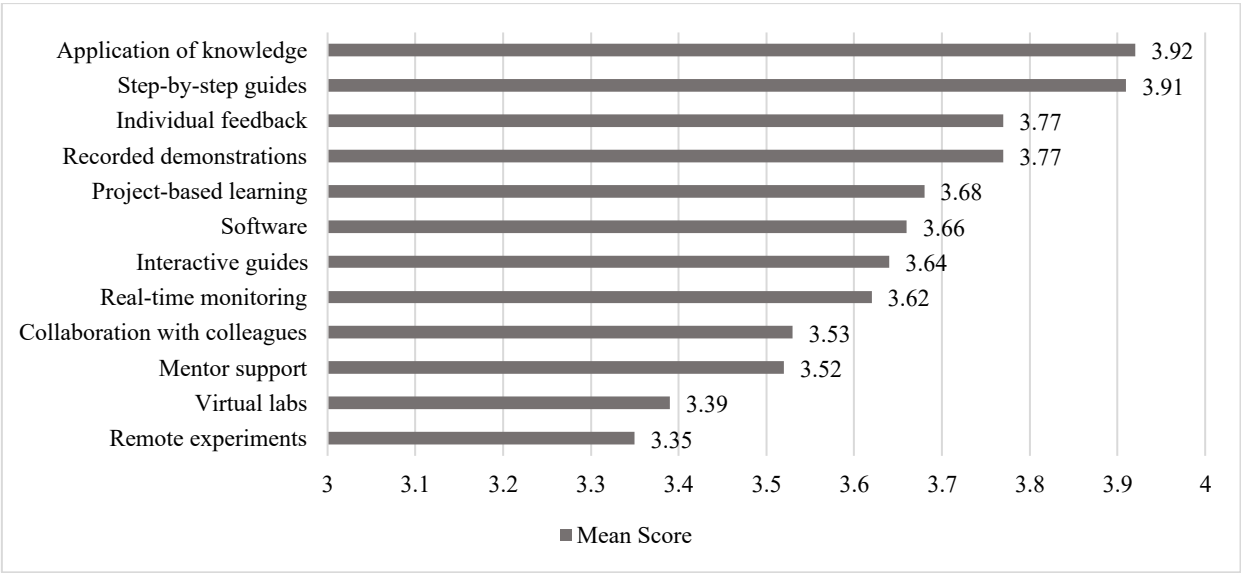

Figure 3.31 *Effectiveness ratings of practical tools*

The analysis showed that respondents rated Mentor support (3.52) and Individual feedback (3.77) as effective tools in online learning. The Kruskal-Wallis rank sum test (p-value < 2.2e-16) indicated that some tools were rated significantly higher or lower than others, indicating a statistically significant evaluation. Since the question included a response option for those who had never used the tools, these responses were excluded from data visualisation. 11% of respondents reported that they had never received individual feedback during online courses, and

16.5% had never received mentor support. The sample indicates that over 80% of respondents had experience with receiving feedback. This makes the collected data reliable enough for the following analysis. Moreover, 91.14% of respondents selected at least one of the options, underscoring the importance of feedback for effective online education. The average rating across all tools was 3.67, which is higher than the mean score. The Wilcoxon Test for Individual Feedback (p-value = 0.2889) indicates that it is not significantly higher than the average, meaning it does not stand out statistically among other tools, and teachers assess its importance on par with others. The Wilcoxon Test for Mentor support (p-value = 0.9984) also does not statistically differ from other tools. Based on this analysis, respondents did not single out any one tool as significantly important, yet this does not negate the relevance and importance of their use.

The next step in testing the hypothesis was to determine how much respondents lacked feedback and support in online learning. (Figure 3.32)

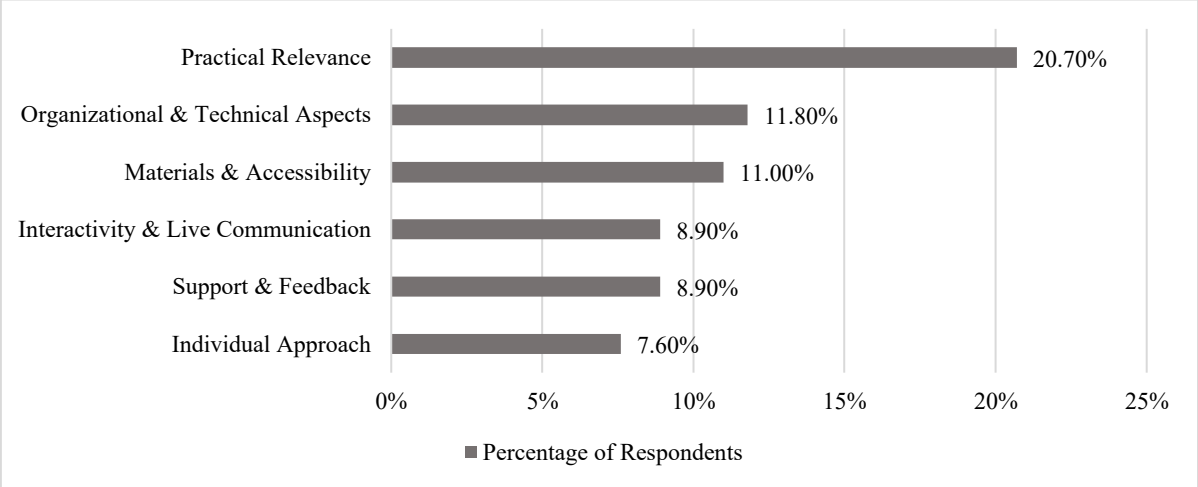

Figure 3.32 *What was missing in the online course*

The analysis showed that respondents' answers were statistically significant and differed from a random distribution (Chi-squared test = 23.515, df = 5, p-value = 0.000269). Only 8.9% of respondents selected "Support & Feedback," indicating that there is a sufficient amount of feedback in the online courses taken by the TVET engineering teachers. Z-test results showed a statistically significant difference from other options (p-value < 2.2e-16), indicating that teachers selected this option less frequently than others. It is important to note that this was an open-ended question, and respondents wrote down their answers in their own words. Therefore, although the percentage of those mentioning the lack of feedback is low, this issue still exists and remains relevant for improving the effectiveness of online learning.

The final question examines to what extent respondents perceive feedback and support as tools for improving online learning. (Figure 3.33)

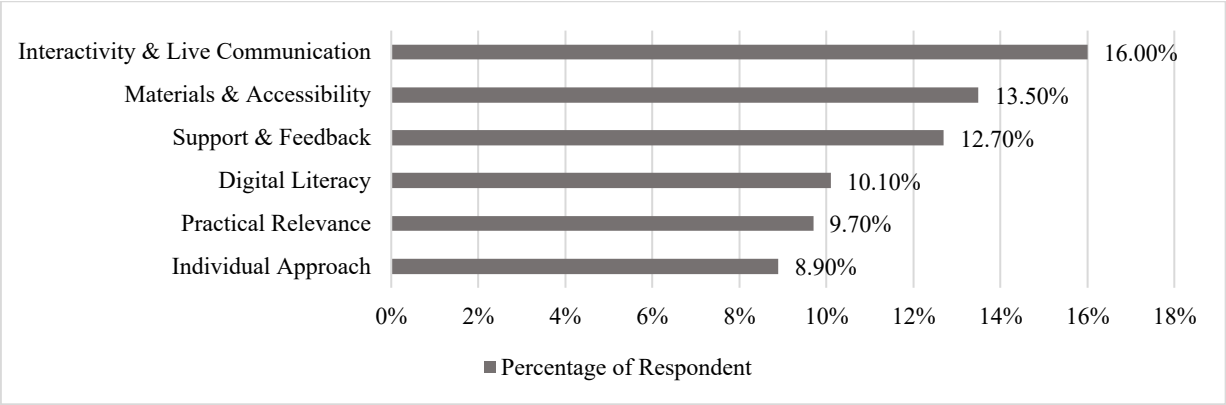

Figure 3.33 *Desired improvements in online courses*

The Chi-squared test (p-value = 0.186) demonstrates that the results do not differ significantly from random, which suggests that the selection of different options was uniform. However, it is also important to note that this was an open-ended question, allowing respondents to write whatever they considered important for online courses. Based on the results, 12.7% of teachers highlighted Support and Feedback as an important tool for improving the educational experience in online learning. The Z-test (p-value < 2.2e-16) differs significantly from the others, indicating that this option was mentioned less frequently than some of the others. However, if respondents mentioned it, this is important for drawing general conclusions.

Summary

The results of the study confirm that regular and meaningful feedback from teacher trainers plays a crucial role in increasing engagement and improving the educational outcomes of TVET engineering teachers in online learning. The analysis revealed that a lack of interaction with teacher trainers is one of the key challenges in distance education. TVET engineering teachers highly value tools such as individual feedback, mentorship support, and interactive Q&A sessions, which contribute to a deeper understanding of the material. Based on the analysis, respondents did not stress any one tool significantly, yet this does not doubt the relevance and significance of its use. Nearly half of the participants consider feedback important for their comfortable online learning experience. Face-to-face communication with the teacher trainers is highly valued by TVET engineering teachers, regardless of the specific format in which it occurs. Moreover, implementing strategies for individual feedback and enhancing interaction between teacher trainers and TVET engineering teachers can significantly improve the quality of online education. Thus, the hypothesis regarding the importance of feedback in online learning is confirmed.

3.2.5 Quality Criteria/ Methodological critique

Methodological critique and the definition of quality criteria for quantitative empirical research are fundamental elements ensuring its credibility and validity (Coughlan et al., 2007). Various approaches to assessing the quality of quantitative research results are proposed in the research literature, one of which is the Ryan-Wenger model (1992). This model identifies two fundamental groups of criteria that enable a comprehensive assessment of a study (Coughlan et al., 2007). The first group is the credibility variables. They help to determine how convincingly and reasonably the study is presented. These are associated with the researcher's competence, the logical structure of the work, and the substantiated presentation of results. Credibility variables enable an evaluation of the level of trust in the research, although they do not always reflect its methodological rigour. The second group is integrity variables. They help to evaluate the reliability and consistency of the research process. They also encompass key aspects of scientific validity, including strict adherence to methodological procedures, justification of the chosen methods, and the reproducibility of results.

Both groups of criteria play a vital role in evaluating the quality of quantitative research, as they help identify both the strengths and potential vulnerabilities of the study. It is crucial to analyse two aspects of the study: reliability and validity. According to Wood (2006), a method demonstrates reliability when it consistently and accurately measures the phenomenon under study. In contrast, an instrument demonstrates validity when it accurately captures what it is intended to measure (Wood & Ross-Kerr, 2011). Such an approach to critical research evaluation not only helps identify potential limitations but also suggests ways to minimise them, which is particularly relevant when developing and applying new measurement tools.

As part of this research stage, a new tool (questionnaire) was developed for the quantitative phase and applied to a new population. To assess its reliability, validity, and applicability, a pilot study was conducted (Russell, 2005). The questions were evaluated by experts in the socio-pedagogical field and refined based on the analysis to ensure a more targeted implementation aligned with the research question (Coughlan et al., 2007). This approach enabled the instrument to be tailored to the research goals, making it both valid and reliable for further use (Polit & Beck, 2006).

To assess internal consistency, the intraclass correlation coefficient (ICC) was used, which indicated a high level of expert agreement. High ICC values suggest that the experts were largely consistent in their judgments, thereby enhancing the instrument's reliability (McGraw & Wong, 1996). However, it is essential to note that the analysis assumed fixed expert judgments, which could introduce subjectivity. In future studies, it would be advisable to conduct Test-Retest Reliability to assess the stability of the questionnaire over time (Streiner, 2003). Construct validity was supported by comparing the questionnaire items with theoretical models and the qualitative research phase. However, the lack of external validation (comparison with similar studies) can be considered a limitation, even though no thematically similar research was identified at the time of the questionnaire's development and testing.

Another critical quality criterion for quantitative research is sample size. This study included 237 participants, which, according to Comrey and Lee (2013), is considered a fair sample size. However, ensuring statistical power requires not only a sufficient number of respondents but also that the sample meets the calculated minimum (Cohen, 1992). According to Cochran's formula (1977), for a 95% confidence level and a 5% margin of error, a minimum sample size of 370 is required. Nevertheless, Babbie (2016) argues that in specialised studies, even smaller samples can provide valid results if they are representative. Gorsuch (1983) also supports this, stating that 100 respondents completing a questionnaire can ensure reliability. In this study, the sample was formed based on key characteristics of the target group, minimising potential representativeness errors. According to Polit and Beck (2006), to avoid bias in responses, participation of at least 50% of the sample is necessary, which was fully met in this study.

The sample was formed based on voluntary participation (self-selection bias), which could result in systematic error, as the study may have attracted predominantly motivated and tech-savvy respondents. This error could lead to inflated evaluations of the effectiveness of digital tools, as less experienced users may have been less likely to participate in the survey (Groves, 2011).

Moreover, it leads to another potential limitation of the data collection method (Google Forms) — the digital divide, i.e., unequal access to digital technology among respondents (Field, 2018). Limitations may include low levels of digital literacy, which hinder some teachers' participation, and service access restrictions in Russia, potentially reducing respondent outreach.

These limitations may have influenced the respondents' perceptions of digital tools and distorted the data. Moreover, conducting an online survey meant that there was no control over the environment in which participants filled out the questionnaire. Unlike interviews or observations,

online surveys cannot control the context or the presence of distractions, which may lead to inattentive or rushed answers (Dillman et al., 2014). However, despite these limitations, this method remains optimal for the given study due to the geographical dispersion of respondents and time zone differences.

Returning to the respondent sample, which was strictly limited to TVET engineering teachers, another potential limitation arises — social desirability bias. Since part of the questionnaire focused on self-assessment of potential and professional activity, respondents may have tended to choose more socially acceptable responses, especially when evaluating their competencies (Podsakoff et al., 2003).

Another quality criterion is a well-constructed and valid questionnaire (Johnson, 2014). The questionnaire included closed-ended questions, predefined answer options, open-ended questions, and Likert scale items, a standard approach that also carries several limitations. Fixed-answer questions may not reflect the full spectrum of respondent opinions, reducing the depth of analysis (Fowler & Fowler, 2013). Although the questionnaire included open-ended questions, their share (22% of the total) was relatively low, which may have affected the results. Furthermore, fewer respondents answered the open-ended questions compared to the closed-ended ones, indicating a potential unwillingness to express opinions about the studied phenomenon. Another limitation is the subjectivity of interpreting categorical ratings in Likert scale questions. As Krosnick (1999) points out, respondents may interpret scale gradations differently, thereby reducing measurement accuracy.

An important quality criterion is the selection of questions used to test the hypotheses, as well as the method that can help choose these questions. In the present study, the questions were initially developed to be relevant and comparable to those used during the qualitative stage of the research. However, the author selected questions for testing each hypothesis on a subjective basis, excluding those deemed irrelevant for hypothesis testing to minimise data distortion and noise (DeVellis & Thorpe, 2022). Questions were selected based on their logical alignment with the corresponding hypothesis (Clark et al., 2021).

A sensitivity analysis (Saltelli et al., 2004; Saltelli et al., 2007; Morgan et al., 2007) of the hypotheses to question selection was conducted during the study, allowing for an assessment of how the choice of specific questions influenced the average values of the measured indicators. This analysis is paramount for confirming the robustness of the results and ensuring an accurate interpretation within the methodological framework of the study (Open Science Collaboration, 2015). The sensitivity analysis revealed that the degree to which each hypothesis depends on the selected questions varies. The results are presented in Table 3.11.

Table 3.11 *Sensitivity Analysis Results*

Hypothesis	Mean_Original	Mean_Replaced	Difference	Sensitivity
Hypothesis 1	0.384	0.316	0.0688	Low
Hypothesis 2	1.87	1.64	0.237	High
Hypothesis 3	1.65	1.87	0.222	High
Hypothesis 4	2.47	2.54	0.0703	Low
Hypothesis 5	0.995	1.06	0.0683	Low

Hypotheses 1, 4, and 5 demonstrate a high level of robustness, while Hypotheses 2 and 3 exhibit significant sensitivity to changes in the set of questions used, indicating a potential dependence of the results on the measurement methodology and question selection. Although the questions were chosen subjectively—and the sensitivity analysis also confirms this—the subjectivity is offset by the rigour of the rationale provided (Podsakoff et al., 2003; Field, 2024). High sensitivity in

hypotheses does not indicate an error in analysis or a flaw in the data but rather reflects the specific methodological nature of the study (Cohen, 1992). Moreover, in the present study, Hypotheses 2 and 3 are, by nature, multidimensional constructs that encompass various aspects, and the exclusion or replacement of any of them may significantly influence the results. It is crucial to note that, despite the high sensitivity of the hypotheses, the presence of a real effect is a strong indication of a well-designed study (Lakens et al., 2018). To ensure meaningful interpretation, the results of the quantitative analysis were approached from an analytical standpoint rather than being "blindly trusting" in mathematical outputs (Tabachnick et al., 2019).

Summary

In conclusion, the limitations identified are better understood as methodological features of the research rather than indicators of error or data insufficiency. The analysis highlighted specific characteristics of working with quantitative data that must be considered when interpreting results. Mauch and Park (2003) defined research limitations as factors that may influence results without necessarily altering the overall outcome and that remain beyond the researcher's control. This study acknowledges the potential limitation of subjectivity; however, efforts were made during the analysis and interpretation stages to minimise its impact. Future research can address this limitation by using data triangulation to uncover hidden factors that the quantitative phase may have missed.

3.3 Summarising The Results/Method Triangulation

Methodological Approach – Triangulation

In this study, the results are integrated using the method of methodological triangulation (between-method triangulation) (Denzin, 2017). (Figure 3.34.)

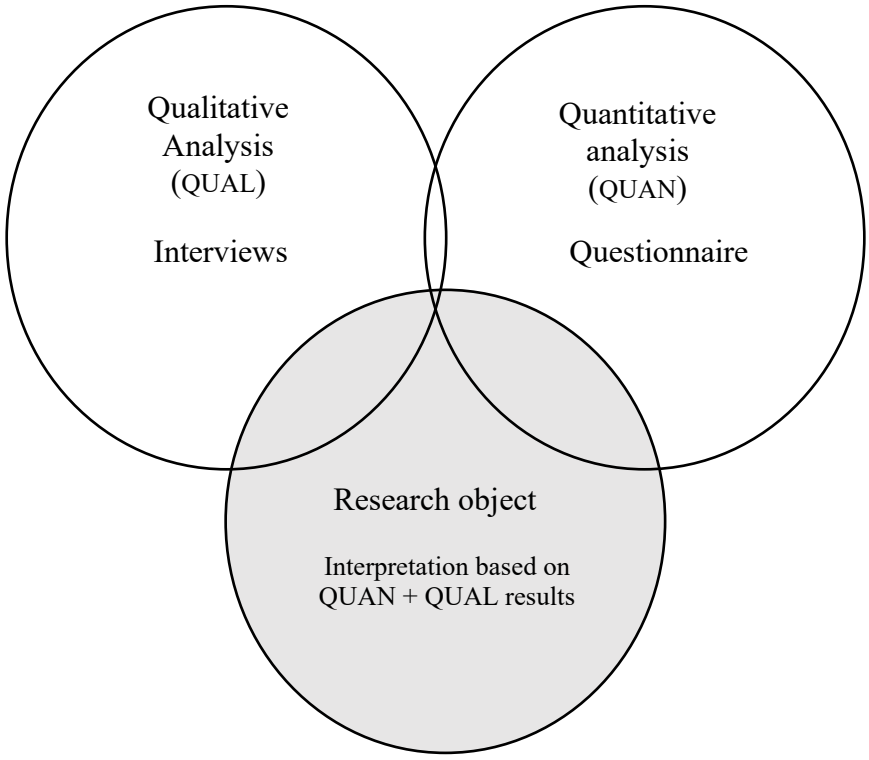

Figure 3.34. Between-method triangulation (based on Denzin, 2017)

This method enables the presentation of the strengths and weaknesses of both qualitative and quantitative data, facilitating a deeper understanding of the research results, broadening the scope

of knowledge, and overcoming the methodological limitations of individual data collection methods (Patton, 1990; Tashakkori & Teddlie, 1998; Creswell et al., 2004; Steckhan et al., 2024).

In this study, data obtained through interviews with teacher trainers teaching online courses for TVET engineering teachers and through a large-scale survey of TVET engineering teachers were compared, and triangulation was used to ensure alignment with the qualitative exploratory sequential design research (Creswell, 2009; Creswell & Creswell, 2018). Moreover, this method enables a more detailed description of the phenomenon's complexity and a comprehensive evaluation of it (Frost, 2011; Gorard & Taylor, 2004, p.45; Treur et al., 2024). It is essential to note that these methods complement each other, thereby creating distinct perspectives on the studied phenomenon, which can later be integrated into a unified result (Gorard & Taylor, 2004, p. 46; Flick, 2017).

The selected mixed methods strategy aligns with an exploratory sequential design, wherein qualitative data analysis was used to formulate hypotheses, which were subsequently tested through quantitative methods. This structure enables methodological triangulation by integrating results from two distinct data strands, enhancing validity and deepening understanding (Tashakkori & Teddlie, 1998; Creswell & Plano Clark, 2011).

The effectiveness factors of online courses for TVET engineering teachers are examined through various methodological approaches that allow these factors to be viewed from multiple perspectives (teacher trainers teaching online and TVET engineering teachers participating in online learning) (Arias Valencia, 2022). Based on the analysis of interviews with teacher trainers who deliver online training for TVET engineering teachers, conclusions can be drawn regarding the challenges faced in the educational process and the factors identified by teacher trainers themselves that, in their opinion, influence the effectiveness of training TVET engineering teachers. These findings enable the formulation of hypotheses about what facilitates the creation and implementation of effective online courses. However, teacher trainers' views on effectiveness are incomplete without the opinions of the TVET engineering teachers themselves, who have taken online courses and have their perspectives on the factors that enable them to get the most out of their learning. Thus, combining several methods and perspectives enables a multifaceted study and a comprehensive understanding of the factors affecting the effectiveness of online courses from both teachers' and students' perspectives.

The first empirical phase of the study—interviews with teacher trainers who teach TVET engineering teachers via online courses—reflects a methodological perspective that involves an in-depth exploration of factors influencing the effectiveness of online learning. This phase enabled the identification of key hypotheses based on teacher trainers' experiences, observations, and evaluations of the practical aspects of organising online courses. The second empirical phase—surveying TVET engineering teachers with online learning experience—complements the study from a quantitative perspective, providing statistical verification of the identified hypotheses.

This study employs various methodological approaches, which are analysed sequentially but treated as equally valid. The results of the two empirical stages of the study (interviews and questionnaires) are combined to identify similarities, trends, and patterns. In this study, qualitative and quantitative data have already been analysed and interpreted.

The contemporary classification of results in mixed-methods research considers not only the criteria themselves (convergence, complementarity, contradiction, partial agreement, and silence) (O'Cathain et al., 2010; Schlunegger et al., 2024) but also the causes and conditions under which these relationships arise. This approach enables data to be analysed through the prism of

methodological characteristics, theory, and research context (Farmer et al., 2006), helping to formulate meta-conclusions for multi-method research (Sántha & Malomsoki-Sántha, 2023).

Effectiveness Factors of Online Courses for Training TVET Engineering Teachers– Response to the Central Research Question

The triangulation of qualitative and quantitative data enabled the identification of key factors determining the effectiveness of online courses in the TVET engineering teacher training system. Additionally, it uncovered factors not directly addressed by the hypotheses mentioned in the interviews with teacher trainers, which were indirectly confirmed through the quantitative survey. The analysis showed that the main effectiveness factors of online learning are associated with course content adaptation, the use of blended learning formats, the implementation of active learning methods, technological integration, and the importance of feedback. At the same time, several aspects requiring further investigation were identified. A detailed matrix comparing the results of the qualitative and quantitative analyses is presented in Appendix K.

Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses.

The analysis results confirmed that one of the most important factors of online course effectiveness is the adaptation of educational content to learners' professional experience and educational needs. Learning flexibility (57.8%), personalised learning pathways (77.2%), and course adaptation to the learner's abilities (42.6%) were recognised as significant characteristics. Regarding content, particular emphasis was placed on the development of practical skills and training in Teaching Methodology (58.6%) and Innovative Technologies in Education (51.9%), which is supported by the expressed demand for a training module on methodological materials (4.1%). This was not reflected in the primary analysis as it does not directly relate to the hypothesis. This aspect is crucial, as TVET engineering teachers mainly teach courses in engineering disciplines, the perceived effectiveness of which is significantly lower than that of methodological foundations and practical application.

However, important aspects were identified that did not receive quantitative confirmation but are relevant to the study of online learning effectiveness: narrow course topics, teacher trainers' preparedness for the content level, well-structured assignments, assessment of learners' practical experience before task execution, learner discipline, availability of organisational and technical support, emphasis on addressing fundamental educational gaps, consideration of cultural and national features, and the use of entry-level knowledge assessments. Notably, the influence of cultural sensitivity on the learning experience was reported by 15.5% of respondents in the quantitative analysis, which can be considered a confirmed quantitative finding.

The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers.

The analysis revealed that 66.7% of respondents encountered difficulties balancing work and study, highlighting the importance of learning flexibility and blended formats. Although 58.6% of respondents selected the blended format, asynchronous learning was preferred by 75.9%, with 40% of them also supporting blended learning. The inclusion of practical classes (45.1%), multimedia (mean rating: 4.08), and methodological (mean rating: 4.04) materials, as well as interactive textbooks (mean rating: 4.05), positively influences course effectiveness. These ratings reflect participants' evaluations on a 5-point Likert scale, where 1 indicated "very low usefulness" and 5 indicated "very high usefulness." Respondents also actively selected traditional learning elements (such as library access and detailed guides), indicating the importance of integrating them

into the learning process. However, some aspects were not tested quantitatively but were noted by experts during interviews, including the lack of retention rate assessment and instructional group size planning. A significant factor was the necessity of transferring theoretical subjects and those that allow for digital demonstration into an online format, while the rest should be conducted in person.

The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers

Quantitative analysis confirmed the importance of active learning methods, including interactive and multimedia materials (62%), interactive discussions (40.51%), live Q&A sessions (44.73%), simulations and virtual labs (35.44%), and flipped classrooms (32.91%). Three main groups of active methods were identified: live interaction, practice-oriented methods, and gamified technologies. However, this study did not examine the differentiation of active learning methods tailored to different types of information perception or the effectiveness of these methods in terms of retention rates. Interviewed teacher trainers emphasised the importance of environments where learners complete tasks under the instructor's supervision. In turn, TVET engineering teachers expressed a desire to see additional tools for assessment and feedback (28.2%). This suggests the absence of practical tools, such as real-time assignment monitoring by the instructor.

The integration of modern technologies (virtual laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness

The technological component of online courses received high ratings from respondents. The use of virtual labs (mean rating: 3,85), interactive simulators (mean rating: 3,84), and AI and VR/AR tools contributes to increasing learner engagement. 35,4% of respondents noted the importance of simulators and virtual labs, and 29% highlighted the relevance of advanced technologies. Despite the overall positive perception of technology inclusion in the learning process, TVET engineering teachers also expressed concerns regarding Data Security (60,8%) and Privacy Concerns (39,2%), which must be considered when assessing online course effectiveness. The extent to which technologies help learners adapt to changing work environments remains an open question, although it was emphasised by teacher trainers teaching TVET engineering teachers. In addition to advanced technological solutions, TVET engineering teachers highly value mobile platforms, cloud tools, online collaboration platforms, and digital whiteboards in online courses. This suggests that the integration of technologies with varying levels of complexity is generally well-received by TVET engineering teachers.

Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes

Instructor feedback was identified as a crucial factor influencing the perceived usefulness and effectiveness of courses. Interaction with the instructor (27.0%) and real-time feedback (26.2%) are among the key factors of online learning effectiveness. Individual feedback (45.1%), mentor support (mean rating: 3.52), and live Q&A sessions (44.7%) were recognised as helpful tools. However, the quantitative study did not examine the factors mentioned by teacher trainers during interviews, including the importance of assessing learners' emotional and psychological state, knowledge assessment methods during online learning, and strategies for promoting active engagement. Although specific knowledge assessment methods were not explored, respondents indicated that issues with assessment methods do exist (8%) and that including formative assessments would enhance learning effectiveness (9.2%). Real-time monitoring was not used by

19.8% of respondents, while 21.5% considered it effective during practical and lab sessions. Moreover, tools for assessment and feedback were not studied, although 28.2% of respondents indicated they would like to see them in their online courses.

Summary
An analysis based on the triangulation of qualitative and quantitative data revealed key factors that determine the effectiveness of online courses for training TVET engineering teachers. The main components of successful learning were the adaptation of course content, the use of blended learning formats, the application of active teaching methods, the integration of modern technologies, and the importance of feedback. At the same time, the study revealed some aspects that were not covered, as mentioned by teachers or students, such as the impact of group size on engagement, assessment of retention rates, considering the level of teacher preparedness, the importance of knowledge assessment and feedback methods, and training in adapting to changing technological conditions. The results offer a deeper understanding of the factors that influence the effectiveness of online learning and underscore the importance of considering all the factors mentioned, as each plays a crucial role in shaping the educational experience.

3.4 Interpretation of The Results

The aim of this mixed-methods exploratory sequential research was to identify the key factors that determine the effectiveness of online courses in preparing TVET engineering teachers for the professional education system. The focus of the study was on a comprehensive examination of online training for TVET engineering teachers. The research first explored the historical development of engineering educator training in the context of secondary vocational education, the existing theoretical foundation in pedagogical theories applicable to online learning, and the current system of online training for TVET engineering teachers in Russia. This theoretical basis served as the foundation for the development of qualitative analysis categories and the subsequent structure of the quantitative stage.

The next step was to study the opinions of two key parties involved in the educational process. In the first phase, qualitative data were collected through interviews with teacher trainers responsible for training TVET engineering teachers in digital learning environments, aimed at identifying perceived factors contributing to the effectiveness of online courses. In the second phase, these factors underwent quantitative validation through a large-scale survey of TVET engineering teachers with experience in online learning. This sequential design ensured a coherent progression from the identification of factors to their empirical verification.

The results of the theoretical analysis informed the development of the framework for conducting interviews with teacher trainers engaged in the online training of TVET engineering teachers. The findings from each stage served as the logical starting point for the next, making the research seamless and cumulative, with each phase enriching the process with new insights, gradually addressing the core research question. The answer to the research question was derived from conclusions based on the hypotheses generated during the qualitative phase and tested through quantitative verification via a large-scale survey. Data from both the qualitative and quantitative phases were processed through coding, analysis, and subsequent triangulation. The analysis led to the identification of five key comprehensive factors of perceived online course effectiveness, along with their core characteristics and parameters. These five key factors emerged from the qualitative phase, which was grounded in the prior theoretical analysis. Appendix L presents the research sub-questions, data sources, key factors identified in the study, and their attributes and parameters. It illustrates how each phase of the research (qualitative, quantitative, and mixed methods) contributed to identifying the factors that influence the perceived effectiveness of online courses for engineering educator training. The sub-questions were used to explore the central phenomenon,

guiding the study toward answering the main research question. The core phenomena examined included teacher trainers' perspectives on the effectiveness factors in online training of TVET engineering teachers, as well as the views of TVET engineering teachers themselves regarding the identified factors and their perceived usefulness. Thus, this chapter is not only an interpretation of the collected data but also a logical conclusion of the entire research structure, in which each element, from theoretical assumptions to empirical findings, is combined into a single whole.

The investigation into the effectiveness factors of online courses for TVET engineering educator training enabled the identification of key characteristics of educational programs that influence learners' perceptions and learning outcomes. The data demonstrate that the effectiveness of online education is shaped not only by technological elements but also by didactic approaches, program flexibility, and the quality of interaction between teacher trainers and students.

The analysis confirms the significance of five key factors:

- Adaptation of course content to the experience, needs, and goals of engineering teacher trainers
- Blended learning format (combining traditional methods with online tools)
- Use of active learning methods (gamification, collaboration, interactive platforms)
- Integration of advanced technologies (virtual labs, simulations, VR/AR)
- Timely and constructive feedback from teacher trainers

Each of these factors is not only supported by empirical data but also has conceptual backing in contemporary scientific literature, which gives the study a high level of theoretical validity.

Particular attention should be paid to the fact that the study's results not only confirmed the significance of previously proposed hypotheses but also pointed to several new aspects that had not previously received sufficient empirical confirmation. The interconnection between theoretical concepts and empirical data demonstrated the complexity and multi-layered nature of the educational process in a digital environment. Analysis of the theoretical and empirical basis of the study revealed a correspondence between the identified factors and the following scientific concepts presented in Appendix M.

According to the analysis results, the most pronounced pattern is the focus on adapting educational content, which demonstrates learners' high expectations regarding the personalisation of courses. This approach confirms the concept of andragogy (Knowles, 1973), which emphasises the importance of a flexible approach to organising the educational process. The survey results show that 77.2% of respondents noted that adaptation of content to their professional experience and educational goals significantly increases the perceived effectiveness of the course. At the same time, qualitative data indicate that teachers who design courses view adaptation as a multi-layered process that encompasses not only the selection of topics and assignments but also considering the varying levels of student preparedness.

The significance of this finding is reinforced by digital didactics (Bilenko et al., 2020), which emphasises the need for diverse pedagogical strategies, including the design of individual learning paths and the use of adaptive digital platforms. The need to understand learners' readiness levels is also underscored in constructivist theory (Vygotsky, 1978). However, differences were identified in the perception of personalisation's importance: online course teacher trainers emphasise content structuring, whereas learners consider flexibility and the ability to choose their learning paths as critical.

It is essential to note that the interviewed teachers emphasised the excellent effectiveness of educational activities not by unquestioningly adapting to students' wishes but rather by relying on

their previous practical experience and competently formulating individual tasks. This approach is also supported by humanistic educational theory, which focuses on the learner's experience and the setting of realistic tasks (Maslow, 1968), as well as by cognitive theory, which emphasises building knowledge by linking new information to the learner's existing knowledge base (Ausubel, 1978). A recurring element confirmed in both qualitative and quantitative phases is the preservation of traditional pedagogical principles alongside the use of modern instructional methods, including digital technologies. This effect is achieved through the simultaneous demonstration and explanation of instructional content by the teacher, aligning with the principles of the cognitive theory of multimedia learning (CTML) (Mayer & Fiorella, 2021; Wahl, 2023) and reinforcing the importance of managing cognitive load and delivering information in a coherent sequence.

Regarding the next factor—the blended learning format—analysis confirmed its importance as a balanced and highly productive approach. Blended learning enables the integration of the advantages of online education (flexibility, accessibility, scalability) with those of offline interaction (immediate feedback, contextualisation, emotional engagement).

Interviewed teacher trainers noted that the most significant learning effectiveness is achieved not through rigid adherence to a course structure but through flexibility in content delivery and the ability to deviate from the preset path depending on group dynamics and individual learner needs. This approach aligns with humanistic theory, which supports adapting content and teaching methods to the specific context and audience (Akpan & Kennedy, 2020).

It is worth noting that the use of a blended learning format, as appropriate for teaching TVET engineering teachers, was validated in both the qualitative and quantitative phases of the study, which is a noteworthy finding. Interviewed teacher trainers repeatedly emphasised the importance of implementing blended learning, as not all skills can be effectively developed through online learning alone.

> *"It will be some blended learning, a mix of online and face-to-face formats. For specialised knowledge, especially in technical fields, blending online theory with hands-on practice in the workplace is ideal. This approach allows learners to independently study the basics online, then apply what they have learned through real-world practice, ensuring they fully understand the material."*

During the quantitative phase of the study, 58.6% of TVET engineering teachers selected blended learning formats; however, 75.9% preferred asynchronous learning formats, which indicates a need for balance between different methods of presenting material. In particular, this choice is due to the difficulty of combining learning and work for students. In this regard, the basics of behaviorist theory, which emphasise motivation to achieve educational goals, can serve as a starting point for solving the problem of lack of immersion in the educational process (Thorndike, 1898; Akpan, 2020). However, the data reveal a gap between expectations and actual practice. Teacher trainers emphasise methodological support and consider clear didactic structures and the integration of interactive tools as key factors, whereas TVET engineering teachers prioritise flexibility and practice-oriented content.

Moreover, despite selecting distance learning formats, many TVET engineering teachers emphasised the importance of live interaction with teacher trainers and timely feedback. This approach to instructional design is well captured in the model "Der Berufsdidaktische Dreidecker" (Martin, 2016), which allows for the integration of pedagogical skill development, professional practice, and industry engagement in the knowledge transfer process for TVET engineering teachers. This enables the combination of foundational preparation, as mentioned by teacher

trainers, with practical training, which the learners themselves highly value. To combine hybrid and flexible learning formats—frequently cited in both the qualitative and quantitative phases—the application of the HyFlex blended learning model is recommended (Atkinson, 2023).

Furthermore, the analysis indicates that an optimal approach for mastering complex engineering-pedagogical competencies involves a combination of online and in-person components. Face-to-face modules allow participants to practise practical skills and form a community of practitioners. In contrast, online modules provide flexibility, scalability and access to a wide range of educational materials. This approach is supported by Albert Bandura's theory of social learning (Zimmerman & Schunk, 2014) and modern principles of digital didactics (Bilenko et al., 2020), which together create a synergistic effect by integrating online and offline educational environments.

It is essential to emphasise that teachers do not view blended learning as a compromise but rather as a strategic solution for achieving a deeper understanding and skill development. Specifically, modules that simulate practical situations in online environments (e.g., VR laboratories) serve as preparatory stages for in-person discussions and laboratory work with real equipment, contributing to more comprehensive preparation for solving workplace and industrial tasks. All of the above falls under the umbrella of the Pedagogical Double-Decker (Wahl, 2023) theory, which allows students to apply what they have acquired through their experience using a mixed format, engaging in cognitive interaction with the material and thereby creating a fundamental basis for mastering various levels of material.

The third significant factor identified through the analysis is the use of active learning methods, which demonstrated a strong correlation with perceived learner engagement and satisfaction among TVET engineering teachers. Teacher trainers emphasised that active learning methods—such as gamification—enhance learners' motivation and interest in course content.

> *"I like to use some group learning formats…Firstly, I have personally incorporated gamification themes into my teaching practice for quite some time already. "*

The interview results also indicate that the effective use of such methods requires well-designed digital instruction and a certain level of digital literacy among both teacher trainers and learners. The significance of engaging learners in the educational process and positioning them as active participants in their learning journey is supported not only by the qualitative and quantitative findings of this study but also by constructivist theory (Vygotsky, 1978), which emphasises the value of active learner engagement in knowledge construction through interaction and problem-solving.

The analysis of TVET engineering teachers' perspectives showed that 62% of respondents consider the presence of multimedia and interactive materials in educational courses to be important. Furthermore, 44.7% support live Q&A sessions, and 40.51% emphasise the importance of interactive discussions. All of these formats are characterised by active learner participation and are aligned with the andragogical model of education (Kolesnikova, 2003). Humanistic theory also emphasises the use of active learning strategies to promote motivation and engagement, a view supported by both teacher trainers and learners in this study (Knowles, 1984). The value of active learning methods is also underscored in cognitive learning theory (Vygotsky, 1978; Wenger, 1998; An & Reigeluth, 2008) and social learning theory, which emphasises the positive impact of active formats within asynchronous learning environments (Salmon, 2003, 2011; Ebner & Gegenfurtner, 2019).

However, when discussing active learning methods and their application in the training of TVET engineering teachers, it is essential to highlight the use of the flipped classroom model, which

aligns with key didactic principles of educational cycle design (Baig & Yadegaridehkordi, 2023). Although the respondents did not explicitly use the term "flipped classroom" in interviews or questionnaires, they repeatedly described instructional formats involving independent study of theoretical materials followed by in-depth exploration during practical sessions—both in online and face-to-face settings. It is essential to consider that respondents may not have been thoroughly familiar with specialised pedagogical terminology or may have used it imprecisely. Therefore, particular attention was given in this study to interpreting the underlying meanings conveyed in participants' statements, as well as to the use of clarifying questions during the interviews. In the quantitative phase, the survey was supplemented with open-ended prompts that allowed respondents to specify the types of instructional formats they referred to. Taken together, these methodological considerations provide a sound basis for interpreting the described practices as indicative of the flipped classroom model despite the absence of direct use of the term.

Another practical model is the Hybrid Flexible Education Model (HyFlex), which creates a "seamless" and interactive educational environment for both teacher trainers and learners (Barannikov et al., 2023). Respondents also noted the use of active learning tools, such as quizzes, surveys, and role-plays, during both the qualitative and quantitative stages.

Nevertheless, interviews with teacher trainers revealed significant barriers to implementing active methods. Major challenges include the lack of assessment tools and the difficulty of monitoring learner engagement under instructor supervision. The importance of knowledge verification is also emphasised in cognitive learning theory (Dityatkina, 2018). Scholars in the field of cognitive theory stress the value of incorporating active learning methods—such as live workshops and real-time Q&A—highlighting their effectiveness (Vygotsky, 1978; Wenger, 1998; An & Reigeluth, 2008). The use of active learning formats is further supported by Albert Bandura's social learning theory, which asserts that integrating active methods into asynchronous education enhances learning outcomes (Salmon, 2003, 2011; Ebner & Gegenfurtner, 2019). The use of advanced technologies in online training for TVET engineering teachers proved to be a significant factor in effectiveness, according to both teachers and students. These findings confirm the importance of integrating technologies in the context of modern digital transformation challenges in education, as well as emphasising their role not only as a tool but also as an environment in which the educational process is implemented.

However, the analysis revealed that 40.1% of TVET engineering teachers had no experience with virtual laboratories, and 38.4% had experience with remote experiments. Despite this, the average rating for the use of advanced technologies in the educational process exceeds the mid-scale. However, 29% of respondents note the high importance of advanced technologies (VR/AR, AI) in the educational process for increasing the perceived effectiveness of online learning. These indicators suggest a positive attitude towards digital tools as a factor contributing to engagement and the depth of understanding, while also highlighting the existing gap between technological potential and its actual application.

Despite recognising the value of advanced technologies, TVET engineering teachers expressed concerns regarding cybersecurity (60.8%) and data privacy (39.2%). Thus, the integration of technology is accompanied by cognitive and emotional barriers related to security, which must be addressed when designing educational programs. Alongside advanced technologies, TVET engineering teachers also expressed a preference for simpler technological tools (mobile platforms, digital whiteboards, and cloud-based tools), indicating that while modern technologies are viewed as valuable, the course's pedagogical content remains paramount. In other words, technology serves to enhance—but not replace—the pedagogical logic of a course. This aligns with the concept of the "Pädagogischer Doppeldecker," where the integration of theoretical and practical components is achieved through combined instructional formats that include lectures and

virtual labs or simulators, enabling learners to apply acquired knowledge in a virtual environment (Wahl, 2013; Wahl et al., 2020, Wahl, 2023).

Although the use of advanced technologies potentially enhances perceived effectiveness and learner engagement, the analysis indicates that their impact is limited without clear methodological grounding and alignment with course objectives. The use of tools in isolation from the educational context does not significantly influence program effectiveness. This is supported by principles of digital didactics, which argue that the instructor's primary role is to expand learning spaces and environments—including VR, AR, and AI—while making pedagogically sound decisions based on course goals, learner levels, and curricular structure (Bilenko, 2020). For TVET engineering teachers, it is essential to apply a hermeneutic approach that enables the preparation of educational content within a didactic communication framework suited to the digital environment (Buzaubakova et al., 2023). The hermeneutic approach emphasises the importance of interpreting and adapting digital formats following the context of professional training, where engineering-specific requirements necessitate flexible yet comprehensive didactic solutions.

The "Der Berufsdidaktische Dreidecker" model also highlights the importance of incorporating virtual practice sessions into the learning process, made possible through the effective use of advanced technologies (Martin, 2016). This model enables the design of practice-oriented educational modules that integrate industry and pedagogical contexts, demonstrating the high potential of technology in developing skills through simulated professional activities. Empirical strategies that enable learners to accumulate experience through the use of advanced technologies are supported by foundational educational theory—namely, andragogy (Knowles, 1980; Loeng, 2023). Within the framework of andragogy, digital technologies are viewed not as an end in themselves but as a means of implementing the principles of adult learning, such as autonomy, pragmatism, and the direct applicability of acquired knowledge in real-life situations.

Teacher trainers' feedback proved to be a fundamental aspect influencing the perceived effectiveness of educational programs. This effectiveness factor was one of the most consistent across all stages of the study, demonstrating that feedback is seen not simply as an element of communication but as a key learning mechanism that promotes awareness, reflection, and engagement. During the qualitative stage of the study, respondents repeatedly emphasised the importance of feedback and interaction with learners to engage them in the educational process and enhance the effectiveness of online courses. Their opinion is also shared by 45.1% of respondents in the quantitative stage of the study, who consider individual feedback to be critically important. Additionally, 27% consistently noted feedback as a key component of online learning. Although the numerical indicators appear moderate, their significance is confirmed by their recurrence in open-ended responses, where learners independently emphasised feedback as a deficient but desirable element. This indicates latent dissatisfaction and unrealised potential for interaction, especially in the context of asynchronous learning formats.

The importance of feedback is supported by humanistic learning theory, which views it as a tool that facilitates learner growth and self-actualisation and is essential for achieving high learning outcomes (Knowles, 1984). Feedback is also emphasised in behaviorist theory, where it serves a regulatory function—guiding behavior correction, addressing learning challenges, and achieving desired outcomes (Fields, 1996). In Albert Bandura's social learning theory, constructive feedback is highlighted as essential at all stages of learning and identified as a key component in building competencies through observation, imitation, and reinforcement (Burns, 2024).

"Der Berufsdidaktische Dreidecker" also emphasises the importance of continuous feedback for improving material comprehension (Martin, 2016). Wahl (2013, 2023) highlights feedback not only as a component of didactic interaction but also as a means of constructing a resilient learning

environment in which teacher and learner are equal participants in the educational process. The role of feedback is also reinforced in heutagogy, which focuses on the development of self-directed learning. Feedback enables learners to relate their own experience to new knowledge and make informed conclusions, thereby enhancing metacognitive awareness (Paprock, 1992; Hase & Kenyon, 2003), which aligns with the principles of "Der Berufsdidaktische Dreidecker" (Martin, 2016). Similarly, in Mezirow's work, feedback is viewed as a crucial element for rethinking and transforming professional attitudes (Mezirow, 1991).

Regarding feedback tools, 28.2% of respondents indicated the necessity of assessment and feedback tools in online courses to enhance their perceived effectiveness. Automated assessment systems, adaptive tests, and progress-tracking platforms are all seen as means of ensuring continuous dialogue between the learner and the course, even in the absence of a real-time teacher. The importance of assessment tools, alongside feedback, is supported by constructivist theory, which emphasises the significance of evaluating learners' progress for adjustment and providing feedback (Windschitl, 2002). "Der Berufsdidaktische Dreidecker" affirms the importance of automated assessment systems for the successful implementation of educational programs (Martin, 2016), which is particularly relevant in engineering-pedagogical education, where mastering applied and technical competencies requires precise progress monitoring.

It is essential to note that feedback is crucial for teacher trainers to adjust course content and understand students' learning levels, and equally vital for learners to correct errors and gain meaningful experience. This makes feedback a two-way mechanism: on the one hand, it responds to individual learner needs; on the other, it serves as a foundation for course adaptation, turning learning into a dynamic process. This dynamic was reflected in both the qualitative and quantitative findings of the study.

Alongside the key factors influencing the effectiveness of online training for TVET engineering teachers, several unexpected yet valuable aspects emerged that were not initially part of the study's framework but proved significant and promising for further scientific exploration. These observations not only enriched the interpretation of the findings but also underscored the need for a more systematic approach to designing online courses within the field of engineering-pedagogical education. Moreover, the study's results provide a theoretical foundation for the further development of online didactics as an emerging and distinct area within educational science. The proposed model, grounded in the integration of empirical data and pedagogical theory, may serve as a starting point for formulating new conceptual approaches to teaching in digital environments, particularly in the context of preparing teachers in technical disciplines.

One of the most pressing yet often "invisible" factors influencing learning effectiveness is the challenge of balancing professional responsibilities with participation in educational programs. According to survey data, 66.7% of respondents reported difficulties in maintaining a balance between their work obligations and engagement in online learning. This figure is particularly concerning given that adult learning research consistently identifies this factor as a significant demotivator, often leading to dropout, reduced concentration, and emotional burnout.

This issue can be partially addressed through the adaptation of educational content, the implementation of flexible modular structures, and the provision of various modes of interaction—all of which were discussed earlier in the interpretation of key factors contributing to perceived effectiveness.

An additional barrier identified by the study was insufficient attention to the methodological component of teacher training. Students noted a lack of support in mastering methodological approaches, as well as limited opportunities for practical application of the knowledge they had

acquired. In turn, teacher trainers reported disciplinary challenges and low levels of student preparedness, including gaps in foundational education, which they perceived as significantly diminishing the effectiveness of the teaching and learning process.

> *"We encountered non-compliant discipline. They tell us that they will do tasks, and they do not do anything."*
>
> *"The basic level of competence literacy of the teacher is crucial to understand the material and readiness to make the most of it."*

This situation highlights a gap between the level of expected and actual pedagogical background in trainees, raising the question of the need for a preliminary assessment of readiness for online learning, including evaluation of academic, digital, and emotional competence.

Respondents paid particular attention to the emotional and psychological state of students, which directly affects their ability to perceive and assimilate material. Participants in the study noted an insufficient ability to manage their time and tasks, which led to feelings of fatigue, anxiety, and a lack of resources. This situation contributed to lower engagement and learning outcomes. The importance of paying attention to these factors is reflected in behaviourist theory (Bandura, 2002), which considers the learner's emotional state as a factor influencing learning behavior (i.e. the behavior the learner exhibits during the learning process) and cognitive theory (Flavell, 1979; Vygotsky, 1997), which emphasises the importance of regulating internal state when performing learning tasks. This observation is particularly valuable for the design of online courses where the instructor has no physical presence. Therefore, it is more difficult to 'read' the learner's emotional state. This highlights the need to incorporate elements of emotionally responsive design into online learning, including regular feedback, state questionnaires, and self-care and well-being components within the course structure.

Another important aspect is to consider the cultural and national characteristics of the trainees. This was mentioned by both teachers and trainee teacher-engineers, emphasising the need to localise examples, cases and learning situations. This observation is particularly relevant in the context of international cooperation in TVET, where the same approaches may be perceived differently depending on cultural codes and educational traditions. Universal pedagogical models present the learner's culture 'by default' as neutral or secondary. However, the study notes the importance of paying attention to cultural specificities. One consonant concept is Culturally Responsive Teaching, which emphasises learners' cultural identity, experiences and values and adapting pedagogical solutions to the socio-cultural context (Gay, 2018). However, this factor remains very challenging due to its practical implementation, the misunderstanding of learners' cultural traits, and the insufficient training of teachers.

An interesting and promising hypothesis expressed by one of the experts was the suggestion to analyse retention rates. Although most respondents did not mention this indicator, its inclusion in future studies would enable a more objective assessment of the effectiveness of courses and link subjective evaluations to behavioural metrics (such as duration of participation, activity, and module completion). Such an approach would open the door to more accurate modelling of success factors and potential risks in programme design.

Respondents also highlighted class size as a possible factor influencing the effectiveness of online learning. While TVET engineering teachers did not emphasise this, teaching teachers noted that group size influences the nature of interaction, the ability to receive feedback and the extent to which learners participate in the learning process.

"When there are even 200 people online, even 150 people, there is always the possibility of hiding out. It all depends on the individual, their motivation, and their desire to develop."

This direction requires further analysis in the context of online learning, particularly for engineering and professional disciplines, where knowledge transfer to each learner is essential.

In addition, as a result of the analysis, the problem of completing training 'according to formal requirements' (e.g., to obtain a certificate or by referral from an educational organisation) was repeatedly raised. Both teachers and trainees emphasised the problem of motivation. Teachers noted that trainees participating 'under compulsion' are less interested and practically not involved in the educational process. TVET engineering teachers report that their existing workload prevents them from participating in training and taking courses to obtain a professional development document (76.5%). Work with motivation is especially important because the effectiveness of courses directly depends on the level of intrinsic motivation, which has been repeatedly mentioned in the theories of adult learning (Deci & Ryan, 2000).

Another important aspect concerns the consideration of cultural and national characteristics. Thus, the unexpected findings not only reveal potential problem areas in online learning for TVET engineering teachers but also shape a new research agenda. This agenda includes issues such as balancing academic and professional workloads, emotional well-being, prior academic preparedness, cultural sensitivity, motivation, retention metrics, and the impact of group size on learning effectiveness. All of these factors warrant further empirical investigation and may serve as the basis for future multifactorial models of digital learning effectiveness in the vocational education system.

Summary

The study provides a comprehensive theoretical and empirical assessment of the factors determining the perceived effectiveness of online courses for training TVET engineering teachers. The findings obtained enable us to understand that the key components of successful learning are adapting content to the individual experiences of learners, utilising blended learning formats, employing active methods, integrating technology in a meaningful way, and providing constructive feedback. All of the above factors have not only been confirmed by qualitative and quantitative analysis but also correlate with leading pedagogical theories – andragogy, constructivism, humanistic approaches, digital didactics, Der Berufsdidaktische Dreidecker, and social learning.

The study also uncovered significant discrepancies between teacher trainers' expectations and learners' perceptions, particularly in terms of flexibility, methodological support, and the applicability of technologies. These differences underscore the need to reassess strategies for designing and implementing online programs, considering the context of engineering-pedagogical practice, as well as promoting closer coordination between course developers and end-users.

Of particular value are the study's unexpected findings related to learner motivation, the balance between professional duties and education, cultural sensitivity, emotional well-being, retention rates, and class size. These factors, which were not initially included in the study's scope, proved to be significant and indicate the need for a more multidimensional approach to assessing the effectiveness of digital learning in the TVET system.

Thus, the interpretation of the results makes a significant contribution to the development of academic discourse in digital pedagogy and forms the foundation for building more flexible, sustainable, and adaptive models of online learning in engineering pedagogical education. The

findings also offer concrete recommendations for practitioners and outline avenues for future scholarly research, which will be presented in the following chapter.

CHAPTER 4: DISCUSSION

The objective of this mixed-methods exploratory sequential study is to identify the key factors influencing the perceived effectiveness of online courses for TVET (Technical and Vocational Education and Training) engineering teachers, as perceived by both course teacher trainers and the participating TVET engineering teachers. Previous research has predominantly examined online education through either technical or didactic lenses, thereby limiting the applicability of their findings. Notably, most studies focus on specific pedagogical theories without addressing the intersections crucial for engineering-pedagogical training. The absence of comprehensive studies investigating the perceived effectiveness of online courses by both teacher trainers and learners within the Russian TVET teacher training context highlights the need for this research. The considerations mentioned above underscore the uniqueness and critical importance of this study in the context of rapid technological advancements.

This research endeavours to bridge the identified gap by employing a methodological approach that encompasses theoretical analysis, a qualitative phase involving interviews with the online course teacher trainers, and a subsequent quantitative phase conducted through a large-scale survey of TVET engineering teachers. The qualitative phase facilitated an in-depth exploration of the phenomenon, grounded in the teacher trainers' personal experiences and their accounts of the processes and challenges they encountered. Conversely, the quantitative phase provided insights from the learners' perspective, assessing the alignment of their needs with teacher trainers ' perceptions and identifying divergences. This approach enabled hypothesis testing and expanded the research inquiry through the triangulation of results.

The study is anchored in the historical framework of TVET engineering teachers' training in Russia, tracing developments from the 1920s to the present. This historical analysis highlighted significant milestones in the training system, offering a comprehensive understanding of the current TVET engineering teachers' education landscape. Furthermore, the theoretical foundation of the study includes an extensive review of pedagogical theories and didactic approaches pertinent to adult online learning. The research draws upon established educational theories—constructivist, humanistic, and andragogical—as well as contemporary models such as heutagogy and the Berufsdidaktische Dreidecker.

Detailed discussions on the problem statement, research objectives, questions, literature review, methodology, and empirical findings are presented in the preceding chapters. This chapter provides a concise summary of the research outcomes, practical recommendations, suggestions for future studies, an assessment of the study's limitations, and a final evaluation of the findings' applicability to the implementation of online courses for TVET engineering teachers. The recommendations are grounded in both the theoretical and empirical components of the study, representing a logical extension of the conducted analysis.

4.1 Summary of the Study

The findings of this study indicate that the perceived effectiveness of online courses designed for TVET engineering teachers' training is influenced by a constellation of complex factors validated by both teacher trainers and learners.

An integrated analysis of the qualitative and quantitative phases identified five principal factors affecting the perceived effectiveness of online courses:
1. Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses.

2. The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers.
3. The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers.
4. The integration of modern technologies (virtual laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness
5. Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes

Beyond affirming these factors, the study uncovered several unexpected yet significant elements that influence the efficacy of online education for TVET engineering teachers. These include professional overload, lack of motivation, emotional and occupational burnout, inadequate methodological preparation, and cultural-sociological nuances. These insights expand the understanding of the prerequisites for sustainable and effective online learning in the TVET engineering teacher's domain.

The results underscore the importance of a holistic approach to the design and delivery of educational programs utilising digital tools. Moreover, they highlight that the success of online education transcends isolated technological or didactic features, hinging instead on their interplay and alignment with the authentic educational needs of teacher-engineers.

By integrating theoretical analysis with qualitative and quantitative research phases, the study provides a nuanced understanding of existing barriers, assesses the current landscape, and envisions potential trajectories for the evolution of digital education in professional pedagogy. Consequently, the research lays the groundwork for developing multi-tiered, adaptable, and evidence-based approaches to online course design, with findings applicable to both academic and practical spheres—including educational policy formulation, course development, professional development programs, and support mechanisms for teachers in digital environments.

4.2 Implications for Practice

Based on the identified factors influencing the perceived effectiveness of online courses for TVET engineering teachers, this chapter delineates a series of practical recommendations. These suggestions are pertinent to course developers, teacher trainers, educational methodologists, institutional leaders, and policymakers who shape the strategic direction of TVET engineering teacher training systems. Each recommendation is a direct outcome of the mixed-method exploratory sequential research, theoretically substantiated and firmly rooted in the empirical findings of the study. This chapter provides practical guidance and implications corresponding to each of the five key factors that affect the perceived effectiveness of online education.

Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses.

The study's results showed that adapting course content is one of the most significant factors in determining the perceived effectiveness of online learning. TVET engineering teachers emphasised the importance of a personalised and flexible approach focused on professional tasks, level of training, and previous experience. At the same time, teacher trainers emphasise the importance of balancing individualisation with the structural logic of the educational course.

Based on these findings, the following recommendations are proposed:

Incorporate educational initial and longitudinal diagnostics of students in the online course. It is recommended to implement diagnostic tools at the start of the programme, during its implementation, and at the end. Diagnostic tools may include tests, questionnaires, self-assessment tools, and assessment scales that enable the determination of the level of professional competence, current tasks, and motivational attitudes of participants. Such an approach facilitates audience segmentation, allows for the flexible adaptation of material delivery, and enables prompt responses to critical signals from learners, such as difficulties with content, waning interest, or potential social, professional, or emotional issues.

- Employ (or develop, if unavailable) adaptive educational platforms for the delivery of online courses. It is advisable to integrate platform solutions that allow individual learning paths for students (e.g., based on progress tracking, content recommendations, and machine learning algorithms). This measure will increase the relevance of educational courses and user satisfaction. In instances where adaptive platforms present technological or financial challenges, simpler and more accessible tools that can be managed manually by course organisers (e.g., Telegram, WhatsApp, or similar services) should be considered. While less technologically advanced, these solutions can partially implement the principles of individualisation and content adaptation.
- Following on from the previous recommendation, another crucial area to note is the design of a modular course structure. Modular programmes enable the implementation of adaptive programmes for different levels of learners without complex technical requirements. Content can be formed as independent modules, with the option to choose the sequence in which they are completed. This approach gives students a sense of control over their learning process, which agrees with the basic principles of adult learning theories.
- Integrate real-world cases and professional tasks into the educational programme, grounded in the theoretical foundations of the subject matter. Including tasks in the curriculum that closely resemble the real-life practice of TVET engineering teachers will ensure a practical focus, increase motivation and engagement in the educational process, and enable the immediate application of the knowledge gained in professional activities.
- Last but not least, the creation of adaptive communication strategies between teachers trainers and TVET engineering teachers. Teachers, tutors, and mentors should be trained in flexible interaction formats that enable them to not only convey information but also transfer knowledge and accompany students on their educational journey. This includes offering personalised assignments, guiding the direction of material mastery, and providing timely and responsive feedback.

The recommendations above constitute fundamental actions necessary to achieve the core principles of adaptive educational programmes and may be expanded upon during practical implementation.

The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers.

Regarding the blended learning format, research results demonstrate that it is perceived as the most convenient and productive method for organising online education among both teacher trainers and learners. Combining online and offline components provides flexibility, personalisation, accessibility, and practical interaction. This format addresses the limitations of existing online course formats and creates conditions for deeper and more meaningful engagement with the material. This is especially important in the context of training engineering and teaching specialists who combine educational and professional activities.

Consequently, the following recommendations are deemed appropriate:

- Design hybrid courses based on the principles of HyFlex (Hybrid-Flexible Education) and the Berufsdidaktische Dreidecker (Vocational Didactic Triple-Decker/Pedagogical Triplane

Model). It is advisable to employ models that concurrently accommodate self-directed online learning and timely in-person practice of professional skills. The educational programme may include foundational theoretical modules in an online format, as well as in-person modules focused on applying knowledge, executing tasks, undertaking projects or group work, and providing feedback.

- Develop combined learning trajectories tailored to the objectives of the educational course. It is essential to offer various course completion pathways, such as fully online asynchronous courses, blended formats (e.g., 70% online and 30% in-person, or vice versa), or in-person sessions supplemented with digital technologies. This approach will enable the creation of flexible educational courses tailored to the capabilities and needs of the target audience, aligning with the concept of personalised education. Moreover, these trajectories can be developed at the level of a section or topic of an educational course and do not necessarily have to be extrapolated to the entire curriculum.
- Given that 75.9% of respondents identified the asynchronous learning format as the most in-demand, it is advisable to establish systematic mechanisms for in-person/video support within asynchronous courses. Fully online courses should incorporate regular live sessions with teacher trainers (e.g., Q&A sessions, consultations, group discussions, case studies) and maintain active communication channels for learners (e.g., Telegram, WhatsApp, or similar services) to facilitate opinion exchange and sustain learning motivation.
- Considering the focus on training TVET engineering teachers, it is crucial to integrate cases and practical assignments with offline components. Incorporating tasks that necessitate interaction with real professional environments (e.g., conducting demonstration lessons or micro-lessons, observations, and interviews within educational institutions) enhances the practical relevance of the training. It strengthens the connection to future professional activities. Furthermore, such formats allow for peer feedback and community building, which, from a sociological perspective, is as significant as knowledge acquisition and application. If in-person formats are unavailable, these cases and assignments can be implemented in simulated digital environments, such as VR/AR.
- However, the effectiveness of the aforementioned recommendations is contingent upon the professional development of course teacher trainers in blended and HyFlex design. The successful implementation of any blended learning model requires training teachers in creating modular blended course scenarios, integrating synchronous and asynchronous elements, and managing group dynamics in both online and offline settings.
- Furthermore, it is also essential to monitor and evaluate the effectiveness of blended learning and identify the most effective models for different categories of learners. It is recommended to collect data on the effectiveness of blended programmes in terms of satisfaction, performance, engagement and retention. This approach facilitates the implementation of necessary changes to existing formats and the development of best practices for training TVET engineering teachers in a digital environment.

The recommendations presented are the result of theoretical and empirical research and provide a basis for implementing blended learning formats in educational organisations with varying socio-economic conditions and material resources. This approach does not require significant financial investment and can be integrated into the existing curriculum.

The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers.

The results of the study indicate that the use of active learning methods has a significant impact on learner engagement and the perceived effectiveness of online courses for TVET engineering teachers. Active methods such as gamification, group and collaborative work, project-based

learning, interactive discussions, and simulations enable learners to shift from the position of passive recipients of information to active participants in the educational process. This aligns with the principles of both foundational and contemporary educational theories (e.g., andragogy, digital didactics, constructivism, and humanism) in adult learning.

Based on the analysis, the following recommendations can be formulated:

- Integrating gamified elements and interactive tasks into the educational course structure serves as a key engagement strategy. It is recommended to incorporate formats such as points, rankings, badges, team competitions, mini-games, and content-based quests into the course structure to enhance engagement. Applying gamification principles increases engagement, enhances motivation, helps overcome professional rigidity among TVET engineering teachers (shifting them from a "know-it-all" to a learner mindset), and raises interest even in complex subjects.
- Implementation and development of scenarios for collaborative work among students in an educational course. Tasks within the educational process should involve collaboration, role distribution, discussion, and collective decision-making. These formats can be implemented through project assignments, discussion forums, brainstorming sessions, group case studies, or the creation of shared digital products. Collaborative learning is particularly effective for TVET engineering teachers working in team-based environments (e.g., where theoretical and practical instruction is delivered jointly by different teacher trainers).
- Utilisation of digital platforms that support active interaction. It is advisable to implement platforms that facilitate various formats of blended learning and allow both asynchronous and synchronous discussions (e.g., Padlet, Miro, Mural, Google Jamboard, Zoom Breakout Rooms), enabling small group work and collective result visualisation. These tools help create a learning community and encourage in-depth exploration of topics.
- Implementation of blended and hybrid learning technologies in the educational process. These technologies can be applied at multiple levels of the educational course (e.g., curriculum level, subject level, module/topic level, lesson level, or instructional design level). Moreover, their use should be situational rather than restricted. A typical structure in this format might involve providing theoretical content in open access (e.g., videos, presentations, articles). At the same time, in-person or live sessions are used for discussion, analysis, and the application of practical knowledge. This interaction can be realised either face-to-face or online. This approach helps to increase student engagement in the educational process and emphasises the practical application of the material.
- Active learning should also include tasks that require reflection and independent analysis. Learners should receive assignments that encourage critical thinking, self-assessment, and integration of learned material into their professional context. This can be achieved through online journals, portfolio development, and the creation of individual case studies or problem scenarios from their professional practice. Ideally, each course would include a reflection journal with prompts and questions to guide learners in processing the material through their personal experiences and contexts.
- As with the previous point, a key recommendation is the need to train teacher trainers in developing active and interactive learning scenarios. Training teachers to design tasks that actively engage learners is crucial to the success of online education. Furthermore, teacher trainers should be trained in managing group dynamics in digital environments and applying modern instructional design models (e.g., SAMR, ADDIE, Bloom's Digital Taxonomy). It is also crucial to train teacher trainers in the use of distance learning technologies (e.g., case-based learning, internet technologies, network-based learning, and information-rich educational environments) to ensure a comprehensive understanding of online learning and the ability to employ diverse tools flexibly for optimal outcomes.

- A consistent and essential recommendation is the regular collection of feedback on the use of active learning methods. Educational courses should include tools for monitoring learner perceptions of these formats. These may include surveys, mini-reflections, and feedback collection forms. This approach will enable timely adjustments to methods and increase their effectiveness.

Regarding active learning methods, it is crucial not only to use them judiciously (avoiding cognitive overload with too many formats) but also to apply them competently based on the teacher trainers' skills. Additionally, it is necessary to continuously update knowledge in this area, as tools evolve rapidly and may vary depending on geographic and linguistic contexts. For example, certain platforms may be inaccessible in specific regions or not available in certain languages, posing potential challenges. Active learning methods are particularly effective when combined with adaptive content delivery and real-time feedback. Nevertheless, the recommendations presented here can serve as a foundation for developing a competent and systematic approach to using active learning methods, with adjustments based on the target audience.

The integration of modern technologies (virtual laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness

The findings of the study demonstrate that integrating modern technologies—including VR/AR, simulations, virtual laboratories, AI assistants, and others—into online courses for training TVET engineering teachers is perceived as a significant factor that strengthens engagement, interest, and, most importantly, the practice-oriented dimension of the learning process. Despite the numerous benefits of using modern technologies, significant barriers exist, including limited digital literacy, underdeveloped infrastructure in educational institutions, data security concerns, and insufficient methodological training for teacher trainers, all of which hinder the widespread adoption of advanced technologies. This makes a systematic and pedagogically grounded approach to integrating technology into the educational process essential.

Based on these findings, the following recommendations are proposed:

- One of the key and fundamental recommendations is the meaningful and pedagogically justified implementation of advanced technologies. These technologies should not be used for their own sake but as a means to achieve specific educational goals. Each course element that incorporates simulations, VR/AR, or AI tools should be aligned with learning outcomes, professional competencies, and the instructional logic of the module. This approach aligns with the principles of digital didactics and the Pädagogischer Doppeldecker model, which positions technology as an enhancing—not replacing—element of course content.
- It is recommended to develop virtual practical modules and simulations that closely reflect engineering and pedagogical practice. Technologies should primarily be used to develop skills that are difficult or impossible to master within entirely theoretical online modules. These could include simulations of teaching scenarios, modelling of laboratory conditions, VR walkthroughs of workshops and classrooms, or simulations of student behaviour. This recommendation is particularly relevant in contexts with limited access to physical equipment or when training must be conducted in distributed teams.
- A critical step in integrating modern technologies into the educational process is the provision of ongoing support for teacher trainers. Teacher trainers should receive training on selecting, applying, and adapting digital tools. Additionally, continuous methodological support is recommended, which can be provided through tutors, mentors, or consultants. It is also essential to create a repository of use-case scenarios for technologies, including didactic guidelines on what to use, where, when, and why.

- When implementing modern technologies, it is vital to do so gradually through flexible modular integration. It is not necessary to redesign an entire course; instead, start with one or two interactive components (e.g., a virtual lab, a simulation task, or a case in an AR environment) that align with course objectives. A modular approach enables the assessment of effectiveness, facilitates adjustments in delivery, and prevents overload for both teacher trainers and learners.
- The implementation of modern technologies should be accompanied by a preventive assessment of the digital maturity of all participants in the educational program (teacher trainers, learners, mentors, etc.) and the resource capacity of the educational institution. Before integration, it is advisable to conduct an audit of the institution's digital infrastructure and assess the digital literacy of teacher trainers and TVET engineering teachers. This will allow for the selection of a realistic implementation scenario and help minimise resistance to change.
- The analysis revealed that 60.8% of TVET engineering teachers are concerned about data security in the digital environment. Accordingly, it is recommended to inform all participants about data handling policies, organisational data protection measures, and best practices for maintaining digital safety. Security systems should be implemented, and appropriate data protection norms must be observed in virtual environments.
- Last but not least, integrating simple technological solutions alongside high-end technologies is recommended. Not all modern innovations require costly investments. Cloud whiteboards, mobile apps, adaptive quiz platforms, and visualisation tools (e.g., Genially, Canva) also enhance engagement and interactivity, especially when embedded within well-structured instructional design. This approach ensures a balance between technological sophistication and didactic appropriateness.

When speaking about the integration of modern technologies, we are not only referring to advanced technical solutions that are often difficult to implement in short-term programs due to financial constraints. Moreover, some programs may become overloaded if modern technologies are added without careful consideration and planning. The recommendations provided above serve as guiding points to help assess the readiness of both the educational institution and its learners to adopt such technologies.

The analysis showed that while the inclusion of modern technologies is not a top priority for TVET engineering teachers, it is a strong amplifying factor for positive learning outcomes. Thus, it is not merely technological capability but deliberate technological integration that ensures the effectiveness of an online course.

Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes

The findings of this study confirm the critical importance of timely and constructive feedback for TVET engineering teachers in online courses. Both teacher trainers and TVET engineering teachers participating in the courses noted that high-quality, prompt, and personalised feedback enhances motivation, supports self-awareness and professional reflection, and contributes significantly to learning outcomes. However, the implementation of this factor is complicated by the presence of large cohorts, the use of asynchronous communication formats, and the absence of precise assessment mechanisms.

In this context, the following recommendations are proposed:

- The use of chats and social media groups in asynchronous learning formats fosters an educational community where learners can exchange views about the course. This format enables teacher trainers to interact with learners at their convenience, helping to avoid the sense of neglect that often occurs in asynchronous courses. This recommendation is most effective in groups of up

to 25 participants if the goal is personalised feedback. For general feedback and addressing emerging questions during the course, group size can be larger, with issues managed through thematic blocks and a series of Q&A sessions. Clear timelines and rules of engagement should be established in these forums to prevent burnout among teacher trainers.

- To ensure effective and timely feedback, it is advisable to optimise group sizes or implement subgroup systems with assigned mentors. For high-quality feedback, course cohorts should be limited in size or divided into smaller groups (up to 25 learners), each supervised by a tutor or mentor. For TVET engineering teachers, optimal group sizes differ by program focus: 15–25 learners for pedagogical programs and no more than 7 for engineering-focused tracks. This approach is especially critical in asynchronous learning but is also relevant to blended formats. It facilitates more responsive and individualised feedback, reducing instructor workload.
- Feedback processes should be structurally embedded in the course. Mandatory feedback points should be incorporated throughout the course structure, including interim feedback after each module, final comments on assignments, trajectory adjustments, regular reviews of common mistakes, and analysis of individual cases. Feedback should be predictable and regular, with learners informed in advance about when and how they will receive it. This reduces anxiety and increases satisfaction with the learning process.
- To conserve human resources, digital tools for automating feedback should be utilised. When individualised feedback is unfeasible, standardised feedback templates, automated progress reports embedded in LMS platforms, and tools offering personalised bots or micro-feedback via text or video (e.g., Loom, Google Classroom, Moodle) can enhance perceived support and engagement.
- Instructor training in feedback techniques should be conducted, or methodological materials should be provided. Workshops on the principles of constructive feedback—such as "feed-up" (on goals), "feedback" (on achievement), and "feed-forward" (on future development)—will equip teacher trainers with the tools to deliver effective and timely feedback. Teacher trainers should also be trained in recognising learners' emotional cues and adjusting tone, especially in asynchronous interactions.
- Feedback should be integrated into the learning process as a tool for metacognitive development. It should not only correct errors but also promote reflection and self-assessment. Assignments should prompt learners to reflect on the feedback received (e.g., "What did you learn from the feedback?", "What will you adjust next time?", "What new skills did you acquire?") or to apply the material in their professional context (e.g., "Which part of this module will you use in your work?"). This deepens understanding and encourages continuous growth.
- Peer-feedback mechanisms should be embedded into the course. In large groups, assignments may include peer evaluation. When appropriately designed—with clear criteria, examples, and training in providing constructive comments—peer feedback increases awareness, critical thinking, and content mastery and eases the instructor's burden.
- A multi-level and multimodal feedback strategy is recommended, combining automated and personalised responses. This may include instant feedback through quizzes, assignment comments (e.g., in Google Classroom, Moodle, Canvas, or Trello), regular checkpoints, mini satisfaction surveys, and AI-driven bots that provide learner-specific feedback. In addition to traditional written comments, teacher trainers can use short videos, voice messages, group webinars, or Q&A sessions, making feedback more dynamic and emotionally impactful.
- Feedback from learners on the quality of instructor feedback should also be gathered and analysed. Integrating mini-surveys or reflective blocks into the online course can help gauge how helpful, timely, and transparent the feedback was. Such data allow teacher trainers to tailor their communication style and content to match learner needs better.

Feedback-related challenges were repeatedly raised during interviews and mentioned in surveys by TVET engineering teachers, underscoring the foundational role of this factor in course design. Feedback has both strengths and risks, as a carelessly delivered comment may demotivate a

learner. Nevertheless, feedback is essential for human connection in digitally mediated learning. Collectively, the recommendations above not only provide didactic support within an online course but also help build a feedback culture that supports the professional development of TVET engineering teachers.

Practical Recommendations Based on Unexpected Findings

In addition to the five primary factors of the perceived effectiveness of online courses, the analysis revealed several unanticipated yet significant aspects that have a considerable impact on the quality and effectiveness of training for TVET engineering teachers. Although these factors emerged more as unexpected discoveries than pre-planned outcomes, their recurrence in both interviews and survey data highlights the relevance of offering targeted recommendations for each.

These factors include challenges in balancing work and study, emotional burnout, insufficient foundational preparation, lack of learning motivation, the influence of group size, cultural and sociological differences, and the importance of course completion (retention rate). Taking these elements into account not only enhances the resilience of educational programs but also supports the development of a systemic approach to designing online learning that is responsive to the diverse life and professional contexts of TVET engineering teachers. This section addresses all the factors except group size, which was already discussed in detail in the feedback recommendations.

The recommendations below aim to support a "second level of effectiveness," referring to the conditions that amplify the key factors and foster meaningful engagement of TVET engineering teachers in the learning process.

- Work-Study Balance

The study revealed that 66.7% of TVET engineering teachers encounter difficulties in balancing their professional responsibilities with learning, which impacts their motivation, engagement, content mastery, and course completion. To address this issue, the following recommendations are proposed:

- Introduce flexible content delivery by providing access to materials at convenient times, employing various formats of online learning (synchronous, asynchronous, blended), and applying the previously mentioned modular approach and microlearning principles.
- Implement micro-lesson formats (5–10 minutes) that can be accessed via mobile platforms (e.g., through messengers or mobile-optimised learning platforms).
- Include visual representations of the course workload by displaying the expected learning effort and time commitment required for each module or task.
- Provide an option for official short-term learning pauses (from 24 to 72 hours) while retaining learner progress. This would allow participants to temporarily suspend their studies due to work obligations (e.g., business trips or professional meetings).
- Integrate learning into the work context by designing assignments that are simultaneously useful in professional practice (e.g., developing instructional materials for current courses, analysing real-life cases) and aligned with the course's learning objectives.

- Emotional and Professional Burnout

The empirical phase of the study revealed that the emotional well-being of both teacher trainers and learners often receives insufficient attention during the implementation of online learning. However, respondents consistently noted that their emotional state (e.g., overload, fatigue, apathy,

burnout) significantly affects their engagement in the educational process and their ability to assimilate the material.

To address this issue, the following recommendations are proposed:

- Include regular check-in surveys in the educational process, serving as brief self-reflection tools to gauge participants' current state (e.g., asking "How are you feeling today?" before starting a lecture or practical session). Gamified formats can be used, such as emojis, mood scales, or selecting a Zoom background colour corresponding to one's mood. These brief prompts can help assess learners' readiness to absorb information and, through longitudinal analysis, identify critical points in the course when engagement begins to decline.
- Incorporate course sections and materials on digital well-being, self-regulation, time management, and anxiety reduction techniques. Given the focus on adult learners aspiring to become or already working as TVET engineering teachers, such content can support both course engagement and future pedagogical practices.
- Provide a visually and emotionally supportive interface by adopting a friendly platform design, streamlining the virtual environment, and minimising visual clutter (e.g., avoiding overly dense slides and excessive text elements).
- Establish a mentorship structure within educational programs. Mentors should be equipped to recognise signs of burnout and respond accordingly. This aligns with previously proposed tutor-support models, emphasising their dual academic and emotional support functions. Appointing a mentor is particularly important in large groups, whereas smaller groups can be managed directly by the instructor.
- Maintain a reasonable workload and task volume, alternate activity formats, and create a distinction between essential and supplementary materials to prevent overload and sustain interest.

  - Insufficient Foundational Knowledge

Interview responses indicated that some learners struggle with assignments and content comprehension due to gaps in their foundational knowledge and prior education. TVET engineering teachers themselves acknowledged difficulties with specific subject areas, particularly those related to digital and engineering disciplines.

The following recommendations are proposed:

- While earlier recommendations addressed the need for diagnostic testing, it is important to emphasise that learners who perform poorly should receive personalised suggestions to complete additional micro-courses or targeted preparatory materials. This is particularly relevant for engineering modules, where a lack of core skills can prevent the achievement of the intended learning outcomes.
- Where feasible, divide the course audience by proficiency level (e.g., basic vs. advanced). However, this requires significant program restructuring and may be impractical for small cohorts. It is most applicable when group sizes exceed 100, where such segmentation becomes crucial for effective learning and instruction.
- If foundational knowledge gaps are a recurring issue, consider offering preparatory modules that are pre-recorded and accessible before the start of the main course. These may include optional content on topics such as "Introduction to Teaching Methodology," "Digital Literacy," or "Basic Zoom Skills." This approach broadens access and reduces exclusion due to a lack of prior knowledge.
- If a few individuals in the group consistently fall behind, they should be grouped and assigned a dedicated tutor or mentor who can assist with unclear or complicated topics.
- Implement peer-learning strategies by forming "mentor–novice" pairs, where more experienced learners support less experienced peers throughout the learning process.

- Lack of Motivation

Another unexpected outcome of the study was the issue of course participation "by assignment" without a conscious learning intent, which negatively impacted both learning outcomes and learner engagement. A total of 76.5% of participants reported enrolling in professional development courses due to workplace requirements, while 50% indicated that their primary goal was to obtain a certificate or diploma. In most cases, this situation is difficult to change, as it largely depends on external circumstances rather than the learners themselves.

The following recommendations may help engage unmotivated participants in the learning process:

- It is important to clearly articulate the relevance of the course at the very beginning: why the training is necessary, what outcomes it delivers, and how it is connected to both professional and personal development. Highlighting issues participants encounter daily in their work and referencing them (where appropriate) in the course description can increase engagement regardless of the initial reason for participation.
- The main body of recommendations already emphasised the importance of including practical tasks tied to learners' everyday professional responsibilities. Additionally, this information can be collected one month prior to the course via a survey of prospective participants to identify key topics or develop assignments that match their interests. If collecting such information proves challenging, then course content should be aligned with current educational trends (e.g., the use of AI in education).
- Consider incorporating storytelling and success stories into the educational program. A helpful practice is inviting experienced TVET engineering teachers to share real-life challenges and how they overcame them. Alternatively, a peer-sharing block may be included, where learners discuss problems they face and receive suggestions from fellow participants. These practice-based, interactive dialogues support both motivation and deeper engagement with the material.
- Another strategy to increase motivation is to decompose the course into micro-goals and track progress through regular achievement checkpoints (e.g., using gamification, as previously discussed).

- Cultural and Sociological Specificities

During interviews, teacher trainers mentioned encountering cultural differences that often created difficulties during the delivery of courses. For instance, some learners refused to participate in video recordings due to religious reasons, even though video submissions were a mandatory element for subsequent pedagogical assessments. Such situations are increasingly common due to the mixing of diverse cultural and social groups within a single educational environment.

To address these issues, the following measures are recommended:

- Where possible, localise content—for example, by adapting case studies to regional realities or professional environments. It is essential to recognise that TVET engineering teachers in a central metropolitan area confront distinct challenges compared to one in a rural setting. While empirical results showed that such differences are often minor, religious and cultural factors can create significant barriers. Therefore, a thorough study of the target audience should precede the implementation of any course.
- If localisation is too resource-intensive, a more universally applicable strategy is the development of multicultural learning scenarios. This might involve the inclusion of tasks that reflect diverse professional and sociocultural contexts or, conversely, designing content that avoids culturally sensitive topics in favour of universally applicable knowledge.
- Employ neutral language and avoid culturally ambiguous terminology or examples.

- As previously noted in the interpretation of results, it is critical to train teacher trainers in culturally responsive teaching and equip them with the skills to work with learners from diverse backgrounds and regions.
- Divide the program into a core block and an adaptive block. The adaptive component may include localised case studies or assignments tailored to regional contexts or specific learner needs.

  - Retention Rate as a Measure of Course Sustainability

One expert highlighted the importance of tracking course completion rates as a key metric. Indeed, the retention rate is a significant indicator when evaluating learning effectiveness.

Implementing retention rate tracking is not resource-intensive and can be facilitated through the following measures:

- Regularly collect statistics and analyse completion rates by module, topic, and group.
- Identify "drop-off points"—sections of the course where learner engagement declines—and introduce interventions (e.g., simplifying tasks, offering consultations, adjusting formats). Such "critical points" often occur in the middle of the course or right before its conclusion.
- Set up automatic notifications and reminders via messaging apps or implement chatbot functionality.

It is essential to note that retention rate data can be utilised to enhance course design and evaluate the impact of pedagogical decisions.

Summary

The practical recommendations presented—derived from both key factors and unexpected findings—enable the development of a comprehensive and multilayered model for designing online learning tailored to TVET engineering teachers. These recommendations underscore that course effectiveness cannot be achieved through isolated technological, didactic, or organisational solutions. On the contrary, the success of educational programs emerges at the intersection of these elements, provided they are harmonised, aligned with learners' real-world experiences, and responsive to diverse educational contexts (e.g., cultural and social).

The integration of thoughtfully structured content, flexible learning formats, active instructional methods, advanced technological tools, and professional pedagogical support forms an educational ecosystem capable of supporting adult learners under conditions of professional workload, emotional stress, and the demand for sustainable, practical outcomes.

The proposed recommendations aim not only to overcome barriers but also to establish conditions for deep engagement, conscious participation, and successful course completion. Considering the specificity of engineering-pedagogical training, these aspects may represent the "invisible" yet critically important conditions that determine not only the effectiveness but also the human-centred nature of the educational process.

The findings of this study provide a strong foundation to argue that such a holistic strategy may serve as a cornerstone for high-quality training of TVET engineering teachers in the digital era.

4.3 Recommendations for Further Research

The present study has laid the groundwork for further exploration of the factors influencing the effectiveness of online courses for TVET engineering teachers. At the same time, like any research endeavour, it has certain limitations and boundaries shaped by methodological choices, sampling strategies, contextual conditions, and the overall research design.

4.3.1 Assumptions

The initial assumptions were statements that determined the direction of the study and served as a basis for conducting it (Foss & Waters, 2016). This part identifies factors that may have influenced the research results and their interpretation but remained beyond the researcher's control. It was expected that participants during the interview stage and while completing the survey would provide sincere responses that reflected their genuine opinions and experiences. This assumption is critical to ensuring the validity of the analysis and conclusions regarding the perceived effectiveness of the online courses. The researcher assumed that respondents were "acting in the interest of science" and that their motivation for participating was linked to a desire to contribute to improving the practice of training TVET engineering teachers (Alvesson, 2003, p. 14). It was intended that the mixed-method exploratory sequential approach was an appropriate research strategy for investigating a complex phenomenon such as the perceived effectiveness of online courses (Creswell & Plano Clark, 2018). It was expected that the selected research design would enable the identification of key trends and patterns despite the inability to control all variables (Maxwell, 2013).
Moreover, the researcher supposed that the pedagogical practice of preparing TVET engineering teachers shares common characteristics that allow for the generalization of findings to similar educational contexts (Yin, 2017).

4.3.2 Limitations

This part outlines the deliberate boundaries established by the author during this mixed-methods exploratory sequential study to maintain focus on the investigated phenomenon. Limitations refer to conditions and circumstances beyond the researcher's control (Rudestam & Newton, 2015). The first and primary limitation concerned the nature of the sample. The qualitative phase of the study involved teacher trainers of online courses, while the quantitative phase focused on TVET engineering teachers with experience in online learning. Although the representativeness of the sample was achieved and confirmed, these samples may not fully reflect the breadth of experience and diversity of conditions within the national system of training TVET engineering teachers. This restricts the direct generalizability of the findings to other educational systems, though it does not diminish the significance of the conclusions for analysis and potential adaptation in varied contexts. The following limitation relates to the voluntary nature of participant involvement. There may be a bias toward more motivated and engaged respondents, which could have influenced the study's outcomes. The use of online surveys also presents limitations in terms of dissemination. However, the target group is accustomed to using digital technologies in their professional activities, and the email addresses used to distribute information about the study were affiliated with TVET institutions. An additional limitation arises from a gap in the academic literature regarding research explicitly focused on training TVET engineering teachers through online courses. As previously noted, most studies addressing online training for TVET engineering teachers remain isolated, necessitating a careful, fragmented analysis and synthesis of disparate sources. One of the critical limitations of the survey design is the inability to determine causality between statements. Furthermore, individual surveys are not suited to capturing trends as they emerge or over short periods (Simon & Goes, 2013). This study did not aim to detect trends but rather sought to capture the perceptions of two independent groups at a given point in time. The

specific characteristics of the Russian context may limit the generalizability of findings to other educational systems, especially those outside the post-Soviet space. However, given the focus on online courses, this limitation is mitigated, and the findings remain relevant for future studies in other territorial contexts. Moreover, the study was conducted under conditions of high workload for both teacher trainers and TVET engineering teachers (caused by external factors such as digitalisation, crises, and migration, as well as internal ones such as the end of the academic year and the middle of the educational semester), which may have influenced the nature and depth of the responses provided. Lastly, the study did not include long-term longitudinal monitoring of course effectiveness, which limits the ability to track sustained changes in educational practice.

4.3.3 Delimitations

This section provides recommendations for future research, which logically build upon the preceding points and offer directions for the continued development of studies and knowledge accumulation in the field of training TVET engineering teachers through online courses. The study established several deliberate limitations designed to focus the analysis and achieve greater depth in the subject under investigation. These deliberate limitations represent conscious boundaries intentionally set by the researcher (Rudestam & Newton, 2015). The study focuses exclusively on online courses developed for TVET engineering teachers and does not include other forms of professional development (e.g., internships, conferences, offline courses). Moreover, the research focuses solely on the perceptions and experiences of participants (teacher trainers and learners) without objectively assessing measurable learning outcomes (e.g., improvements in competencies based on testing results). The primary focus of the study was on TVET engineering teachers' training in Russia, which was due to the specificity of the research question and the depth of material required for analysis. Additionally, the research was limited in its selection of data collection methods, relying primarily on semi-structured interviews and questionnaires. These tools were deemed sufficient to identify patterns and implement methodological triangulation, ensuring the validity and reliability of the findings (Charmaz, 2014, 2024). Finally, the researcher chose to adopt a mixed-method exploratory sequential design with an emphasis on the qualitative phase as the foundation for constructing the quantitative instrument. While this approach enabled a deeper understanding of the phenomenon, it also constrained the scope for generalisation at the initial stage.

4.3.4 Strengths & Weaknesses

The crucial aspect of the study is an analysis of the strengths and weaknesses of the empirical part. Understanding the strengths helps substantiate the scientific value of the results obtained, demonstrates the validity of the methodology used, and highlights the contribution of the study to the development of theory and practice in professional education. The description of weaknesses serves as an element of scientific reflection, helping to identify areas for further advancement of the research topic.

Strengths

One of the key advantages underpinning this study is the use of an exploratory sequential mixed-method design. This methodological approach enables a comprehensive examination of the complex phenomenon of perceived effectiveness in online learning for TVET engineering teachers (Creswell & Plano Clark, 2018). The qualitative phase provided the foundational basis for subsequent stages, enabling the collection of data on the practical experiences of teacher trainers and their perceptions regarding the training of TVET engineering teachers, including associated barriers and opportunities. In turn, the quantitative phase enabled the validation of identified thematic blocks across a broader sample of online learners in TVET engineering education,

helping to identify general patterns and key factors influencing perceived effectiveness. Methodological triangulation enhanced the reliability of the findings by ensuring data complementarity and compensating for the limitations of each phase. The comparative analysis of perspectives from two target groups within a single research project allowed for the identification of both areas of consensus and divergence in perceptions of online learning (Denzin, 2017).

Based on the collected data, specific recommendations were developed for the design, implementation, and support of online courses focused on the real working conditions of TVET engineering teachers. This approach makes the research relevant not only to the scientific community but also to practitioners, including curriculum developers, instructional designers, administrators, and policymakers (Laurillard, 2013).

The study's focus on a specific and under-researched professional group is a clear advantage. Investigating the online training of TVET engineering teachers addresses a gap in the academic literature (OECD, 2021). Moreover, the study integrates theoretical analysis, historical and pedagogical review, and empirical data to create a coherent and comprehensive picture of the development and current challenges in the training of TVET engineering teachers, thus enhancing the scholarly value of the findings.

Methodologically, the study is grounded in contemporary foundational and educational theories—including andragogy, humanism, cognitivism, constructivism, digital didactics, and the Pedagogical Double-Decker model—which provided a robust theoretical framework and enabled a nuanced interpretation of the results within the scope of current scientific approaches to adult learning (Reigeluth, 2013).

From a contextual standpoint, the study's in-depth engagement with the Russian system of preparing TVET engineering teachers ensured the high validity of the empirical data. At the same time, the patterns identified—particularly those related to flexibility, the digital environment, feedback, and motivation—exhibit a high degree of universality and may be adapted to other educational contexts, including international settings (Yin, 2017).

Expanding the study beyond the anticipated results and enriching it with unexpected factors that affect the perceived effectiveness of online learning (e.g., professional burnout, lack of motivation, cultural differences) enables the research to move beyond traditional approaches and renders its recommendations practically relevant and applicable in real-world conditions. An additional strength lies in the author's professional background as a TVET practitioner, which facilitated trust-based engagement with respondents, informed the selection of research instruments, enabled context-sensitive data interpretation, and facilitated the relevant operationalisation of studied concepts. This comprehensive approach enhanced the interpretive depth of the analysis, findings, and recommendations. In terms of scholarly contribution, the present study expands the understanding of perceived effectiveness factors in the context of online learning for TVET engineering teachers. The integrated model of factors and practical recommendations, previously not systematised within a single study, makes this work particularly valuable for informing policy and practices in digital professional education.

Weaknesses

Despite the strengths outlined above, this study has several limitations, some of which stem from the constraints of the research design and the resources available to the researcher. The professional orientation of the study may be considered a limitation, as it restricts the possibility of directly extrapolating the findings to other educational systems, particularly in culturally diverse contexts. Nevertheless, the focus on online education mitigates this limitation due to the

universality of digital practices. This is further offset by the potential to adapt the findings to other TVET contexts and utilise them as a foundation for further research or the development of pilot educational models.

The study was conducted primarily within the Russian context, which, on the one hand, ensured analytical depth; however, on the other hand, it requires caution when interpreting the results outside this system. However, given the global nature of online education, several findings may apply to international comparative studies and inform the design of educational programs.

Voluntary participation in the interviews and survey may have introduced sampling bias towards more motivated, digitally literate, and engaged respondents, which affects the representativeness of perceptions from less involved participants and reduces the generalizability of results (Bryman, 2016).

The absence of longitudinal observation limits the analysis of sustained changes, capturing only the immediate perceptions of learners without tracking long-term shifts in professional practice (Cohen et al., 2017). Furthermore, the data rely solely on subjective assessments and perceptions of effectiveness, which is fraught with possible distortions (Patton, 2014).

Finally, the limited set of data collection tools (interviews and surveys) excludes, for example, observation or the analysis of learners' digital footprints, which could have further enriched the research. Moreover, these tools do not allow for the establishment of causal relationships and may be subject to distortions due to subjective perceptions, socially desirable responses, or participants' limited reflexivity (Maxwell, 2013).

From the author's perspective, a key achievement of this study is the integration of theoretical foundations with practical recommendations, thereby enhancing its contribution to both the academic and applied fields. The research has made it possible to scientifically substantiate, systematise, and broaden the understanding of which factors ensure the perceived effectiveness of digital learning for TVET engineering teachers and how successful solutions might be scaled.

Summary

Despite the identified limitations, the study demonstrates a high level of methodological rigour, theoretical relevance, and practical value, establishing a solid basis for further scientific and applied developments in the field of digital vocational education.

4.3.5 Recommendations

Based on the identified limitations and the specific focus of the conducted study, it is advisable to continue exploring the perceived effectiveness of online courses for TVET engineering teachers in the following directions:

- Conduct longitudinal studies to track the long-term effects of completing online courses, including in real professional practice. Such research may focus on a specific sample or educational program, collecting data throughout learners' progress and making adjustments at each stage. This approach would complement subjective perceptions with objective assessments of competency changes.
- Expand the geographical scope of the sample. Including respondents from other countries would enable comparative analysis and provide a foundation for exploring cultural differences and their impact on perceived online learning effectiveness.

- Conduct comparative analyses of various online learning models (asynchronous, synchronous, blended, etc.) to evaluate their impact on satisfaction, retention rates, and professional outcomes.
- Conduct in-depth research on the experiences of online course teacher trainers, including course design methods, challenges in working with digital tools, and feedback practices. Special attention should be paid to professional support and the digital readiness of teacher trainers. A panel study with a stable sample of participants is recommended.
- It is advisable to develop and pilot motivational engagement models for TVET engineering teachers participating in mandatory professional development programs. The impact of various tools (e.g., storytelling, naming strategies, etc.) should be tested, as well as the role of mentoring in enhancing engagement.
- An important area for future research is examining the role of the institutional context in supporting online learning—specifically, the influence of administrative, infrastructural, and methodological support on the success of online training for TVET engineering teachers.
- Evaluate the effectiveness of online courses based on the application of acquired knowledge in professional activities. Such studies could involve analysing changes in curricula, the adoption of new approaches, increased student satisfaction, and other indicators.
- Future research should also examine the perceived effectiveness of online courses implemented outside the realm of formal education. For example, training of TVET engineering teachers in industrial settings (e.g., internships, corporate upskilling programs, sectoral development initiatives) is of particular interest in terms of adapting the didactic models and pedagogical approaches identified in this study.
- Conduct comparative studies between academic and corporate/industrial training of TVET engineering teachers to adapt the didactic models developed in this research to sector-specific development conditions. Applying corporate training evaluation models (e.g., the Kirkpatrick Model) could help verify the findings and enhance their practical applicability (Kirkpatrick, 1977).

CONCLUSION

The primary objective of this study was to identify the key factors influencing the perceived effectiveness of online courses for TVET engineering teachers. The use of a multi-stage research approach (a mixed-methods exploratory sequential study) enabled an in-depth and multidimensional analysis of the phenomenon under investigation. On the one hand, the experience of online course teacher trainers was examined; on the other, data were collected on the perceptions of TVET engineering teachers. The application of between-method triangulation allowed the integration of qualitative and quantitative findings, mutually compensating for their limitations and enhancing the analytical validity of the study.

Theoretical analysis and the investigation of the historical and pedagogical foundations of engineering educator training in Russia revealed that, despite its strong traditions, the system is facing contemporary challenges—digitalisation, a deficit in digital competence, and the need for flexible adaptation of educational practices. These challenges are universal across TVET systems worldwide and necessitate a reevaluation of instructional design principles.

The empirical analysis identified five key factors that positively influence the perceived effectiveness of online learning: content adaptation, blended formats, active learning methods, technological integration, and constructive feedback. In addition to these, several less obvious but critically important aspects were identified, including professional burnout, lack of motivation, and difficulties in balancing work and study—all of which impact the effectiveness and sustainability of the educational process.

Based on the findings, a set of practical recommendations was developed, covering a wide range of topics—from the design of educational programs to participant support and instructor professional development. Special attention was given to addressing cultural and sociological considerations, developing flexible learning pathways, and enhancing feedback mechanisms as a foundation for the metacognitive development of adult learners.

The study also outlines promising directions for future research: conducting longitudinal and cross-cultural comparative analyses, integrating findings into corporate and industrial training formats, and investigating institutional support environments for teacher trainers. All of this supports the conclusion that this study not only addresses a significant gap in the academic literature but also contributes to the development of evidence-based models for digital education in engineering teaching.

Thus, the presented study contributes to the development of the theory of digital learning in vocational education and training (TVET), expanding it by integrating methodological approaches, pedagogical practices and empirically identified factors influencing the perception of the effectiveness of online courses. Of particular importance are the identified relationships between course structural elements, digital contexts and subjective evaluation of course usefulness, providing a deeper understanding of the mechanisms of effective online learning.

Based on the obtained data, the theoretical development of methodological and didactic foundations of online didactics can be continued, relying on the integration of classical and modern pedagogical theories. The developed approaches serve as a basis for formalising the principles of digital teaching oriented to the specific needs of engineering-pedagogical staff. They can also be used in other areas of adult education and training.

The work is also of interest from a methodological perspective: the implemented design, which combines the depth of qualitative analysis with the confirmation of hypotheses using quantitative

methods, followed by data triangulation, demonstrates the potential of mixed research in pedagogy.

In the context of rapid change and transformation in professional education, the findings can provide a basis for designing sustainable, context-sensitive, and impactful online programmes that meet both the challenges of the present and the demands of the future.

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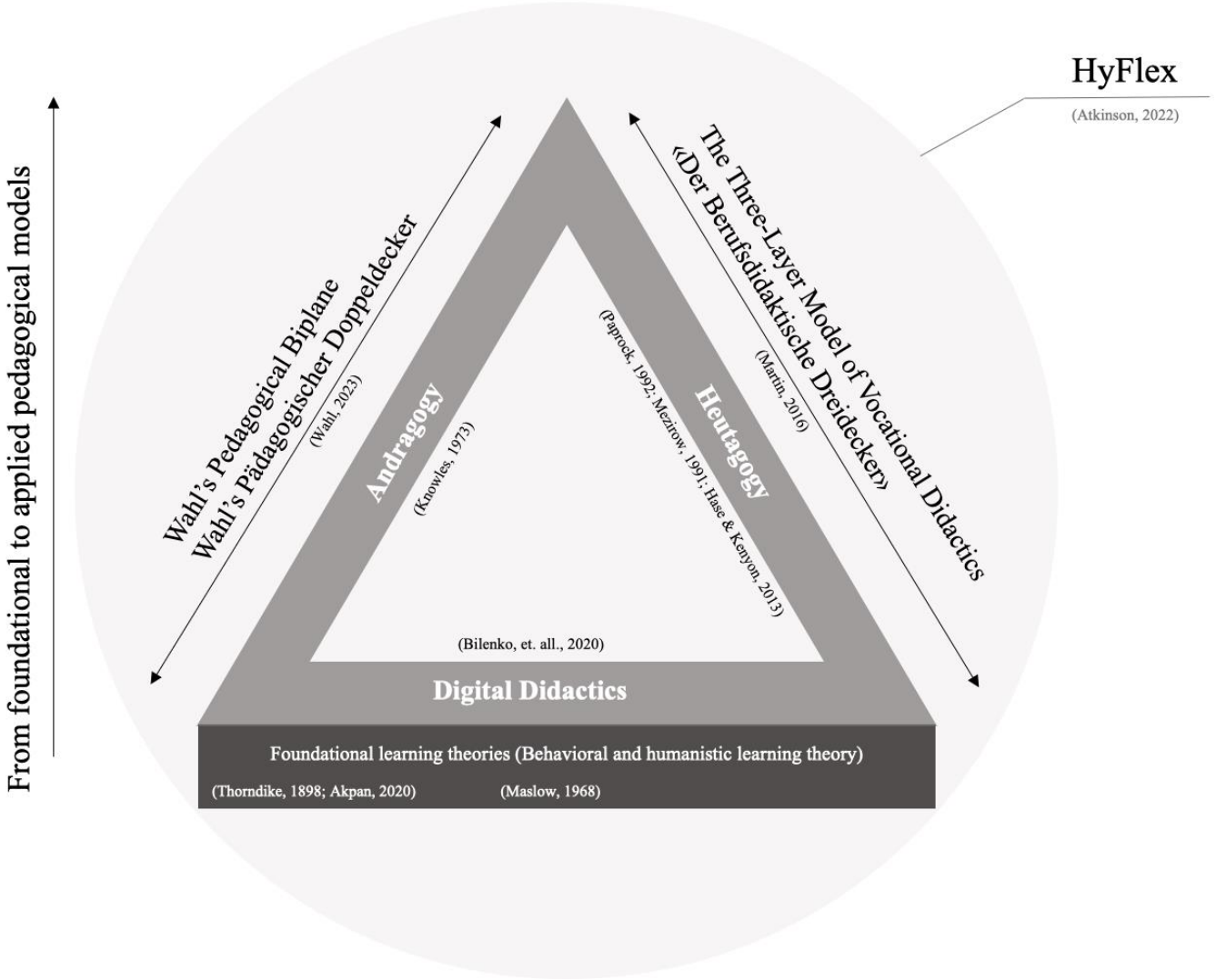
APPENDICIES

Appendix A *Online Learning Model for TVET Engineering Teachers*



Appendix B *Key Characteristics of Each Stage of TVET Teacher Training Development*

Phase	Title	Key Features
Phase 1	Foundations of TVET Teacher Training in the Early Soviet Period (1920s–mid-1930s)	1) At the beginning of the 1920s and the second half of the 1930s, there was a reduction in the psychological-pedagogical component in curricula with a focus on general technical and specialized training; 2) In the early 1920s, the introduction of general encyclopedic knowledge in specialized (technical, agricultural, etc.) courses for students with higher specialized education; 3) In the mid-1920s and the first half of the 1930s, the introduction of a fundamental psychological-pedagogical component in the training of teachers of specialized disciplines; 4) The introduction of continuous industrial and pedagogical practice, complicating the material and volume of pedagogical practice, attaching to educational institutions a base (educational institution or enterprise) for undergoing practice; 5) Improvement of curricula and expansion of didactic tools (organizational forms and methods of teaching); 6) Introduction of strict administration of the educational process in the second half of the 1930s; 7) By the mid-1930s, the development of the system of pedagogical education for teachers of vocational schools was fading; 8) Creation of educational-scientific-production complexes, which included an educational institution, a research institute or department, basic institutions, and enterprises for pedagogical and industrial practice; 9) Allocation of an additional year in the training of vocational education teachers; 10) Training of a new form of teachers - "cycle teachers"; 11) Reduction of study periods in higher education institutions for students with secondary specialized education; 12) The appearance of integrative courses that combine specialized disciplines and the methodology of their teaching, etc.
Phase 2	Wartime Adaptations and Post-War Restructuring (1940s–1958)	1) By the early 1940s, the system of vocational technical education experienced a "hidden deficit of pedagogical staff," characterized by the presence of a sufficient number of teachers whose qualifications were too low to properly meet the needs for workforce training. 2) The training of teachers for the system of secondary vocational education was canceled in the 1930s, and only in mid-1943 was the decision made to create special instructor technical schools and pedagogical faculties (courses) under the Main Directorate of Labor Reserves for training teachers in specialized disciplines. 3) Due to the deficit, especially during and after the war years, the main pedagogical staff was formed from industry specialists, which necessitated the creation of a system for upgrading the qualifications of professional-pedagogical staff. This system included the Central courses for the improvement and retraining of engineering-pedagogical workers of labor

Phase	Title	Key Features
		reserves and the Central Institute for the improvement and retraining of staff for schools of mechanization for agriculture and its branches. This stage of pedagogical education lasted until December 1958.
Phase 3	Expansion and Differentiation of Teacher Education (Late 1950s–1979)	1) In the 1950s to 1970s, the boundaries between sectoral professional-pedagogical and traditional "school" pedagogical education were blurred; 2) During these years, there was an attempt to organize the training of workers in labor polytechnic schools with industrial training; 3) The training of general technical disciplines teachers was carried out in pedagogical institutes, while teachers of labor (industrial training) were trained in industrial-pedagogical technical schools; 4) Starting from the 1960s, engineering-pedagogical faculties and departments were functioning, which were established in polytechnic and sectoral institutes for the training of teachers with higher education; 5) Despite the wide network of educational organizations that prepared teachers and masters of industrial training, it was not possible to meet the demand for personnel for professional educational organizations.
Phase 4	Institutional Modernization and Research Integration (Late 1970s–Early 1990s)	1) In the late 1970s, there was a transition to universal secondary education, and vocational technical schools were organized; 2) Research activity in the field of vocational-pedagogical education began to develop, and the scientific research activity of engineering-pedagogical departments and faculties was activated; 3) Starting from the 1970s, work on international cooperation in the field of vocational-technical and engineering-pedagogical education has been conducted; 4) During this period, many pedagogical higher education institutions resumed the training of cycle teachers in specialties such as "general technical disciplines and labor," "biology and fundamentals of agricultural production," and "drafting, drawing, and labor." It is important to note that the curricula for the training of cycle teachers and engineering teachers largely overlapped, especially in specialized subjects. 5) The training of labor education teachers for grades 5-8 of general education schools was resumed; 6) At the end of the 1980s and the beginning of the 1990s, structural changes occurred in the organization of vocational-pedagogical education: advanced level secondary educational institutions were created based on industrial-pedagogical schools: "pedagogical colleges"; 7) The number of industrial-pedagogical schools and technical schools with evening and correspondence departments increased.
Phase 5	Post-Soviet Transition and Conceptual	1) At the beginning of the 1990s, there was a decline in the prestige of pedagogical staff and the deficit of teachers in vocational educational organizations was filled with incompetent and unfit personnel; 2) Pedagogical education underwent several transformations due to the collapse of the USSR, the transition to a market economy, and the change in "popular" working professions;

Phase	Title	Key Features
	Renewal (1992–2000)	3) The concept of engineering-pedagogical education was replaced by vocational-pedagogical education; 4) The first state educational standards emerged, regulating the content of professional educational programs for the training of teachers for primary and secondary vocational education; 5) Educational-methodological associations of higher and secondary educational institutions of the Russian Federation for vocational education were established, which are engaged in the development of the educational-methodological base for educational programs for the training of pedagogical staff; 6) Special attention was paid to the development of a regulatory legal framework to regulate the activities of teachers and the training of pedagogical staff for vocational education; 7) The concept of vocational-pedagogical education and program documents for the development of vocational-pedagogical education were scientifically substantiated and developed; 8) The first State Educational Standard in the history of vocational-pedagogical education was approved, which includes state requirements for the minimum content and level of training of graduates in the specialty "Vocational Training"; 9) Since 1998, the implementation of a comprehensive program for the step-by-step training of engineer-teachers in the system of continuous education began, which includes bachelor's degree, specialized diploma, and master's degree programs; 10) Since 1998, the training of teachers with higher vocational-pedagogical education has been carried out within one specialty "Vocational Training (by industries)"; 11) The end of the 1990s was characterized by the diversification of organizational training of teachers for vocational training.
Phase 6	Reform, Standardization, and Structural Realignment (2000–2020)	1) At the dawn of the new millennium, significant changes occurred in the teacher training system for vocational education, including the replacement of the "Professional Training" curriculum with "Technological Education." 2) Since 2000, teachers with higher professional pedagogical education have been granted the qualification of "vocational training educator." 3) The early 2000s saw the first definition of professional pedagogical education as the process of forming a capable individual for vocational training and the result embodying a set of knowledge and skills for successful work in vocational education. 4) Initiatives by the Ministry of Education of the Russian Federation aimed at addressing the shortage of teaching staff in vocational education organizations included the creation of methodological associations and the definition of "professional pedagogical education." 5) Despite reforms and initiatives, such as the Federal Target Program for the Development of Education for 2016-2020 focusing on a competency-based approach, problems related to the relevance of training and teacher preparedness remained pressing.

Phase	Title	Key Features
		6) The establishment of the WorldSkills Russia Academy in 2017 reflected ongoing efforts to improve vocational education programs and teacher training. 7) In December 2019, the professional standard for vocational education teachers was abolished, highlighting the lack of a systematic approach to teacher training.
Phase 7	Digitalization and Practice-Oriented Transformation (2020–Present)	1) The COVID-19 pandemic became a driver for the development of digital skills, technologies, and didactics among teachers of secondary vocational education; 2) Various organizations and institutions have emerged for the training, qualification enhancement, retraining, and re-education of teachers within the secondary vocational education system; 3) Efforts began to popularize and enhance the prestige of teachers in secondary vocational education, including the creation of the All-Russian competition among pedagogical workers in the secondary vocational education system, "Master of the Year"; 4) The innovative program for training skilled workers, "Professionalism," becomes a new stage in the training of pedagogical workers and the retraining of teachers in the secondary vocational education system; 5) Normative legal documents have been adopted, emphasizing the importance of training teachers in the secondary vocational education system for the country's development; 6) Federal technoparks for vocational education have been established for the training, retraining, and qualification enhancement of pedagogical staff in the secondary vocational education system; 7) Ideas for the revival of engineering-pedagogical training and the creation of advanced training programs for teachers in the secondary vocational education system have emerged; 8) Since 2023, the State University of Education has been actively involved in the training of teachers for the secondary vocational education system; 9) In 2023, the President of the Russian Federation highlighted the importance of advanced training for teachers in the secondary vocational education system and the modernization of the existing teacher training system for the secondary vocational education system.

Appendix C *Types of Distance Education Technologies (Author's Compilation of Research Results)*

	Case Technology	Internet Technology	Network Technology	Technologies Based on Information Learning Environment
Description	The compilation of educational and methodological complexes (lectures, instructional guidelines, reinforcement tasks), integrated into a unified entity.	Utilizing software to facilitate the educational process and assess knowledge within the realm of the internet	The technology utilizing satellites and the internet, providing access to educational materials (such as e-books, video tutorials, and other learning resources) from any location with accessible internet connectivity.	The technology utilizes informational learning environments and is based on a hardware-software model of the domain of knowledge under study, which is enriched with specific teaching methodologies and methods.
Educational Tools/ Instruments	Educational programs entail comprehensive descriptions of the educational process, instructional and hands-on materials, audio and video resources accompanying each lecture, laboratory sessions, as well as electronic textbooks or software.	Electronic educational materials housed within a unified information system of an educational institution, as well as self-practice training complexes, electronic textbooks, seminars, chats, e-mails, and other technological solutions.	The standardized set of tasks across all disciplines, developed in accordance with approved state educational standards. Electronic testing takes the form of real-time lecture testing, individual computer-based training, modular control testing, written examinations, and examination testing based on the study outcomes of the discipline.	Open-source software enables modifications or additions to be made to existing educational resources (distributed databases, virtual libraries, electronic textbooks, etc.).
Didactic Feature	Self-study of print and multimedia educational materials is provided in the form of case studies. A distinctive feature is the conduct of face-to-face sessions in the form of introductory lectures, seminars, workshops, game-based activities, consultations, and assessment formats. Special attention is paid to group work	Educational materials are provided for self-study in a virtual format. A distinctive feature is the opportunity for interaction with the instructor, as well as for conducting assessments and intermediate examinations.	Self-directed learning in asynchronous mode involves the utilization of various forms of classroom activities (introductory and modular lectures), virtual tutoring, individual and group training sessions, modular consultations, and testing, along with conducting consultations via the Internet Knowledge assessment is	The array of materials from which an educator can construct educational content and implement it both in face-to-face settings and online environments constitutes a complex. A distinguishing feature is the individualized learning process, grounded in models of the learner's cognitive activity. Knowledge acquisition occurs through the resolution of substantive tasks

	Case Technology	Internet Technology	Network Technology	Technologies Based on Information Learning Environment
	with a tutor-educator. A distinguishing feature is the prompt management of the learner's development. Educational materials are characterized by an orientation towards learners' practical activities, task-based developmental tasks, high interactivity, and ongoing updating.		conducted through an electronic testing system.	developed within the framework of constructivist cognitive science.
Technologies	Computer networks and contemporary forms of communication (such as video conferencing, chat discussions, etc.), the utilization of electronic libraries, databases, and electronic administration systems.	"Hybrid technologies utilize electronic learning materials and educational programs accessible through internet technologies."	The modular principle involves the division of disciplines into separate self-contained blocks, each of which is subject to assessment measures.	Highly structured, intellectual, and adaptive learning environments are characterized by predefined programmatic nature and directions of instruction, as well as forms of learner engagement that are implemented sequentially and aimed at achieving the ultimate educational objective.

Appendix D *Pretest interview protocol*

№	Category	Question	Comments from experts	Adjusted question or other changes	Change in the sequence of questions
1	Objectives and Goals of Online Training	What are the main goals you want to achieve with online courses designed to train TVET engineering teachers in vocational education?	E1:"I believe the wording should be clearer to specify that the goals are set during the development phase." E2:"Clarifying that the goals are set by the instructor during development makes it more specific."	What are the main goals you set for yourself when developing and conducting online courses for training engineering teachers?	1
2	Challenges in Delivering Online Training	What are the most significant challenges, in your experience, related to conducting effective online training for TVET engineering teachers?	E1:"The question should focus on the challenges encountered, not just experienced."	What are the most significant challenges you encounter when conducting effective online training for engineering teachers?	2
3	Instructional Methods and Pedagogical Techniques	What teaching methods and techniques do you consider particularly effective in online courses for training engineering and technical personnel?	E3:"Focusing on 'engineering teachers' aligns with the specific target audience."	What teaching methods and techniques do you consider most effective in online courses for training engineering teachers?	3
4	Evaluation and Assessment of Training Impact	How do you measure and evaluate the impact and success of online training programs for	E3: "Adding 'effectiveness' helps in evaluating both qualitative and quantitative aspects."	How do you measure and evaluate the effectiveness and success of online training	8

№	Category	Question	Comments from experts	Adjusted question or other changes	Change in the sequence of questions
		TVET engineering teachers?		programs for engineering teachers?	
5	Technological Tools and Their Role in Enhancing Learning Effectiveness	How, in your opinion, does the integration of technology enhance the effectiveness of online courses for training TVET engineering teachers?	E1: "The wording could be streamlined for better flow."	How, in your opinion, does the integration of technology enhance the effectiveness of online courses for training engineering teachers?	10
6	Support Systems and Learning Resources	What resources and support systems do you consider important for ensuring the effectiveness of online training for TVET engineering teachers?	No comments	-	6
7	Course Customisation and Adaptation to Learner Needs	How do you adapt online courses to account for the specific needs and experiences of TVET engineering teachers in vocational education?	E2: "Please, clarify the question."	How do you adapt online courses to account for the specific needs and experiences of engineering teachers in vocational education?	4
8	Strategies for Learner Engagement and Interaction	What strategies have you used to enhance engagement and interaction in the online learning environment	E2: "Using present tense makes the question more relevant."	What strategies do you use to enhance engagement and interaction in online learning for engineering teachers?	5

№	Category	Question	Comments from experts	Adjusted question or other changes	Change in the sequence of questions
		for TVET engineering teachers?			
9	Opportunities for Continuous Professional Development (CPD)	How important is continuous professional development for TVET engineering teachers, and how does online training contribute to their ongoing growth?	E3: "Adding 'professional' clarifies the type of growth we're discussing."	How important is continuous professional development for engineering teachers, and how does online training contribute to their professional growth?	14
10	Factors Influencing the Adoption of Online Learning	What factors influence the adoption and mastery of online learning among TVET engineering teachers in vocational education?	No comments	-	7
11	Practical Implementation of Online Educational Components	How do you address practical aspects such as hands-on activities and lab work in the context of online education for TVET engineering teachers?	E1: "Simplifying 'address practical aspects' to 'organize hands-on activities' makes it clearer." E3: "Rephrase it a little bit"	How do you organize hands-on activities and lab work in online education for engineering teachers?	9
12	Teacher–Learner Interaction and Communication	How, in your opinion, does the quality of teacher-student interaction affect the outcomes of online courses for engineering	E2: "Make it more focused on 'engineering teachers'. It helps to keep the target audience specific."	How, in your opinion, does the quality of instructor-student interaction affect the outcomes of online courses for engineering teachers?	12

№	Category	Question	Comments from experts	Adjusted question or other changes	Change in the sequence of questions
		and technical personnel?			
13	Ethical Considerations in Online Education	What ethical considerations or issues arise in the context of online training for TVET engineering teachers in vocational education?	No comments	-	13
14	Knowledge and Skills Transfer in Online Settings	How do you ensure the effective transfer of knowledge and skills acquired in online courses to the actual teaching practice of TVET engineering teachers?	No comments		11
15	Innovations and Recommendations for Improvement	Based on your experience, what innovations or changes would you suggest to enhance the effectiveness of online training for TVET engineering teachers?	No comments		15
16	Additional Comments and Suggestions		E2: "You didn't ask at the end what I'd like to add. " E3: "Adding a question that could help us to ensure that	Is there anything I haven't asked that you believe is important to discuss regarding the effectiveness of	16

№	Category	Question	Comments from experts	Adjusted question or other changes	Change in the sequence of questions
			we capture any overlooked information."	online courses for training engineering teachers? Perhaps you have additional insights or clarifications that we haven't covered?	

Appendix E *Interview Protocol*

Individual Interview Protocol

Date of Interview: _____ Time of Interview: _____

Place of Interview: _____

Interviewer: Nataliia Dolgova

Interviewee: _____

Identification Pseudonym: _____

Interview Guidelines:

№	Category	Adjusted question or other changes
1	Objectives and Goals of Online Training	What are the main goals you set for yourself when developing and conducting online courses for training TVET engineering teachers?
2	Challenges in Delivering Online Training	What are the most significant challenges you encounter when conducting effective online training for TVET engineering teachers?
3	Instructional Methods and Pedagogical Techniques	What teaching methods and techniques do you consider most effective in online courses for training TVET engineering teachers
4	Course Customisation and Adaptation to Learner Needs	How do you adapt online courses to account for the specific needs and experiences of TVET engineering teachers in vocational education?
5	Strategies for Learner Engagement and Interaction	What strategies do you use to enhance engagement and interaction in online learning for TVET engineering teachers?
6	Support Systems and Learning Resources	What resources and support systems do you consider important for ensuring the effectiveness of online training for TVET engineering teachers?
7	Factors Influencing the Adoption of Online Learning	What factors influence the adoption and mastery of online learning among TVET engineering teachers in vocational education?
8	Evaluation and Assessment of Training Impact	How do you measure and evaluate the effectiveness and success of online training programs for TVET engineering teachers?
9	Practical Implementation of Online Educational Components	How do you organize hands-on activities and lab work in online education for TVET engineering teachers?
10	Technological Tools and Their Role in Enhancing Learning Effectiveness	How, in your opinion, does the integration of technology enhance the effectiveness of online courses for training TVET engineering teachers?

№	Category	Adjusted question or other changes
11	Knowledge and Skills Transfer in Online Settings	How do you ensure the effective transfer of knowledge and skills acquired in online courses to the actual teaching practice of TVET engineering teachers?
12	Teacher–Learner Interaction and Communication	How, in your opinion, does the quality of teacher-student interaction affect the outcomes of online courses for TVET engineering teachers?
13	Ethical Considerations in Online Education	What ethical considerations or issues arise in the context of online training for TVET engineering teachers in vocational education?
14	Opportunities for Continuous Professional Development (CPD)	How important is continuous professional development for TVET engineering teachers, and how does online training contribute to their professional growth?
15	Innovations and Recommendations for Improvement	Based on your experience, what innovations or changes would you suggest to enhance the effectiveness of online training for TVET engineering teachers?
16	Additional Comments and Suggestions	Is there anything I haven't asked that you believe is important to discuss regarding the effectiveness of online courses for training TVET engineering teachers? Perhaps you have additional insights or clarifications that we haven't covered?

Appendix F *Coding transcripts*

Themes	Codes	Key Quotations	Word Frequencies	Category
Course Effectiveness Factors	• Audience differentiation • Pedagogical skills • Different approaches • Distance learning • Motivation • Quality of Interaction • Effectiveness • Work Techniques • Applicability • Specific subject • Hands-on experience • Engagement rate • Practical Sessions • Remote Learning • Practical Experience • Methodological Knowledge	E1: «The first problem is that we do not differentiate our audience according to the functional roles of engineering teachers, which vary. We encounter those who are effectively teaching and are responsible for general professional disciplines—I emphasize—or specialized disciplines, focusing on theoretical education. Even within these categories, there's a difference between specialized and general professional roles. The goals and tasks of these courses they teach are different systems of tasks, and, of course, different approaches to their preparation are required.» E1: "We select for distance courses those questions that do not require direct, so to speak, practical work in the classroom, because analyzing a lesson plan, choosing a technology—everything can be discussed online." E1: "I advocate that vocational education teachers should have higher qualifications." E1: «The innovative field lies in providing higher qualifications both technically, engineering qualifications, and pedagogical qualifications. Moreover, I must admit that engineering is primary. It's possible to make an engineer into a teacher, but not vice versa. We must all understand this.» E1: I believe that courses, especially for engineer-teachers, should be comprehensive. They should combine knowledge related to breakthroughs in technology, in mechanical engineering, food production, molecular production, in space. But a person must understand how the industry in which they work is developing. The second point is, of course, the enhancement of pedagogical knowledge, which is not always an enhancement, sometimes it's treatment for a stale pedagogical view. E1: We look at parameters like dropout rates. We understand that dropouts are often linked to the fact that the teacher we entrusted to	830	Course Design and Evaluation

Themes	Codes	Key Quotations	Word Frequencies	Category
		teach part or the whole course, well, sometimes they just aren't interesting. E3: «The presence of free time and motivation to study» E3: The basic level of competence literacy of the teacher is crucial to understand the material and readiness to take the most of it. E3: «They need to be differentiated by certain groups and already in the context of these groups consider the tasks of engineering pedagogical education.» E3: Replacing hands-on workshops and lab work with online education is challenging because it requires tactile and visual experiences that are crucial for mastering practical skills, especially in fields like met alworking and welding. While online courses and simulators can supplement learning, they cannot fully replace the need for on-site, hands-on training with real equipment. E3: «It will be some blended learning, a mix of online and face-to-face formats. For specialized knowledge, especially in technical fields, blending online theory with hands-on practice at a workplace is ideal. This approach allows learners to independently study the basics online, then apply what they've learned through real-world practice, ensuring they fully understand the material.» E4: The ideal duration of training is up to 1440 hours. E4: Online courses help address the social issue of teachers being detached from their professional activities. E4: Material and technical resources should be at the teacher's workplace that can give them an opportunity to study during worktime. Educator shall be given time resources for training. E4: Online training for engineer-teachers can only cover pedagogical education; practical experience must be gained on-site at the enterprise. E4: An effective course is one that is tailored to a specific subject matter. E6: Whether the program is effective or not effective, probably here you can track more how many people were at the start and how many people		

Themes	Codes	Key Quotations	Word Frequencies	Category
		mastered this program and achieved some result, some intermediate assistants, passed. E6: Online courses are effective when there is a need to incorporate hybrid forms of learning. Some disciplines, not all, but some, still need to be studied, to be mastered in person, especially where there are some workshops or lab works. E7: That is, he made some product himself, independently using the material that you give. E7: Studying and learning with blended learning (practical skills development with the help of simulators), but they should develop something in a real production environment, just to try it on. E8: If a person has a high level of self-organization and is motivated to learn, they will watch lectures and learn it. E8: Online course should be very short and deep… there should be one theme, one course E8: Logically, the effectiveness of this program should be a subsequent snapshot. That is, it is about getting feedback from students after some time on how effective the training was. This is probably the only moment that can really show the true picture of the effectiveness of these courses. E9: Plus, and problem and positive factor is still a setup for results and emotional involvement in the course. E9: For me, a person must have some kind of professional education, full-time, in order to be able to work with distance learning later. E9: You need to understand with whom you work… age category, firstly, and how involvement, involvement, immersion in all this. E10: Engagement, interest, the number of participants who actively engage in performing those practical tasks E10: If the engineer-educator feels satisfied and confident in their abilities upon graduation, then the courses were probably effective. E10: If a learner who is being trained and will be a future engineering-educator has any health restrictions that do not hinder their professional		

Themes	Codes	Key Quotations	Word Frequencies	Category
		teaching activity but do hinder the quality display of recorded material, then a solution is sought. Permission is obtained from other learners to review someone else's session so that the individual understands how it went. Thus, they conduct the session without recording it and come out with self-analysis of this session to discuss some nuances. Our main task is not control, but ensuring quality. E11: «We've often tried to create LMS courses that include the development of skills like communication, giving appropriate assignments, for example, asking to write down 15 variations of entering a classroom. This is because teachers often stumble over such simple things, mainly relying on their life experience and the methods they were taught, which they simply transfer directly into the classroom.»		
Problems	• Lack of Competency Development • Conveying problems • Live communication • Knowledge Reinforcement • Functional roles • Different systems of tasks • Lack of interaction • Barriers • Responsibility issues • Lack of engagement • Underutilization of Software • Time management • Attendance • Lack of Alignment with Professional Goals • Technical issues	E1: «There were courses we had when different cities, different regions, people who were not familiar, we couldn't introduce them to how to get close, it's simply impossible when there is no direct communication.» E1: «But when it comes to more complex issues, communicative ones, related to reflection, professional self-control, and other functionally important, so to speak, activity-related pedagogical competencies, here, of course, there is a problem. It is poorly conveyed through online means.» E1: «Even in an online environment, live communication in class people trust each other more than being remote» E2: We encountered non-compliant discipline. E2: «The second problem, we initially announced a program for anyone who wants to study. Anyone went, then we realized, no, there still must be people with technical education.» E2: «They tell us that they will do tasks and they don’t do anything.» E4: The difference in the language of Federal State Educational Standards and the language of teachers. E4: It is necessary to establish behavioral guidelines for meetings, as people often behave terribly online.	107	Course Design and Evaluation

Themes	Codes	Key Quotations	Word Frequencies	Category
		E4: different levels of responsibility of teachers and lack of necessary technical equipment E4: Failure to receive a response in a timely manner. E4: I have always found it extremely frustrating when teachers of general education subjects attended professional development courses for vocational teacher trainers , as they would disrupt discipline and lacked motivation for learning. E5: They are not engaged; I can't see their cameras and don't know what's happening on their end. And the results are unclear because it's not always obvious how I can assess them. E6: There is no live communication, no atmosphere where we can share opinions, have a conversation, as it happens in face-to-face classes. E6: There's no sense of community E7: Most often barriers are that the person cannot organize themselves and allocate time for learning on their own E7: Teachers go for training not by their own will E8: The first problem we encounter is maintaining an online journal of any courses. In these online journals, you can see who has viewed and who hasn't and we've found that many listeners simply haven't viewed certain topics. E8: For people my age, it's more challenging to engage with online courses—but for younger people, like the youth I work with, they say if there were gamified elements integrated, it would be fantastic. E9: If you're a pedagogue and you don't have an engineering background, courses won't help you at all. E9: The organizational-technical problems and a specificity of perception of materials. E9: Studying for a year or two online—it can be compared to self-education, conduct long-term online programs is inefficient. E9: For some reason, people think that online education is not so responsible, you don't have to prepare for it.		

Themes	Codes	Key Quotations	Word Frequencies	Category
		E9: Lacks the tools to simply show the application of the subject matter in practice like digital tools. E10: The main problem is the formal approach. There's room for some carelessness in material selection and conducting classes. Also, formal relations from the side of those who attend. E10: Another aspect is the quality of resources used for online education, which doesn't always facilitate the effective transmission of necessary information.		
Course goals	• Real-Life Scenarios • Communication • Pedagogy Skills • Easy Access • Practice-Oriented Learning • Continuous professional development • Improve knowledge and qualification • Accessibility • Hands-on experience • Offline-Online Combination • Certification • Methodological knowledge • Theoretical Knowledge • Time saving • Practical tools	E1: «Firstly, we need to define who these people are—those already working, individuals with engineering education and work experience who have come to work in professional educational organizations. Pedagogical training is more productive when we divide the audience and create targeted courses for those who teach theory, those who organize instructional practice, and those who organize industrial practice. E1: «Not only mastering new material but also overcoming gaps in knowledge, skills, anything else.» E1: «The first year is only face-to-face theory. That is, a whole year of psychology, pedagogy, methodology, visiting TVET organizations, observations, basics of scientific research. And the entire second year is practice, in the position of teaching.» E3: Teachers who have come to learn and improve their qualifications. E3: «It is important to understand the audience, its generation and use appropriate teaching methods.» E4: The key interest here is to select a course topic that is engaging for everyone. E5: We constantly conduct a needs analysis at the beginning of the training to assess what learners already know and what they don't, followed by a trial lesson. After that, we compare the results and develop the program accordingly. E5: After the training, teachers will perform their work better.	355	Course Design and Evaluation

Themes	Codes	Key Quotations	Word Frequencies	Category
		E7: Most often, the goals were to transfer practical tools, such as program design, development of specific lessons, project activities E8: The purpose of online courses, as I understand it, is to save time, because it's very difficult to go somewhere now, for example, for offline courses, they either involve business trips or taking time off to go somewhere and sit there. The main goal of online courses is professional development through time savings. E9: They will get acquainted with various teaching methods. E10: The primary goal is readiness of future teachers to engage in professional activities under various conditions… Modern teachers must be proficient in all technologies to carry out their professional duties. E11: Online course must be relevant to them, and they must have a need for this material specifically.		
Teaching methods and technics	• Teaching Methods • Laboratory Practical Work • Practical Techniques • Understanding of Teaching-Learning Process • Feedback • Workshops • Andragogy • Didactics • Digital Didactics • Gamification • Problem solving situations • Case Studies • Generation theories	E1: «Indeed, pedagogy becomes a complex, imaginative activity that requires knowledge of technologies, specific algorithms, and teaching techniques.» E1: «The most successful audience is the audience of teachers, masters who are currently practicing during the course…Before the session, a specific assignment is given that needs to be attempted, relying on one's experience and any sources, to accomplish. And the session is structured as a review, a discussion of errors, findings, with the aim of ultimately improving the product that was initially created. Therefore, we believe the most important thing is to have an educational task that improves as it is performed, its result in the process of such distance discussion.» E1: «We strive to have two plans in our courses. One plan moves forward, mastering new techniques, technologies, imbued with psychological, methodological theory, and pedagogical approaches. On the other hand, we stay grounded and pay attention to and help solve the tasks that are here, now, today.» E1: «I am certainly a supporter of andragogy, I am a supporter of learning and self-education.»	361	Teaching methods and engagement

Themes	Codes	Key Quotations	Word Frequencies	Category
		E1: «Therefore, these distance courses rely more on methodological knowledge, when we teach them planning, control, of course, achievement analytics, and so on. Here we are talking about basic pedagogical skills, the ability to correctly design educational-program documentation, and so on.» E1: «Feedback from real activities, we suggest discussing what we teach with other people and trying to gauge their reactions.» E2: «I created a group of testers from students who sat down, each product tested, filled out appropriate sheets.» E3: «The method of creating problem situations proves itself the most. These are group methods where roles are distributed within the team, including production roles and roles in solving some of their complex pedagogical tasks» E3: «There is feedback, reviews, responses – all the things that help us.» E4: Pedagogical technologies should be superimposed, adapted to production technologies through various models, simulators, which are available in the educational institution. E5: Through assignments, meaning the task needs to be formulated in a way that prompts the learner to go and complete it. E5: Surveys with feedback and strict deadlines after each meeting increase productivity of the course. E6: I like to use some group learning formats. E6: You need to use certain didactic principles, well-known ones, from simple to complex and visualization. E6: Often there is no feedback from students, from faculty and this is the real problem. E6: Firstly, gamification themes personally for me as a teacher have been used for quite some time already. E6: The main thing is to structure the session, to lead it step by step from goal setting to reflection. E7: Going through knowledge stages, skills, practical experiences.		

Themes	Codes	Key Quotations	Word Frequencies	Category
		E7: Digital visual tools and gamification (gamification just worked that men compete with each other, ratings, so there it worked great, but when it comes to the educational environment, they don't really want to compete) E7: You need an adequate feedback collection system so as not to bore, but at the same time not to miss the most important thing. I use standardized feedback with closed answers, where you can read analytics, summarize. And I always work with live feedback, textual. E8: A person should practically have as a result, and feedback, if he has a question, he should somehow answer this question, get an answer immediately, and not from a chatbot. They need feedback from the teacher; they should take a photo or record a video of what didn't work out with this particular issue and send it to get feedback. E9: Methodology is more important than pedagogy, because methodology includes pedagogy in one way or another. Pedagogy does not deal with material presentation, with material exposition. E9: If I'm talking about methods and techniques, it means that methods and techniques should go methods and techniques applied to their material, on their material. E11: «We try to specify, applying methods of anticipatory learning in its original sense and anticipatory professional preparation.»		
Technology integration	• Technology integration • Hybrid Learning • Interactive Boards • Interactive Learning Methods • Technology Usability • LMS • Educational platforms • Interactive tools • Multimedia resources	E1: «Technology is just a means—a means we must put in the hands of those who truly want to make a difference, engage, and more. We don't just list technologies but try to equip teachers with them. It's important not to move into some purely theoretical sphere and try to pump up with modern technologies.» E1: «What's good about LMS courses is that everything can be demonstrated, you can record it, discuss what you saw.» E2: «Theory and practical sessions. We sat down online and made courses together but in distance.»	238	Technology integration

Themes	Codes	Key Quotations	Word Frequencies	Category
	• Artificial Intelligence • Virtual labs • Online Demonstrations • Digital tools • Visual tools	E2: «We integrate only necessary tools, such as multimedia tools, virtual labs.» E3: «It's clear that we often use simulators, trainers in the educational process, and, integration of trainers and simulators into the educational process, this would be possible, for example, with the use of online education, but for the most part, we still need the mastery of practical techniques of the direct audience, directly on the spot of practical training at the enterprise, so it is not always possible for us to master practical techniques through online learning.» E3: «It is necessary to use the tools that today's modern youth use (all possible platforms, tools, all possible groups, some messengers). Tailoring approaches to different age groups and integrating practical tools directly into online (digital) platforms can help bridge this gap in adaptation to the new technologies.» E4: The development of professional competencies is possible through VR technology, for example virtual tours to enterprises E5: On Miro, we often do exercises like writing something, commenting on others, giving a thumbs-up, or choosing a sticker. All of this immediately increases engagement. E6: We don't have such a big experience of using artificial intelligence in education, although we make some separate attempts…but we use a chatbot with some basic questions and answers. E7: You always need to choose the optimal amount of these tools, not overload, not overdo it. E7: Services for synchronous communication, a shared field can help to develop shared environment that gives an opportunity to practice different pedagogical skills. E8: When we talk about digital services, we constantly forget the importance of accessibility to library resources. People should have free access to the literature.		

Themes	Codes	Key Quotations	Word Frequencies	Category
		E9: Some accessible application or something convenient, which everyone has installed there. E10: «Most importantly, moderation in everything, ensuring that both sides, both the one teaching and the one learning, understand and speak in the same informational context.» E10: There are many educational platforms available today where experiments, laboratory work, practical classes, preparation for demonstration exams, and work with equipment on simulators can also be conducted. We use them. There is an opportunity to record the process, the real production process, show it in an online session, and dissect it in detail: what it is, how it works, where it is located, how to operate it, how to troubleshoot, what possible problems there might be, and so on. E10: When materials are developed, there's the opportunity to conduct practical sessions on the educational platform itself. Here, students don't just take assignments, complete them, and attach them, but rather work directly on the platform, performing tasks immediately on it. This helps establish contact between the instructor and the learners.		
Engagement and Interaction	• Engagement strategies • Peer interaction • Reviews • Discussions • Interactive activities • Collaboration • Brainstorms • Gamified interaction elements • Instructor-student communication • Hybrid Learning	E1: We constantly make brief stops so that each listener can express what they've acquired, what they've gained, what they've simply felt. Everyone can talk about their difficulties, and together we find ways to overcome them. We definitely pay attention to their practical difficulties, which we help them overcome. Sometimes we leave time just for group discussions, but there is such a task that each listener prepares some material about certain obstacles. E2: «We made a competition based on the material they learn.» E4: It is important to have face-to-face interaction with the instructor. Moreover, at the end of each course, I always provide a list of recommended literature and specific online courses.	321	Teaching methods and engagement

Themes	Codes	Key Quotations	Word Frequencies	Category
	• Masterminds • Workshops • Group projects • Interactive Tools • Competitions • Interactive content • Community building • Live Lessons and Webinars • Practice-oriented approaches	E4: When there are even 200 people online, even 150 people online, there's always the possibility of hiding out. It all depends on the individual, their motivation, and their desire to develop. E4: We try to implement talent pool development system as an engagement tool in our courses. Certification and competitive movement. Participation in various competitions of professional mastery as a pedagogical engineer. E5: These quick warm-up exercises, such as posting something, writing on the board, conducting a survey, completing a request, or creating your own presentation, all help to boost engagement. We just start a meeting with Kahoot, for example and other warm-up exercises. E5: Workshops and masterminds in terms of interaction between participants…More practical sessions, meetings, and brainstorming, where we, like bees, share ideas with each other…One-to-one meetings with teacher trainers . E6: We engage students in various competitions, experiments, and scientific research. We also have tools, when there is an opportunity to edit something together, add information, use something, some links. E6: We used brainstorming sessions and more complex, more detailed assignments for students who need higher level of knowledge. E6: If it's just a lecture text posted, or it's just, say, a talking head that just speaks, that's one thing, but when it's backed up by some graphics, some illustrations, maybe short videos with examples, demonstrating something, of course, this much more engages in learning this content. E7: Trying to keep hands busy… even if it's a lecture, for example, an online lecture, it should be an interactive lecture with constant communication with the listeners. E7: I directly track so that they immediately review everything with me… if they make mistakes, something doesn't work out, so that I hear about it, so that I help them work it out.		

Themes	Codes	Key Quotations	Word Frequencies	Category
		E8: Lectures are recorded, they watch, and the offline seminar, they prepare questions. Personally, I outlined these questions to them with textbook pages they had to read. So logically they had to watch the stream, read additional literature on those pages and textbooks. I wrote them questions, and they came to the online seminar. Everything should have gaming, interactive and visual elements. E8: There are generally tools that help maintain attention and engage students, for instance, creating a community inside. E8: Within our online course, there is always an offline seminar. E9: Dose every 15 minutes to distract to some videos, like with children, read, play, draw, play. Then you use sound, then you use a picture, then you use writing. Thus, you consider there three types of memory, visual, sensory, auditory. E9: I try to show them on fingers what it is, with examples, and then open Excel and do it all banally in Excel. I mean, you understand how to create a situation of success in the simplest task. E9: With only face-to-face, we will not create a classroom situation and so on. It will be just nodding, a heart-to-heart conversation for two. 15 people are already a lot, because you need to give each one the opportunity … Small groups. Like 5-10 people. E9: you need to be constantly in touch… throughout the day, by email, in chat. E9: When you give some material or ask for material, or I tell you today about this, and tomorrow you tell me about that. And I ask you a question. So that you can answer them, first of all, you have to ask yourself a lot of questions…Just to play out this situation. E10: If you tell people about the difficulties you encounter in your professional activities using modern technologies, including communication and interactive technologies, and if you sincerely explain to people that this online course is aimed not only at transmitting knowledge but also at exchanging experience, and primarily at gaining		

Themes	Codes	Key Quotations	Word Frequencies	Category
		very important, necessary, up-to-date information on the training of engineering teachers, then the interest from the learners increases. E11: Have an opportunity to interact periodically face-to-face (instructor – student) to see each other's perspectives and understand how interested and satisfied both sides are in this interaction.		
Ethical considerations	• Privacy concerns • Data collection • Cultural sensitivities • Communication issues • Age differences	E1: You turned on the recording, you recorded video and this is already such an ethical moment, it's like a published manuscript. E3: In online education, ethical issues can arise, such as resistance to video surveillance during exams due to cultural or religious beliefs, or challenges in group work involving individuals with disabilities. These situations highlight the need for sensitivity and adaptability in educational practices to accommodate diverse needs and perspectives. E5: It is crucial to make them comfortable during learning process, feel good in learning environment and it could influence the retention rate increase. E6: Those very black screens that you see from students and material-technical provision E7: Chat arguments, swearing, inappropriate language, a participant's camera turning on at the wrong time, them not engaging in what was required, which was completely unethical and unpleasant, involuntary microphone activation at an inappropriate moment. E10: If a person does not demonstrate how they work but is ready to discuss the difficulties that arise in their professional teaching activity, then this recording is optional.	46	Course Design and Evaluation
Assessment tools	• Assessment tools • Feedback surveys • Clear Evaluation Tool • Completion rate • Evaluation criteria • Performance indicators	E1: «We see the delta—what a person came with and what they left with. This is direct result-based assessment… Diagnostics of difficulties, burnout, and stagnation.» E1: Try to understand teachers' attitudes through conversations, through simple diagnostic tasks. E1: «We have more of a pass-fail scale rather than a five-point scale.»	155	Course Design and Evaluation

Themes	Codes	Key Quotations	Word Frequencies	Category
		E4: Entrance test for knowledge, for example, of regulatory documentation on specialization E4: Control of the material mastered involves a specific thematic topic and how the instructor utilizes various techniques, methods, and technologies to assess the level of understanding and mastery. E5: Tests that learners complete and checking lessons once a month. E5: The transfer of knowledge from online to practice is assessed through observation, supervision, or site visits—whatever you choose to call it—where you go and see what has actually been applied. E6: We have a rating system and more punitive measures. That is, if you have a low rating, two times a semester, a checkpoint, you didn't pass, you have more problems. E6: Specific criteria are needed for each type of task. E7: I did entrance testing E7: Any educator needs to first bring them into a student state at the program entry stage. E8: They go through the general material, take the final test, some average cuts. E10: Question-answer sessions, hints, consultations, and instant feedback, where it's not the system but rather the instructor providing a subjective evaluation based on established criteria.		
Hands-on activities	• Hands-on activities • Lab works • Virtual simulations • Interactive elements • Practical Assignments • Simulations • Real-World Applications • Remote labs • Blended Learning Format	E1: «We definitely adhere to an activity and practice-oriented approach. It's not just about imparting information; it's closer to problem-based learning. It is also very important for the course to be connected to real activities. Most often this is done not at the level of methods or content, but at a personal level.» E1: «We show that we have the opportunity to change individual work to group work, project-based learning, so we apply and are not afraid of anything, use collaborative learning, flipped classrooms, and so on. And attitudes really change. It's not just, well, dictated explanation for the	188	Teaching methods and engagement

Themes	Codes	Key Quotations	Word Frequencies	Category
	• Detailed explanations • Competency-Based Training • Practical demonstrations	record about what a flipped classroom is, or some kind of meeting, or who knows what else. We have about 60 different tricks up our sleeve.» E1: «We strive for what is called a comprehensive knowledge assimilation school.» E3: «All these courses have a general pedagogical foundation or are in the field of digital literacy» E4: Engineers-teachers develop skills and professional competencies through laboratory and practical sessions…Practice-orientedness depends on the number of laboratory and practical, educational production practice, course and diploma design. That is, those things that are focused on the formation of professional competencies.practice orientation depends on the number of laboratory and practical, educational production practice, course and diploma design. In other words, those things that are aimed at the formation of professional competencies. E6: Not just to complete the project and attach it to the portal, but also defend their project, demonstrate the results of their work E6: The main tool is definitely industrial practices, during which students go to real colleges and teach real disciplines. We try to work out everything that we gave on ourselves. E10: Asking to film a part of the classwork so that we can discuss it either individually or as a group. E10: Everything new that appears is just called something new, but in fact, it is experience accumulated over generations. The more I work, the more engineering and pedagogical personnel I produce, the more I understand that the established system of engineering and pedagogical education used to be the most qualitative. It just needs to be filled with modern content. E10: It's crucial to clearly establish boundaries right away: when the practical work submitted by the learners will be reviewed by the teacher, when the practical work that is performed directly in the presence of the		

Themes	Codes	Key Quotations	Word Frequencies	Category
		teacher will be evaluated, entered into the records, and so on—all the documents. E11: «We also teach applying the knowledge and skills acquired in real life to establish contacts with people, to refine oneself, one's face, body in normal, everyday communication.»		

Appendix G *The qualitative insights that informed the thematic blocks of quantitative metrics*

Hypothesis	Major qualitative findings (Key words)	How each finding was used in the design of the quantitative feature	Thematic blocks of the survey	Questions
-	• Age differences, • Basic education, • Frequency of online course participation, • Professional experience	Due to the repeated references to age-related characteristics in the transcripts, a decision was made to create a separate section with background information. This section is not linked to any specific hypothesis but provides contextual data for analyzing responses in other sections.	General information	Specify your age
Tailoring course content to the specific needs and backgrounds of TVET engineering teachers, combined with practical, real-world applications, significantly enhances the effectiveness of online courses.	• Narrow course topic, • Universal content for a diverse audience, • Teachers attending courses without being prepared for the level of materials, • Presence of motivation and engagement, • Teachers' technical capabilities, • Communication issues, • Lack of discipline and organizational-technical challenges in online courses, • Time savings	This thematic section is intended to gather data on how teachers interact with and perceive online courses in relation to their professional needs and goals. Subsequent analysis will help evaluate how effectively courses are adapted to the specific characteristics of teachers and whether such adaptation influences course selection, participation frequency, and overall effectiveness and satisfaction. The results will serve as a basis for testing the hypothesis that adapted and up-to-date content increases the effectiveness of online education for TVET engineering teachers.	Online courses experience	1) What were your primary objectives when enrolling in online courses? 2) What topics for online courses have you chosen recently?
Selective and purposeful integration of accessible technological tools, such as digital simulations and virtual labs, enhances	• Preference for online over in-person learning, • Blended learning formats, • Use of digital tools for theoretical subjects, • Eliminating gaps in basic education,	This thematic section aims to collect information on how technology influences course selection, learning objectives, and overall satisfaction. The results will allow for evaluating the extent to which targeted integration of tools such as digital simulations and virtual laboratories	Selecting and evaluating participation in online courses	1) What problems or difficulties did you encounter when taking online courses? How comfortable do you feel using various digital tools and technologies?

Hypothesis	Major qualitative findings (Key words)	How each finding was used in the design of the quantitative feature	Thematic blocks of the survey	Questions
the development of practical skills and overall course effectiveness without overwhelming learners.	• Adaptation to changing conditions	positively impacts learning outcomes and help test the formulated hypothesis.		
Selective and purposeful integration of accessible technological tools, such as digital simulations and virtual labs, enhances the development of practical skills and overall course effectiveness without overwhelming learners.	• Technology as a tool, • Providing practical experience through additional technological tools, • Meeting the needs and characteristics of the target learner audience, • Facilitating the creation of a learning environment	This thematic section aims to assess how teachers perceive the most valuable technical resources, the need for additional tools, and the impact of existing technologies on their learning experience in online courses. The responses will help determine the usefulness of various tools and the extent to which the results support the hypothesis. Combined with the section "Selecting and evaluating participation in online courses," this section will help confirm or refute the idea that selective use of technologies, appropriate to a given context and audience, enhances the effectiveness of online education.	Resources and technologies	1) What resources do you consider most important for effective teaching in online education? 2) What additional resources would improve your online learning experience? 3) What other technologies have improved or could improve your online learning experience?
The use of active learning techniques, such as group work, gamification, and interactive tools, along with real-time collaboration on interactive platforms, increases learner	• Practice-oriented and problem-based approaches, • Laboratory and practical work, • Preserving traditional pedagogical approaches, • Implementation of active teaching and engagement methods,	This section aims to gather information on the effectiveness of active learning methods combined with different forms of collaboration with the teacher, as well as participants' preferences and the extent to which online courses meet their stated needs and willingness to participate. The analysis of results will provide teachers'	Engagement and interaction	1) Which of the following tools allowed you to engage more deeply in the online course? 2) How would you like online programs to be adapted to meet your

Hypothesis	Major qualitative findings (Key words)	How each finding was used in the design of the quantitative feature	Thematic blocks of the survey	Questions
engagement and improves educational outcomes in online courses for TVET engineering teachers.	• Interactive formats, • Personal interaction and individualized approach, • Group size, • Influence on various types of information perception, • Ethical issues	assessments of the value of active and interactive teaching methods.		individual needs as an educator? 3) What ethical considerations impact your online learning experience? What teaching methods do you prefer in online courses?
The balanced approach that integrates modern interactive methods with traditional pedagogical principles, including blended learning formats, leads to more effective learning experiences and better skill development for TVET engineering teachers.	• Combining theoretical knowledge with practical skills, • Knowledge of methodology, • Use of various active learning formats, • Basic pedagogical approaches, • Well-designed assignments, presence of personal project experience	This section aims to collect information on tools and methods used in practical sessions within online courses, their effectiveness in transferring knowledge to practical application, and the use of various assessment strategies. The collected data will help evaluate whether a balanced integration of traditional and modern teaching methods enhances the practical application of skills and the overall effectiveness of online educational courses.	Practical exercises and evaluation	1) What tools were used for conducting practical exercises and lab work in the online courses you attended? 2) How would you rate the effectiveness of interactive modules (e.g., tests, quizzes, simulations, interactive exercises) in the online courses?
Selective and purposeful integration of accessible technological tools, such as digital simulations and virtual labs, enhances the development of	Knowledge transfer into practice, application of learned material	This thematic section aims to identify which tools TVET engineering teachers apply from their online course experience, what challenges they face, and what benefits they perceive. The analysis will provide detailed insights into the practical application of online courses and the experience of independently integrating	Experience in delivering online courses (independently, as an educator)	What additional features or improvements would you like to see in online courses to better meet your needs as an educator?

Hypothesis	Major qualitative findings (Key words)	How each finding was used in the design of the quantitative feature	Thematic blocks of the survey	Questions
practical skills and overall course effectiveness without overwhelming learners.		online learning into their work. This section is intended to determine whether teachers incorporate elements into their practice not only from the knowledge provided but also from their personal experience of learning online.		
Immediate and constructive feedback in online courses positively impacts the learning outcomes, engagement, and skill development of TVET engineering teachers.	• Assessment of student progress, • Availability of tests, interaction with learners, • Cultural and national characteristics, • Effective feedback	This thematic section focuses on understanding teachers' attitudes towards satisfaction, effectiveness of online courses, and potential improvements. The analysis will assess the importance of timely and constructive feedback for the effective learning of TVET engineering teachers in online courses.	Overall satisfaction and recommendations	1) What do you think was missing in the online course for you to be fully satisfied with the learning outcomes? 2) What additional knowledge or skills do you need to effectively teach using virtual learning methods? What improvements, innovations, or additional features would you like to see in the online courses you have taken? Please describe any specific elements or changes that you believe would enhance the effectiveness and improve the experience of online courses.

Appendix H *Expert Feedback Form from Pilot Testing of the Quantitative Study Questionnaire*

Dear Expert,

I sincerely thank you for participating in the pilot testing of the questionnaire for the study Key Factors of Online Course Perceived Effectiveness for Preparing TVET Engineering Teachers in Russia. Please review each item carefully and assess its relevance to the study's objective using the scale below. You are also welcome to provide comments and suggestions for improving the wording or content of the questions.

Relevance Rating Scale:
Not relevant – The item is irrelevant. It is poorly formulated, does not reflect the research objective, or should not be included in the final questionnaire. Substantial revision or removal is required.
Slightly relevant – The item is somewhat related to the research topic, but its wording is unclear, incomplete, or potentially misleading. Requires considerable revision.
Moderately relevant – The item is generally aligned with the topic but requires improvement (e.g., rewording, clarification of response options). It may be included in the questionnaire after revision.
Quite relevant – The item is well aligned with the research objective and is clearly formulated. It can be included in the final questionnaire with only minor revisions (if needed).
Very relevant – The item is fully relevant, clearly and precisely formulated, and fully consistent with the research objectives. It is ready to be included in the final questionnaire without modifications.
In the ***Comments column***, you may provide specific remarks regarding the wording of the item or its response options, suggestions for improving structure, language, or content; other considerations related to the given item.
At the end of the form, you may record general feedback on the questionnaire as a whole, including structure and logical organization of the questionnaire, clarity and readability of the items, length of the questionnaire, missing important topics or redundant questions. If you have additional suggestions for improvement, please feel free to provide them.

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
0	Specify your age: • up to 25 years old, • 25-34, • 35-44, • 45-54, • 55-64, • 65+	☐	☐	☐	☐	☐	

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
1	What were your primary objectives when enrolling in online courses? (Select all that apply) • Development of specific practical skills • Professional qualification enhancement • Obtaining a certificate, license, or diploma • Acquisition of specific theoretical knowledge • Career advancement • Research opportunities • Gaining information on pedagogical innovations • Personal interest or passion for the subject • Saving time • Saving money (choosing online learning because it is less expensive than in-person education) • Acquiring new technical skills • Acquiring new practical pedagogical skills • Flexible learning schedule • Access to quality education remotely • Networking and exchange of experience with other professionals • Other	☐	☐	☐	☐	☐	
2	What topics for online courses have you chosen recently? (Select all that apply) • Teaching methodology • Engineering disciplines • Information technology • Educational management • Psychology and pedagogy • Soft skills development • Innovative technologies in education • Other	☐	☐	☐	☐	☐	
3	What problems or difficulties did you encounter when taking online courses? (Select all that apply) • Limited interaction with instructors • Lack of interaction with peers • Difficulties accessing course materials • Insufficient technical support	☐	☐	☐	☐	☐	

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
	• Difficulties with practical or laboratory components • Problems with assessment methods (e.g., biased grading, inappropriate methods, etc.) • Lack of real-time feedback • Difficulty balancing study workload with other responsibilities • Disciplinary issues (e.g., forgetting lectures, lateness, disrupted schedule, etc.) • Other						
4	How comfortable do you feel using various digital tools and technologies? (Please rate on a scale where 1 = Not comfortable at all, 5 = Very comfortable) • Interactive learning platforms • Learning Management Systems (LMS) • Webinars and videoconferencing • Content creation software • Virtual laboratories and simulators	☐	☐	☐	☐	☐	
5	What resources do you consider most important for effective teaching in online education? (Please rate their importance on a scale where 1 = Not important, 5 = Very important) • Interactive modules • Practical assignments • Instructional materials • Video lectures • Discussion forums • Live sessions • Multimedia materials • E-books and journals • Scientific articles • Guest lectures	☐	☐	☐	☐	☐	
6	What additional resources would improve your online learning experience? (Please rate their importance on a scale where 1 = Not important, 5 = Very important) • Technical support • Instructional materials • Peer assessment • Access to experts	☐	☐	☐	☐	☐	

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
	• Real-time troubleshooting • Detailed guides • Interactive textbooks • Collaborative tools • Virtual laboratories • Mentorship programs • Prompt support from the instructor • Access to a library and other useful resources • Chats with fellow learners and instructors • Access to an expert community						
7	What other technologies have improved or could improve your online learning experience? (Please rate their importance on a scale where 1 = Not important, 5 = Very important) • Virtual and augmented reality technologies • Mobile platforms • Interactive simulations • Cloud-based tools • Augmented reality • Artificial intelligence–based tools • Learning Management Systems (LMS, Moodle, etc.) • Web conferencing tools (e.g., MTS Link, Yandex Telemost, SberJazz, etc.) • Online collaboration tools (e.g., Yandex Documents) • Digital whiteboards (e.g., Miro)	☐	☐	☐	☐	☐	
8	Which of the following tools allowed you to engage more deeply in the online course? (Select all that apply) • Interactive discussions • Group projects • Gamification • Peer review and assessment of interim/final assignments • Live Q&A sessions • Flipped classroom approach (study materials at home, practice together online) • Collaborative tools • Case studies and practical application • Role-playing (e.g., teachers act as students for their colleagues)	☐	☐	☐	☐	☐	

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
	• Surveys and quizzes • Visual content (e.g., videos, infographics) • Discussion forums • Simulations and virtual laboratories • Individual feedback						
9	How would you like online programs to be adapted to meet your individual needs as a TVET teacher? (Select all that apply) • More personalized learning pathways • Flexible course scheduling • More practical training sessions • Closer interaction with instructors and colleagues • Prompt technical support • Adaptation of course content to the teacher's abilities and needs • Effective feedback • Integration of advanced technologies (e.g., VR, AR, AI) • Inclusion • Additional resources and programs • Periodic assessments	☐	☐	☐	☐	☐	
10	What ethical considerations impact your online learning experience? Select all that apply) • Confidentiality concerns • Research ethics • Intellectual property • Data security • Cultural sensitivity (differences in cultural traditions) • Inclusiveness (opportunity for everyone to participate in all activities) • Information distortion • Plagiarism • Consent for data processing, consent for video recording, etc.	☐	☐	☐	☐	☐	
11	What teaching methods do you prefer in online courses? (Select all that apply) • Synchronous sessions (in real time) • Asynchronous sessions (at a convenient time for you) • Combined methods (blended learning)	☐	☐	☐	☐	☐	

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
	• Blended learning (theoretical part online, practical part in the classroom) • Independent study of materials • Group projects and discussions						
12	What tools were used for conducting practical sessions and laboratory work in the online courses you attended? (Please rate the effectiveness of each tool on a scale where 1 = Not used, 2 = Not effective, 3 = Moderately effective, 4 = Effective, 5 = Very effective) • Virtual laboratories • Software applications • Remote experiments • Recorded demonstrations • Real-time supervision • Interactive manuals • Step-by-step guides • Collaboration with colleagues • Project-based learning • Individual feedback • Application of acquired knowledge in practice • Mentor support	☐	☐	☐	☐	☐	
13	How would you rate the effectiveness of interactive modules (e.g., tests, quizzes, simulations, interactive exercises) in the online courses? 1 – Ineffective 2 – Slightly effective 3 – Moderately effective 4 – Effective 5 – Extremely effective	☐	☐	☐	☐	☐	
14	What additional features or improvements would you like to see in online courses to better meet your needs as an educator? (Select all that apply) • Improved technical support • More interactive and multimedia materials • Additional tools for assessment and feedback • Ability to adapt content to the specific needs of learners • Improved interaction and communication among course participants	☐	☐	☐	☐	☐	

Question number	Question Description	Not relevant	Slightly relevant	Moderately relevant	Quite relevant	Very relevant	Comments
15	What do you think was missing in the online course for you to be fully satisfied with the learning outcomes? Please describe. (Open-ended response)	☐	☐	☐	☐	☐	
16	What additional knowledge or skills do you need to effectively teach using virtual learning methods? Please describe. (Open-ended response)	☐	☐	☐	☐	☐	
17	What improvements, innovations, or additional features would you like to see in the online courses you have taken? Please describe any specific elements or changes that you believe would enhance the effectiveness and improve the experience of online courses. (Open-ended response)	☐	☐	☐	☐	☐	

Comments: _____

Appendix I *Final Questionnaire Used in the Quantitative Study*

Dear Colleagues,

I am conducting a study to identify key factors that influence the effectiveness of online courses for the training of TVET engineering teachers within the vocational education system.
This survey is addressed to TVET engineering teachers who have completed online training courses within the past three years.
The questionnaire takes approximately 5–10 minutes to complete. Your responses will provide important insights into improving the design and delivery of online learning in this context.
A small token of appreciation is offered at the end of the survey.
Participants are also encouraged to share the questionnaire with eligible colleagues.
Thank you for your valuable contribution.

The Questionnaire

Q0. Specify your age:
- up to 25 years old,
- 25-34,
- 35-44,
- 45-54,
- 55-64,
- 65+

Q1. What were your primary objectives when enrolling in online courses? (Select all that apply)
- Development of specific practical skills
- Professional qualification enhancement
- Obtaining a certificate, license, or diploma
- Acquisition of specific theoretical knowledge
- Career advancement
- Research opportunities
- Gaining information on pedagogical innovations
- Personal interest or passion for the subject
- Saving time
- Saving money (choosing online learning because it is less expensive than in-person education)
- Acquiring new technical skills
- Acquiring new practical pedagogical skills
- Flexible learning schedule
- Access to quality education remotely
- Networking and exchange of experience with other professionals
- Other

Q2. What topics for online courses have you chosen recently? (Select all that apply)
- Teaching methodology
- Engineering disciplines
- Information technology
- Educational management
- Psychology and pedagogy
- Soft skills development
- Innovative technologies in education
- Other

Q3. What problems or difficulties did you encounter when taking online courses? (Select all that apply)

- Limited interaction with instructors
- Lack of interaction with peers
- Difficulties accessing course materials
- Insufficient technical support
- Difficulties with practical or laboratory components
- Problems with assessment methods (e.g., biased grading, inappropriate methods, etc.)
- Lack of real-time feedback
- Difficulty balancing study workload with other responsibilities
- Disciplinary issues (e.g., forgetting lectures, lateness, disrupted schedule, etc.)
- Other

Q4. How comfortable do you feel using various digital tools and technologies? (Please rate on a scale where 1 = Not comfortable at all, 5 = Very comfortable)

	1 = Not comfortable at all	2 = Slightly comfortable	3 = Moderately comfortable	4 = Comfortable	5 = Very comfortable
Interactive learning platforms	▫	▫	▫	▫	▫
Learning Management Systems (LMS)	▫	▫	▫	▫	▫
Webinars and videoconferencing	▫	▫	▫	▫	▫
Content creation software	▫	▫	▫	▫	▫
Virtual laboratories and simulators	▫	▫	▫	▫	▫

Q5. What resources do you consider most important for effective teaching in online education? (Please rate their importance on a scale where 1 = Not important, 5 = Very important)

	1 = Not important	2 = Slightly important	3 = Moderately important	4 = Important	5 = Very important
Interactive modules	▫	▫	▫	▫	▫
Practical assignments	▫	▫	▫	▫	▫
Instructional materials	▫	▫	▫	▫	▫
Video lectures	▫	▫	▫	▫	▫
Discussion forums	▫	▫	▫	▫	▫
Live sessions	▫	▫	▫	▫	▫
Multimedia materials	▫	▫	▫	▫	▫
E-books and journals	▫	▫	▫	▫	▫
Scientific articles	▫	▫	▫	▫	▫
Guest lectures	▫	▫	▫	▫	▫

Q6. What additional resources would improve your online learning experience? (Please rate their importance on a scale where 1 = Not important, 5 = Very important)

	1 = Not important	2 = Slightly important	3 = Moderately important	4 = Important	5 = Very important
Technical support	▫	▫	▫	▫	▫
Instructional materials	▫	▫	▫	▫	▫
Peer assessment	▫	▫	▫	▫	▫
Access to experts	▫	▫	▫	▫	▫

	1 = Not important	2 = Slightly important	3 = Moderately important	4 = Important	5 = Very important
Real-time troubleshooting	▫	▫	▫	▫	▫
Detailed guides	▫	▫	▫	▫	▫
Interactive textbooks	▫	▫	▫	▫	▫
Collaborative tools	▫	▫	▫	▫	▫
Virtual laboratories	▫	▫	▫	▫	▫
Mentorship programs	▫	▫	▫	▫	▫
Prompt support from the instructor	▫	▫	▫	▫	▫
Access to a library and other useful resources	▫	▫	▫	▫	▫
Chats with fellow learners and instructors	▫	▫	▫	▫	▫
Access to an expert community	▫	▫	▫	▫	▫

Q7. What other technologies have improved or could improve your online learning experience? (Please rate their importance on a scale where 1 = Not important, 5 = Very important)

	1 = Not important	2 = Slightly important	3 = Moderately important	4 = Important	5 = Very important
Virtual and augmented reality technologies	▫	▫	▫	▫	▫
Mobile platforms	▫	▫	▫	▫	▫
Interactive simulations	▫	▫	▫	▫	▫
Cloud-based tools	▫	▫	▫	▫	▫
Augmented reality	▫	▫	▫	▫	▫
Artificial intelligence–based tools	▫	▫	▫	▫	▫
Learning Management Systems (LMS, Moodle, etc.)	▫	▫	▫	▫	▫
Web conferencing tools (e.g., MTS Link, Yandex Telemost, SberJazz, etc.)	▫	▫	▫	▫	▫
Online collaboration tools (e.g., Yandex Documents)	▫	▫	▫	▫	▫
Digital whiteboards (e.g., Miro)	▫	▫	▫	▫	▫

Q8. Which of the following tools allowed you to engage more deeply in the online course? (Select all that apply)

- Interactive discussions
- Group projects
- Gamification
- Peer review and assessment of interim/final assignments
- Live Q&A sessions
- Flipped classroom approach (study materials at home, practice together online)
- Collaborative tools
- Case studies and practical application
- Role-playing (e.g., teachers act as students for their colleagues)
- Surveys and quizzes
- Visual content (e.g., videos, infographics)
- Discussion forums
- Simulations and virtual laboratories
- Individual feedback

Q9. How would you like online programs to be adapted to meet your individual needs as a TVET teacher? (Select all that apply)

- More personalized learning pathways
- Flexible course scheduling
- More practical training sessions
- Closer interaction with instructors and colleagues
- Prompt technical support
- Adaptation of course content to the teacher's abilities and needs
- Effective feedback
- Integration of advanced technologies (e.g., VR, AR, AI)
- Inclusion
- Additional resources and programs
- Periodic assessments

Q10. What ethical considerations impact your online learning experience? Select all that apply)

- Confidentiality concerns
- Research ethics
- Intellectual property
- Data security
- Cultural sensitivity (differences in cultural traditions)
- Inclusiveness (opportunity for everyone to participate in all activities)
- Information distortion
- Plagiarism
- Consent for data processing, consent for video recording, etc.

Q11. What teaching methods do you prefer in online courses? (Select all that apply)

- Synchronous sessions (in real time)
- Asynchronous sessions (at a convenient time for you)
- Combined methods (blended learning)
- Blended learning (theoretical part online, practical part in the classroom)
- Independent study of materials
- Group projects and discussions

Q12. What tools were used for conducting practical sessions and laboratory work in the online courses you attended? (Please rate the effectiveness of each tool on a scale where 1 = Not used, 2 = Not effective, 3 = Moderately effective, 4 = Effective, 5 = Very effective)

	1 = Not used	2 = Not effective	3 = Moderately effective	4 = Effective	5 = Very effective
Virtual laboratories	▫	▫	▫	▫	▫
Software applications	▫	▫	▫	▫	▫
Remote experiments	▫	▫	▫	▫	▫
Recorded demonstrations					
Real-time supervision	▫	▫	▫	▫	▫
Interactive manuals	▫	▫	▫	▫	▫
Step-by-step guides	▫	▫	▫	▫	▫
Collaboration with colleagues	▫	▫	▫	▫	▫
Project-based learning	▫	▫	▫	▫	▫
Individual feedback	▫	▫	▫	▫	▫
Application of acquired knowledge in practice	▫	▫	▫	▫	▫
Mentor support					

Q13. How would you rate the effectiveness of interactive modules (e.g., tests, quizzes, simulations, interactive exercises) in the online courses?
1 – Ineffective
2 – Slightly effective
3 – Moderately effective
4 – Effective
5 – Extremely effective

Q14. What additional features or improvements would you like to see in online courses to better meet your needs as an educator? (Select all that apply)

- Improved technical support
- More interactive and multimedia materials
- Additional tools for assessment and feedback
- Ability to adapt content to the specific needs of learners
- Improved interaction and communication among course participants

Q15. What do you think was missing in the online course for you to be fully satisfied with the learning outcomes? Please describe. (Open-ended response)

Q16. What additional knowledge or skills do you need to effectively teach using virtual learning methods? Please describe. (Open-ended response)

Q17. What improvements, innovations, or additional features would you like to see in the online courses you have taken? Please describe any specific elements or changes that you believe would enhance the effectiveness and improve the experience of online courses. (Open-ended response)

Note: The questionnaire was originally distributed in Russian and has been translated for the purposes of this dissertation.

Appendix J *Summary of hypothesis questions*

Hypothesis	Question number	Variant number
Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses	1	1,4,7,11,12,13
	2	-
	3	8
	9	1,6
	14	4
	15	6
The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers	3	1,2,5,7,8
	5	2,3,7
	6	2,7,8,9,11,12
	9	2
	11	3
	16	1
	17	2,3,5,6
The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers	5	1,2,5,6,10
	8	1,3,5,6,8,9,10,12,13
	12	1,3,6,7,9,10,11
	13	
	14	2
	15	2,3,5
	16	
The integration of modern technologies (virtual laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness	4	
	6	7,9
	7	1,3,5,6
	8	13
	9	8
	10	1,4
	17	2,4
Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes	3	1,7
	6	10,11,13
	8	5,6,14
	9	4,7
	12	10,12
	15	
	17	

Appendix K *Comparison Matrix*

Hypothesis	Qualitative data supported by quantitative analysis (factors of online course effectiveness)	Unaddressed aspects (identified but not quantitatively tested)	Unaddressed aspects (identified during the qualitative research stage but not directly related to the hypothesis)
Adapting course content to the professional experience, educational needs, and objectives of TVET engineering teachers increases the perceived usefulness and effectiveness of the courses	- Emphasis on the development of practical skills (56,1%) - Availability of a flexible schedule (57,8%) because difficult to balance study and work (66,7%) - Training in Teaching Methodology (58,6%) and Innovative Technologies in Education (51,9%) - Adaptation of the course to the learner's capabilities (42,6%) - Personalized learning pathways (77,2%)	- Narrow course topics - Preparedness of teachers for the level of course materials - Presence of discipline - Availability of organizational and technical support - Emphasis on addressing gaps in foundational education - Availability of entry-level testing necessary to assess learners' knowledge (assessment tools for evaluating teacher knowledge were not studied) - Consideration of cultural and national characteristics	- Cultural sensitivity affects the learning experience (15,5%) - Importance of having a module on teaching materials (4,10)
The blended learning format, which combines traditional methods with online tools, is a key factor in the convenience and effectiveness of courses for TVET engineering teachers	- ability to balance study and work (66,7%) - Presence of practical sessions (45,1%) and multimedia materials (mean rating: 4,08) - Availability of interactive textbooks (mean rating: 4,05) and teaching materials (mean rating: 4,04) - Inclusion of traditional formats in the online learning process	- Assessment of retention rate - Well-designed assignments - Learners' prior experience in practical activities - Group size - Transfer of theoretical subjects and those suitable for process demonstration via digital tools into the online format	- Asynchronous learning was selected by 75,9%

Hypothesis	Qualitative data supported by quantitative analysis (factors of online course effectiveness)	Unaddressed aspects (identified but not quantitatively tested)	Unaddressed aspects (identified during the qualitative research stage but not directly related to the hypothesis)
	- Flexibility in course scheduling (57,8%) - 58,6% chose blended learning - Possession of digital literacy and platform use skills (51,41%) - Interactivity and live communication (16,0%)		
The use of active learning methods (gamification, collaboration, interactive platforms and activities) enhances engagement and improves the educational outcomes of TVET engineering teachers	- Live interaction and discussions, including live Q&A sessions (44,73%), interactive discussions (40,51%), personalized feedback (mean rating: 3,47) and discussion forums (23,63%) - Practice-oriented methods, including simulations and virtual labs (35,44%), case studies and practical application (29,11%), practical guides (mean rating: 3,73), step-by-step instructions (mean rating: 3,365) and flipped classroom (32,91%) - Game-based and interactive technologies, including gamification (27,00%), quizzes and polls (33,33%) role-playing games (27,85%), and presence of interactive and multimedia materials (62%) - Practical Application (20,68%)	- Addressing different types of information perception - Creating an environment where learners complete assignments under the instructor's supervision - Assessment of retention rate	- 28,2% want additional tools for assessment and feedback
The integration of modern technologies (virtual	- Use of virtual laboratories (mean rating: 3,85)	- Training for adaptation to changing technological conditions	- Integration of mobile platforms, cloud tools, online

Hypothesis	Qualitative data supported by quantitative analysis (factors of online course effectiveness)	Unaddressed aspects (identified but not quantitatively tested)	Unaddressed aspects (identified during the qualitative research stage but not directly related to the hypothesis)
laboratories, simulators, and VR/AR) contributes to the development of professional skills in TVET engineering teachers and enhances learning effectiveness	- Interactive simulators, AI-based tools, VR & AR - Simulators and virtual laboratories increase engagement (35,4%) - Integration of advanced technologies (29%) - Data Security (60,8%) - Private Concerns (39,2%).		collaboration tools, and digital whiteboards
Prompt and constructive feedback from the teacher trainers increases learner engagement and improves educational outcomes	- Real-time feedback (26,2%) - Interaction with instructor (27,0%) - Prompt instructor support, mentorship programs, chats with peers and teachers - Individual feedback (45,1%) - Live Q&A sessions (44,7%) - Flipped classroom (32,9%) - Effective feedback (34,6%) - Closer interaction with teacher trainers and peers (34,6%) - Mentor support (3,52) - Individual feedback (3,77) - Support&Feedback (12,7%)	- Assessment of knowledge during training - Assessment of learners' emotional and psychological state - Interaction with the audience and active participation in practicing specific skills during training	- Issues with assessment methods (8%) - Presence of control checkpoints (9,2%) - 19,8% of respondents did not experience real-time control; 21,5% consider it an effective method for practical and laboratory sessions - 28,2% want additional tools for assessment and feedback

Appendix L *Mapping Research Sub-Questions to Identified Key Factors and Their Attributes*

Research Sub-Questions	Data Sources	Theme findings	Results for the next step
Qualitative question: What key factors influence the perceived effectiveness of online courses for training TVET engineering teachers in the professional education system, according to the teacher trainers who deliver these courses?	Standardized in-person open-ended in-depth interview (N=11)	- Course design and evaluation - Teaching methods and engagement - Technology integration	• Active learning methods • Adaptation of course content • Blended learning format • Advanced technologies • Feedback
Mixed methods question: How can the results of in-depth interviews with teachers be used to develop a questionnaire to investigate the views of TVET educational engineers and validate factors of effectiveness of online courses?	Interview → Coding → Identification of factors → Questionnaire	- Active learning methods - Adaptation of course content - Blended learning format - Advanced technologies - Feedback	• Online courses experience • Selecting and evaluating participation in online courses • Resources and technologies • Engagement and interaction • Practical exercises and evaluation • Experience in delivering online courses (independently, as an educator) • Overall satisfaction and recommendations
Quantitative question: How do TVET engineering teachers taking online courses assess the impact of various factors on the perceived effectiveness of these courses?	Mass survey of TVET engineering teachers (N=237)	- Adapting course content to the professional experience, educational needs and objectives of engineering teachers increases the perceived usefulness and effectiveness of courses - Blended learning format, combining traditional methods	• Course content and learning resources • Learning formats and flexibility • Practical application and professional development • Interactivity and engagement

Research Sub-Questions	Data Sources	Theme findings	Results for the next step
		and online tools, is a key factor in the convenience and effectiveness of courses for engineering teachers - The use of active learning methods (gamification, collaboration, interactive platforms and work) promotes engagement of engineering teachers and enhances their educational outcomes - Integration of modern technologies (virtual labs, simulations and VR/AR) promotes the development of professional skills of engineering teachers and enhances learning outcomes - Prompt and constructive feedback from the instructor increases student engagement and educational outcomes	• Personalization and learner support • Digital competence and security
Exploratory sequential design question: How do the results of the large-scale survey of TVET engineering teachers align with the opinions of online course teacher trainers regarding the factors that determine the perceived effectiveness of online learning in the context of TVET teacher preparation?	Between-method triangulation Data Transformation Model	- Adaptation of educational content - Flexible and blended learning formats - Practice-oriented learning - Active learning methods - Advanced technologies - Interaction, support and feedback	• Course structure and content • Trainee preparedness and discipline • Organizational and technical support • Individual and cultural sensitivity • Technological adaptation

Research Sub-Questions	Data Sources	Theme findings	Results for the next step
			• Psychological aspects of training
Unexpected finding	Interviews (I) Questionnaire (Q)	- Lack of time for online learning (work-study disbalance) (Q) - Disciplinary issues (I) - Gaps in basic education (I) - Insufficient emphasis on methodological preparation (Q) - Importance of assessing learners' emotional and psychological state (I) - Interest in using mobile platforms and collaborative tools (Q) - Consideration of cultural and national aspects in education (I)	(Q) – engineering teachers often undergo training "under pressure," which shapes the key goal as obtaining a certificate and acquiring knowledge applicable to work. Moreover, they repeatedly emphasized the importance of monitored completion of practical tasks with feedback and the inclusion of more visual content in online courses. (I) – approach the educational process more fundamentally and emphasize that effective learning is impossible without comprehensive development and proper mindset Additionally, teacher trainers highlighted the importance of a narrow course focus and addressing disciplinary issues.
Primary research question: What are the key factors that determine the *perceived* effectiveness of online courses for preparing engineering teachers in the professional education system?		- Adaptation of course content to the experience, needs, and goals of engineering teachers - Blended learning format (traditional methods + online tools) - Use of active learning methods (gamification, collaboration, interactive platforms)	

Research Sub-Questions	Data Sources	Theme findings	Results for the next step
		- Integration of modern technologies (virtual labs, simulations, VR/AR) - Timely and constructive instructor feedback	

Appendix M *Scientific Concepts*

Factor	Confirmation in the literature
Adaptation of course content to the professional experience, educational needs, and goals of TVET engineering teachers	• Andragogy (Knowles, 1973) • Digital Didactics (Bilenko et al., 2020) • Constructivist Theory (Vygotsky, 1978) • Humanistic Pedagogical Theory (Maslow, 1968) • Cognitive Theory (Ausubel, 1978) • "Der Berufsdidaktische Dreidecker" (Martin, 2016)
Blended learning format (combining not only online and offline modes but also traditional and modern pedagogical approaches)	• Behavioral Theory (Thorndike, 1898; Akpan, 2020) • "Der Berufsdidaktische Dreidecker" (Martin, 2016) HyFlex (Atkinson, 2022)
Use of active learning methods (gamification, collaborative work, interactive platforms and activities)	• Humanistic Theory (Knowles, 1984) • Cognitive Learning Theory (Dityatkina, 2018) • Cognitivist Theory (Vygotsky, 1978; Wenger, 1998; An & Reigeluth, 2008) • Social Learning Theory by Albert Bandura (Salmon, 2003; Ebner & Gegenfurtner, 2019)
Integration of modern technologies (virtual laboratories, simulators, and VR/AR)	• Digital Didactics (Bilenko, 2020) (Byzaubakova, 2023) • "Der Berufsdidaktische Dreidecker" (Martin, 2016; Martin, 2018) • Andragogy (Knowles, 1980; Loeng, 2023)
Timely and constructive feedback from the instructor	• Humanistic Theory (Knowles, 1984) • Behaviorist Theory (Fields, 1996) • Social Learning Theory by Albert Bandura (Burns, 2024) • "Der Berufsdidaktische Dreidecker" (Neuweg, 2018) • Heutagogy (Paprock, 1992; Mezirow, 1991; Hase & Kenyon, 2013) • Constructivist theory (Windschitl, 2002)
Unexpected findings	• Behaviorist theory (Bandura & Walters, 1964) • Cognitive theory (Vygotsky, 1997; Flavell, 1979)

EIGENSTÄNDIGKEITSERKLÄRUNG

DECLARATION OF AUTHORSHIP