VTE VOCATION, TECHNOLOGY & EDUCATION

ORIGINAL ARTICLE

Bridging theory and practice: Exploring digital transformation in entrepreneurship education through a conceptual curriculum development framework in TVET

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ABSTRACT

This study constructs a conceptual framework for curriculum development tailored to guide the digital transformation of entrepreneurship education in technical and vocational education and training (TVET) institutions. Building upon Vial's digital transformation conceptual diagram, this framework integrates the process-oriented concepts of "digital transformation", "entrepreneurship education", and "curriculum development". Supported by a detailed literature analysis, the framework establishes a solid conceptual foundation, emphasizing the classical curriculum elements of "objectives", "content", "organization", and "evaluation". It further enriches these components by incorporating key insights from 12 entrepreneurship courses from various regions in China, which are explored through a qualitative content analysis of the dimensions from the constructed framework. This framework serves as both a theoretical and practical guide, offering specific strategies for adapting the TVET curriculum to align with digital trends, thereby facilitating effective global implementation while providing localized insights from the Chinese context.

Key words: digital transformation, entrepreneurship education, curriculum development, technical and vocational education and training, conceptual framework, implementation strategies, literature analysis, content analysis

INTRODUCTION

In an era marked by escalating challenges, societies worldwide are grappling with the rapid pace of digital innovation, burgeoning demands for sustainability and environmental protection, the complexities brought about by accelerated migration processes, and the necessity for entrepreneurial mindsets.[1] To address these multifaceted demands, technical and vocational education and training (TVET), the education sector most closely aligned with the labor market for provisioning qualified labor and facilitating the transition of young people from education to employment, must stay abreast of these changes.[2]

The *UNESCO Medium-Term Strategy (2022-2029)* reveals a close relationship between digital transformation, TVET's digitization, and four strategic objectives, with three directly intertwined with digital transformation. Furthermore, out of nine strategic outcomes, five are closely associated with the digital transformation of TVET and the cultivation of digital skills.[3] The

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Received: 11 May 2024; Revised: 16 June 2024; Accepted: 18 June 2024
https://doi.org/10.54844/vte.2024.0589

UNESCO Strategy for TVET (2022-2029) emphasizes the necessity of skills for the digital economy transformation, highlighting the importance of meeting the needs of digital transformation across various sectors.[4] Innovation in digital technologies demands a corresponding transformation in pedagogical methods and educational technologies; the dual pillars of the digital economy, digital industrialization, and the digitization of industries necessitate the flexible alignment of talent development goals, programs, and curriculum with market demands; and changes in interpersonal interaction modalities require teachers to comprehensively enhance their digital capabilities and master the information, knowledge, training, and skills needed for best teaching practices, promoting multimodal teaching approaches.[5] Thus, a comprehensive digital transformation, from technology and economy to society, prompts corresponding changes in TVET's talent development goals, teaching methods and educational technology.

Simultaneously, the *UNESCO Strategy for TVET (2022-2029)* underscores a consistent emphasis on entrepreneurship skills. As highlighted in one of the main action areas, entrepreneurship skills are reiterated. For instance, in long-term significant projects by the United Nations Educational, Scientific, and Cultural Organization-International Centre for Technical and Vocational Education and Training (UNESCO-UNEVOC) Centre, entrepreneurship has always been emphasized as a critical module.[6] Through TVET, equipping individuals with entrepreneurial capabilities enables success in sustainable enterprises, contributing to post-pandemic recovery and a sustainable society. Furthermore, it fosters a resilient and innovative workforce, propelling sustainable economic growth, innovation, and job creation.[7]

Against the backdrop of digitalization, research in entrepreneurship education has been on the rise. A search for "entrepreneurship education" in the Web of Science database shows a sharp increase in the annual publication of related literature since 2019, with a continual growth trend. However, research on the digital transformation of entrepreneurship education, especially regarding TVET's pivotal role in a society valuing digital and entrepreneurial capabilities, remains scant.

Research from a curricular perspective directly affects educational quality and learning outcomes, ensuring the relevance and timeliness of educational content.[8] To respond to and keep pace with the rapidly changing impacts of digital transformation, this research aims to construct a curriculum development framework to guide the digital transformation of entrepreneurship education within TVET, based on a comprehensive literature review and by integrating the three elements of "digital transformation", "entrepreneurship education", and "curriculum development", each characterized by their process-oriented nature.

In China, the Ministry of Education has consistently emphasized that the digitalization of education is a crucial aspect of building a strong educational system. The Ministry has issued a series of standards to improve the digital standards and norms of education and to enhance the capacity for digital educational support. Additionally, under the guidance of the Ministry, the Smart Education of China platform has been established. This platform, being the world's largest digital learning platform, serves various levels and types of education, with TVET being a significant module. This study has selected entrepreneurship courses from the TVET module of this platform as cases for exploration.

By conducting a qualitative content analysis contextualized within the Chinese context, this framework serves as both a theoretical and practical guide. It offers specific strategies for adapting the TVET curriculum to align with digital trends, facilitating effective implementation globally while providing localized insights from the Chinese context.

CONCEPTUAL GROUNDWORK

In his seminal work, Vial synthesizes 134 published definitions to formulate a unified definition of digital transformation.[9] He characterizes it as "a fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity and redefine its value proposition for its stakeholders".

Building on this definition, Vial presents a conceptual diagram that vividly and concretely illustrates the components of digital transformation: "process", "digital technologies", "resources", "capabilities", "outcome", "value proposition", and "stakeholders".[9]

This literature review is structured around these critical components to explore the nature of digital transformation, entrepreneurship education, and curriculum development. It introduces the four elements of Tyler's curriculum theory and delves deeper into the related concepts of digital transformation and entrepreneurship education.[10] These explorations and discussions will contribute directly to forming a comprehensive and instructive framework for the digital transformation of

curricula in entrepreneurship education.

Digital transformation

Definition of digital transformation

To date, there remains no universally accepted definition of digital transformation. Although considerable efforts have been undertaken to establish a unified definition, the necessity of such clarity is widely acknowledged. A unified definition enhances conceptual rigor, facilitating a deeper understanding for both practitioners and researchers and advancing the theoretical and practical aspects of the discipline.[11] Despite the absence of a broadly accepted and unified definition, it is generally recognized that digital transformation signifies a foundational shift in how organizations deliver value. This shift is characterized by the comprehensive integration of digital technology into all operational facets.[12,13] The transformation extends beyond mere technological adoption, encompassing a cultural shift that compels organizations to continuously challenge established norms, promote experimentation, and regard failures as integral to innovation.[14,15]

In this study, the primary focus is on the digital transformation conceptual diagram by Vial,[9] which is based on the unified definition of digital transformation proposed by Vial. We acknowledge and adopt this definition not only because it is one of the few unified definitions of digital transformation but also because it encapsulates the complex and multidimensional nature of digital transformation. This definition serves as a potent guiding principle for understanding and implementing initiatives in this area, providing a comprehensive framework that addresses the multifaceted aspects of digital transformation.

Process: the ongoing and dynamic nature of digital transformation

The literature increasingly views digital transformation as a dynamic process.[1,16,17] It highlights various dimensions in which digital transformation involves continuous adaptation, strategic planning, and the integration of technological innovations across diverse domains. This perspective illustrates the comprehensive and multifaceted nature of digital transformation as an ongoing process rather than a singular event.[1,12,16–18]

Warner and Wäger propose a process model comprising nine micro foundations that elucidate the generic contingency factors that trigger, enable, and hinder the building of dynamic capabilities for digital transformation.[17] Similarly, Vial constructs a process framework articulated across eight building blocks, serving as a tool to guide the strategic planning and implementation of digital transformation in various organizational contexts.[9]

Capabilities: essentials of digital competences

In the current rapidly evolving technological landscape, the cultivation of digital competences has emerged as a pivotal factor in the digital transformation of TVET.[19] On one hand, influenced by digital technologies, educational content and methods have rapidly transitioned to digital formats to facilitate easier sharing and transmission of information. This shift necessitates the development of digital competences as essential components for enhancing educational quality and efficiency.[20] On the other hand, TVET students are preparing to enter various industries where the application of digital technologies has become a foundational requirement. By nurturing these digital skills, TVET can better prepare students to adapt to digital work environments and enhance their professional competitiveness.[21]

Furthermore, the interplay between digital and entrepreneurship competences is notably significant. Effective digital competences can assist entrepreneurs in leveraging online resources more efficiently, which is crucial for reducing startup costs and enhancing operational efficiencies.[22] Additionally, the demand for digital tools in entrepreneurial activities compels entrepreneurs to engage continuously in learning and mastering new technologies, thereby further enhancing their digital competences.[23]

Several digital competence frameworks have been developed to effectively foster these competences among students. UNESCO, for instance, has introduced a Global Framework of Digital Literacy Skills, which encompasses 26 skills across seven domains.[24] The universal digital skills framework, which merges the European Digital Competence Framework for Citizens and UNESCO's framework, includes seven skill domains, 26 skills, and eight proficiency levels.[25] Among all the available frameworks, the European Union's Digital Competence Framework for Citizens (DigComp 2.2) stands out as one of the most comprehensive and widely adopted frameworks, featuring five competence areas with 21 competences.[26]

It is evident that the cultivation of digital competences is crucial for adapting to the labor market and achieving entrepreneurial success, and it plays a central role in the adaptation of TVET to digital transformation.

Stakeholders: key players in the TVET ecosystem during digital transformation

The discourse on the TVET ecosystem naturally extends to the broader concept of the skills ecosystem.[27] Within the TVET ecosystem, core components include structured institutions, such as technical schools,

polytechnics, and dedicated training centers. These entities provide specialized courses that blend theoretical instruction with practical experience in distinct technical disciplines.[28] In contrast, the skills ecosystem adopts a wider scope that transcends traditional educational settings, embracing both conventional and unconventional educational frameworks. This includes mechanisms such as apprenticeships, direct job training, digital courses, vocational training facilities, and programs aimed at fostering entrepreneurship.[29]

As the TVET sectors undergo digital transformation, it is imperative to acknowledge and engage with a diverse array of stakeholders from both the TVET and skills ecosystems. These stakeholders range from educational and training institutions—including support staff, educators, and students—to broader societal elements, such as the labor market, family units, community groups, governmental bodies, non-governmental organizations, business entities, and the information and communication technology (ICT) sector.[30] Notably, the ICT sector plays a pivotal role as a provider of digital solutions, researchers, and content creators integral to the digital evolution of TVET.

Entrepreneurship education

Process: recognizing entrepreneurship education as a dynamic and evolving journey

The field of entrepreneurship education is marked by a plethora of definitions and interpretations, reflecting a wide range of approaches and perspectives from various educational institutions, scholars, and practitioners.[31–33] Central to the concept of entrepreneurship education are elements that foster creativity, innovation, and the ability to recognize and exploit opportunities, although the specific focus and implementation may differ substantially across contexts.[34] This diversity is attributed to the application of entrepreneurship across various sectors and disciplines as well as to its evolving nature within the global economy.[35] The definitions underscore entrepreneurship education's multidimensional nature, which seeks not only to impart knowledge about business creation but also to develop a broad set of competences increasingly deemed essential in today's dynamic economic environment.[34,36,37] It is increasingly recognized as a dynamic and evolving process integral to transformational learning experiences that equip students with essential entrepreneurship competences.[38–40]

Capabilities: frameworks and models shaping competence in entrepreneurship education

Numerous studies have proposed frameworks or models to develop entrepreneurship competences that initially target organizations. For example, Hayton and Kelley introduced a competency-based framework tailored to support corporate entrepreneurship and highlighted key competences, such as innovation, venturing, and new enterprise model development.[41] Similarly, Ploum *et al.* proposed a framework specifically for sustainable entrepreneurship, integrating environmental and social sustainability into entrepreneurial practices by suggesting competences necessary for entrepreneurs who aim to address sustainability challenges while pursuing economic objectives.[42]

The focus has gradually extended from corporate environments to educational settings, with specialized frameworks and models designed for educational institutions. Popescu proposed a model to focus on developing similar competences within the educational sector.[43] Lilleväli and Täks discussed how competence models can systematically support the development of entrepreneurship competences across different educational levels, providing a structured approach to embedding various learning outcomes and defining the roles of entrepreneurship education.[44]

However, among the most recognized in the cultivation of entrepreneurship competences is the EntreComp Framework developed by the European Union.[45–47] Compared to other models or frameworks, the EntreComp Framework offers a broad, holistic view of entrepreneurship as a life skill applicable in numerous contexts beyond mere business creation—such as social enterprises, community activities, and personal development. Its design emphasizes versatility, adaptability, and integration into various educational and professional development settings. This framework supports a wide range of educational goals, spanning from primary education to adult learning, encouraging users to incorporate their competences into existing curricula and training programs.

Value proposition: focusing on value creation as entrepreneurship education's objective

The academic discourse widely acknowledges value creation as the central objective of entrepreneurship education.[48] Bruyat and Julien critique the isolated study of entrepreneurs or teams, positing that entrepreneurship derives not only from individual actions but also from dynamic interaction with the environment.[31] This interaction leads to both personal transformation and the creation of value, making learning and value creation fundamental aspects of entrepreneurship. This perspective aligns closely with the educational objectives of learning-focused institutions and suits their needs more appropriately than other entrepreneurial definitions.

Lackéus and colleagues advocate for a pedagogical approach that prioritizes value creation through practical activities where students generate benefits for external stakeholders.[48] This method enriches educational

experiences by developing entrepreneurship capabilities, regardless of the immediate success of value-creation efforts.

Moreover, the Danish Foundation for Entrepreneurship defines entrepreneurship education as the process of transforming opportunities and ideas into value for others, which can be financial, cultural, or social.[49] This definition inherently includes the notion that value creation should be innovative, requiring initiative from the creator, involving the acquisition of necessary resources, and managed by the initiator, who also bears the risk of failure.[50,51]

Value creation is extensively recognized as contributing to societal well-being and enhancing feelings of meaningfulness, engagement, and life satisfaction, as it involves helping others not just to make a living but to enrich lives.[52]

In conclusion, the goal of entrepreneurship education is to cultivate the capability to create value in students, which is essential not only for their personal economic success but also for the long-term development and innovation of society.

Impact of digital technologies on digital entrepreneurship, and entrepreneurship education

Digital entrepreneurship

The impact of digital technologies on entrepreneurship has led to the emergence of a new concept known as "digital entrepreneurship". Digital entrepreneurship is distinguished by the integration of advanced technologies into business practices, the innovative use of digital platforms to enhance operations and market presence, and the continual transformation of traditional enterprise models to thrive in the digital economy.[53]

Outcome: digital enterprise model

Academic research on digital entrepreneurship primarily focuses on four key aspects: digitalized entrepreneurship procedures, analysis levels, digitalized ecosystems, and digitalized enterprise models.[54] The digital enterprise model leverages digital technologies in areas such as product development, distribution, stakeholder interaction, and internal operations. It fundamentally differs from traditional models by emphasizing network orchestration, digital platforms, and innovative service-based models across various industries. This model incorporates modernized processes that enhance agility and offer new opportunities for competition and growth in the digital economy. In the realm of entrepreneurship education, the enterprise model has been a significant component of the curriculum and its outcomes. With the influence of digital transformation, entrepreneurship education in TVET increasingly focuses on the digitalized enterprise model.

Stakeholders: key players in the digital entrepreneurship ecosystem

Furthermore, Sussan and Acs provide a framework that bridges the gap in our understanding of entrepreneurship in the digital age.[55] This framework is based on the integration of the entrepreneurial ecosystem (institutions and agents) and the digital ecosystem (users and digital infrastructure). The interactions between agents and users, which incorporate insights into consumers' individual and social behavior, become the central point of analysis. This indicates the existence of a digital entrepreneurship ecosystem, where the stakeholders—comprising institutions, agents, and users—are crucial, especially in how agents and users interact within the ecosystem.

Digital technologies: tools and methods transforming entrepreneurship education

The concept of "Digital Entrepreneurship" primarily emerges from the transformative roles played by digital technologies. Digital technologies act not only as facilitators and mediators but also often represent the core product in entrepreneurial ventures, thereby becoming an integral and omnipresent component in the landscape of modern entrepreneurship.[53]

Digital technologies have profoundly transformed the educational landscape with the introduction of various digital tools and applications that enhance learning experiences and operational efficiency. Learning management systems (LMSs), such as e-learning platforms, provide a comprehensive framework for the delivery and management of educational content, allowing for the systematic tracking of progress and interaction.[56] Edutainment and game-based learning tools, such as digital games, merge entertaining content with educational material, creating engaging and motivational learning environments.[57] Immersive learning technologies, including virtual reality (VR) and augmented reality (AR), provide authentic simulations and interactive experiences that deepen understanding and memory.[58] Adaptive learning technologies driven by artificial intelligence (AI) and machine learning optimize the learning process based on real-time data, tailoring educational experiences to individual learners.[59] Mobile educational technologies support learning anytime and anywhere through mobile devices, making access to educational resources more convenient.[60] Lastly, collaborative learning tools enhance communication and teamwork between students and educators *via* digital platforms that support real-time interaction and collaboration.[61] Together, these digital technologies foster a dynamic, interactive, and personalized

educational environment that meets the diverse needs of today's learners.

In the realm of entrepreneurship education, digital technologies, such as e-learning platforms, online courses, VR/AR, digital collaboration tools, and social media and digital marketing tools, are critically important for their role in fostering entrepreneurship competences and mindsets. These tools have received considerable attention because of their capacity to support training and development in entrepreneurship competences.[62] Additionally, digital tools designed for research and data analysis are equally vital; they provide essential information and insights that aid users in making data-driven decisions, thereby enhancing the likelihood of entrepreneurial success.[63] Tools based on digital technology have become key resources for educating students on how to navigate and succeed in complex business environments. Such integration of digital tools into educational frameworks not only prepares TVET students for the practical challenges of entrepreneurship but also ingrains a robust digital competence necessary for the modern business world.

Resources: foundations for success in digital entrepreneurship and education

In entrepreneurship education, particularly in the realm of digital entrepreneurship, the significance of human capital resources, such as student capabilities and teacher skills, is fundamental to the successful digital transformation of entrepreneurship education.[64] Furthermore, entrepreneurship education provides crucial experiential knowledge and social capital, which are especially vital during the early stages of digital ventures.[53] Social capital plays a pivotal role by facilitating access to key resources, knowledge sharing, partnership sourcing, and risk management, all of which are critical for the success of entrepreneurship education and digital transformation.[65] Additionally, organizational culture is highlighted as influential, as it affects the integration of digital technologies within organizations.[64] Thus, human capital, experience, knowledge, social capital, and culture are integral to supporting successful digital entrepreneurship within entrepreneurship education.

Curriculum development

Process: evolving nature of curriculum development

In traditional education, the curriculum is often defined as "content" or a "product", based on an absolutist epistemology.[66] This perspective holds that knowledge is independent of individual, temporal, societal, cultural, or specific human conditions, positing that the classroom should deliver repeatable knowledge and content. Students are expected merely to passively receive and reproduce the anticipated answers, thus reducing the need for inquiry in the educational process. Under this definition, the curriculum fosters students who are not encouraged to be proactive.[67] Contrasting this, Dewey underscores the importance of incorporating a robust philosophy of experience in education and curriculum design to counteract the limitations of a static knowledge framework.[68] He argues that education under an experience-based curriculum definition sees development as the essence of education, and only the concept of curriculum as a process can accommodate the evolution of knowledge within society. Knight further supports this dynamic approach by suggesting that the complexities of learning in higher education are best managed through a process-oriented approach.[69] In this view, curriculum development is a continuous and responsive activity rather than merely adhering to a set of static guidelines.

The elements of curriculum

Tyler presents a fundamental understanding of curriculum through four key processes: identifying the school's purposes, selecting educational experiences that fulfill these purposes, organizing these experiences effectively, and developing evaluative tools to assess whether the school's purposes are being met.[10] Tyler views the curriculum not merely as content to be delivered in a traditional classroom setting but as a dynamic process encompassing four basic elements: objectives, content, organization, and evaluation.

While Tyler's curriculum design theory has stood as a cornerstone of modern educational theory, it has not been without its critics over time. For instance, Taba criticized Tyler's model for its top-down approach, proposing a more flexible, bottom-up model of curriculum development.[70] Apple, from his critical pedagogy perspective, challenged Tyler's curriculum model for overlooking the power and ideological biases behind the selection of curriculum content and knowledge, advocating for a curriculum that pays greater attention to social justice and power structures.[71] Pinar, a significant scholar in curriculum theory, critiqued Tyler's model for its technical and process-oriented nature and called for the integration of more philosophical and reflective thought into curriculum theory with his concept of "Curriculum Reconceptualization".[72] Despite these critiques, the four elements Tyler identified are still widely regarded as fundamental components of curriculum design.

Constructing a conceptual framework

This section presents the conceptual framework constructed in this research based on the aforementioned literature review (see Figure 1). Within this conceptual framework, the foundational concepts of

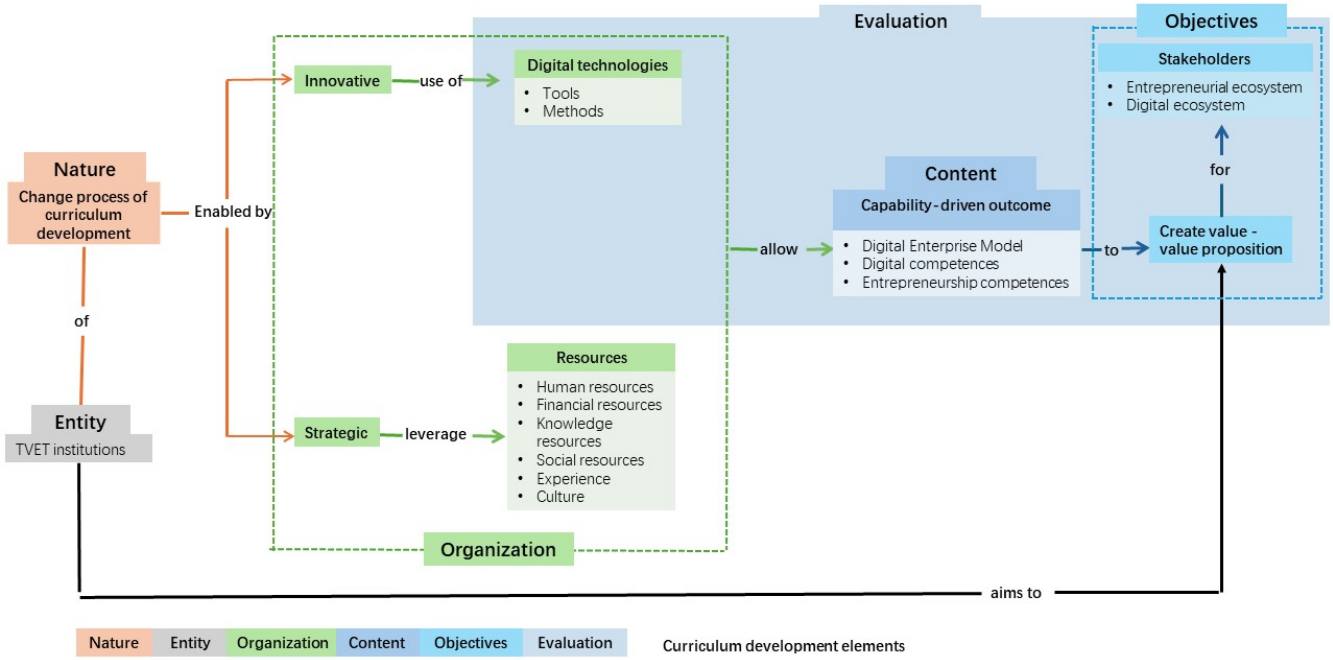

Figure 1. The conceptual framework for exploring the curriculum development of digital transformation in entrepreneurship education. TVET, technical and vocational education and training.

"digital transformation", "entrepreneurship education", and "curriculum development" are integrated. These concepts are inherently process oriented in their underlying philosophy and nature, which are explored extensively in the previous sections of the literature review.

The construction of this conceptual curriculum development framework is based on Vial's conceptual diagram of digital transformation, integrating key elements such as "process", "digital technologies", "resources", "capabilities", "outcome", "value proposition", and "stakeholders", all pertinent to "entrepreneurship education" and "digital transformation". The relevance and practicality of these elements have been substantiated in the literature review. Additionally, the four primary elements of curriculum development—"objectives", "content", "organization", and "evaluation"—further delineate this conceptual diagram, enhancing the operability, guidance, and exploration of the digital transformation process of curriculum development in entrepreneurship education.

METHODOLOGY

By adopting a qualitative research design, this research focuses on the content analysis of 12 entrepreneurship courses from the TVET module of the Smart Education of China platform. The conceptual framework constructed from the literature review serves as the basis for exploring the digital transformation of curriculum development.

Sample and resources

The Smart Education of China platform encompasses four subplatforms: the National Primary and Secondary School Smart Education Platform, the National TVET Smart Education Platform, the National Higher Education Smart Education Platform, and the National 24365 University Student Employment Service Platform. The National TVET Smart Education Platform includes resources from the national-level TVET program teaching and learning databases, which are endorsed by the Ministry of Education. Each national-level TVET program teaching and learning database is unique in its respective professional field. The 12 courses selected for this study come from the only national-level TVET program teaching and learning database of entrepreneurship in China (see Table 1). These 12 courses are the complete set of entrepreneurship courses developed based on the construction philosophy of this teaching and learning database. The construction organizations of these 12 courses are institutions with exemplary entrepreneurship education experience nationwide, recognized by the Ministry of Education as demonstration universities for deepening the reform of entrepreneurship education. They come from various regions across the country and represent the highest

Table 1: The list of the 12 courses from the national-level TVET program teaching and learning database of innovation and entrepreneurship

Category	Module		Number	Course	Institution
Innovation	Thinking and awareness		1	Innovation Thinking	Shenzhen Polytechnic University
	Knowledge and skills		2	Innovation Methods and Training	Tianjin Light Industry Vocational Technical College
	Practical application		3	Maker Technology	Zhongzilian Education Technology Co. Ltd
Entrepreneurship	Thinking and awareness		4	Entrepreneurship Basics	Zhejiang Industry & Trade Vocational College
	Knowledge and skills	Opportunity	5	Opportunity Identification and Marketing	Shandong Institute of Commerce and Technology
		Team	6	Entrepreneurial Quality Assessment and Team Building	Ningbo Polytechnic
		Resource	7	Entrepreneurial Financing Practices	Zhejiang Industry & Trade Vocational College
		Entrepreneur	8	Entrepreneurial Management	Shenzhen Polytechnic University
	Practical application		9	Entrepreneurial Simulation Training	Nanjing Vocational University of Industry Technology
Entrepreneurship and speciality integration courses			10	Cross-border E-commerce Entrepreneurship	Yiwu Industrial & Commercial College
			11	Internet+ Entrepreneurship	Jiangsu Vocational Institute of Commerce
			12	Industry Entrepreneurship Practice	Hangzhou Polytechnic

TVET, technical and vocational education and training.

level of entrepreneurship education within the field of TVET in China. These 12 courses were developed by the respective institutions to reflect the actual conditions of their regions and student populations. The course resources are continuously iterated and developed to cater to both online learners outside the institution and students enrolled in courses within the institution.

The Smart Education of China platform is a public and free educational resource platform. All content resources analyzed for these 12 courses are derived from the publicly available resources on this platform. The analysis resources for each course include the course syllabus, lesson plan, learner online feedback, and other textual content.

Analytical framework

The relevant textual content obtained for these 12 courses will be comparatively analyzed based on the concepts within the constructed framework: Stakeholders, Value Creation, Digital competences, Entrepreneurial competences, Digital Business Models, Digital Technologies, and various resources (including Human Resources, Financial Resources, Knowledge Resources, Social Resources, Experience, Culture, Evaluation Tool, and Evaluation Method).

Methods and data analysis

To ensure the reliability of the coding process, we performed an intercoder reliability analysis using Cohen's Kappa values. Two independent researchers (Coder A and Coder B) coded the text extracted from the resources of the 12 courses based on a coding manual (see Table 2). The coders independently reviewed and coded the text according to the manual.

A detailed coding manual was developed, defining the coding rules for each dimension: Stakeholders, Value Creation, Digital competences, Entrepreneurial competences, Digital Business Models, Digital Technologies, Human Resources, Financial Resources, Knowledge Resources, Social Resources, Experience, Culture, Evaluation Tool, and Evaluation Method. The manual includes definitions and examples for each code to ensure consistency in the coding process. Table 3 is an example of the coding process for the "Stakeholders" dimension. Discrepancies between the coders were discussed and resolved.

Cohen's Kappa values were calculated for each dimension to assess intercoder reliability. The results are summarized in Table 4. These results indicate a high level of agreement between the coders across all dimensions, demonstrating the robustness and reliability of the coding process.

FINDINGS AND DISCUSSION

The session aims to solidify the constructed conceptual curriculum development framework by exploring the commonalities and differences in the digital transformation of the 12 courses during curriculum development. This analysis investigates the 12 courses across four dimensions: objectives, content, organization, and evaluation. Accordingly, the exploration and discussion of these dimensions will help reinforce and refine the conceptual curriculum development framework with localized insights from the Chinese context.

Objectives

Stakeholders

Upon comparison, it is evident that almost all 12 courses list students and teachers as primary stakeholders, highlighting their central role in entrepreneurship education. Teachers consistently act as primary

Table 2: The coding rule for the "Stakeholder" dimension

Coding number	Stakeholders
1	Students and teachers
2	Enterprises and industry experts
3	Social learners
4	Startup founders
5	Entrepreneurship mentors
6	Venture capital institutions
7	Industry experts

Table 3: The coding process for the "Stakeholders" dimension

Number	Course	Coder A Stakeholders	Coder B Stakeholders
1	Innovation Thinking	1, 2, 3	1, 2
2	Innovation Methods and Training	1, 3	1, 3
3	Maker Technology	1, 4	1, 4
4	Entrepreneurship Basics	1	1
5	Opportunity Identification and Marketing	1, 3	1, 3
6	Entrepreneurial Quality Assessment and Team Building	1, 4	1, 4
7	Entrepreneurial Financing Practices	1, 3	1, 3
8	Entrepreneurial Management	1, 5	1, 5
9	Entrepreneurial Simulation Training	1, 2, 4	1, 2, 4
10	Cross-border E-commerce Entrepreneurship	1, 4, 6	1, 6
11	Internet+ Entrepreneurship	1, 2, 4	1, 2, 4
12	Industry Entrepreneurship Practice	1, 3, 4, 5	1, 3, 4, 5

Table 4: The calculated Cohen's Kappa values for each dimension

Number	Dimension	Kappa value
1	Stakeholders	0.95
2	Value creation	0.91
3	Digital competences	0.97
4	Entrepreneurial competences	0.89
5	Digital enterprise models	0.97
6	Digital technologies	0.93
7	Human resources	0.93
8	Financial resources	0.89
9	Knowledge resources	0.86
10	Social resources	0.95
11	Experience	0.85
12	Culture	0.85
13	Evaluation tool	0.85
14	Evaluation method	0.91

facilitators of the learning process across all courses. Many courses also include enterprises and industry experts as stakeholders, emphasizing the connection between education and real-world business practices. Some courses, such as "Cross-border E-commerce Entrepreneurship" and "Innovation Methods and Training", include social learners as stakeholders, indicating a broader target audience beyond traditional students. This also corroborates the previous literature review, which highlighted the extensive range of stakeholders in entrepreneurship and digital ecosystems, potentially including TVET institution faculty and students, external labor markets, community groups, governmental bodies, non-governmental organizations,

business entities, and the ICT sector.

However, not all courses involve a wide range of stakeholders, underscoring the varying degrees of industry participation across different courses. Overall, the broad range of stakeholders involved in these 12 courses includes students, teachers, enterprises and industry experts, social learners, initial business owners, and venture capitalists.

Value creation

In terms of value creation, all courses focus primarily on enhancing students' skills, such as innovation, entrepreneurship, and practical business skills. Some courses aim to improve students' competitiveness in international and domestic markets, linking the educational process directly to economic outcomes. Many courses emphasize the importance of teamwork, which is crucial in entrepreneurial environments. Some courses, such as "Industry Entrepreneurship Practice", focus on industry-specific entrepreneurial skills, catering to niche markets and specialized fields. The "Maker Technology" course emphasizes mastering advanced manufacturing technologies, showcasing the integration of cutting-edge technology into the curriculum. General entrepreneurship courses, like "Entrepreneurship Basics", aim to enhance entrepreneurial awareness and management skills, supporting a wide range of entrepreneurial activities and operational capabilities.

Overall, nearly all courses emphasize skill enhancement, focusing on both practical and theoretical entrepreneurial skills. Some courses directly emphasize the impact on economic value, aiming to improve students' economic competitiveness and ability to generate business value. The courses also cover a broad range of values, from comprehensive development to specific values, such as industry-specific training.

Summary

The scope of both stakeholders and value creation is extensive, which is attributable to the broad definition of entrepreneurship education. Entrepreneurship education encompasses a wide range, from preschool education to lifelong learning, covering goals ranging from personal capability development to actual entrepreneurship.[73] Consequently, the outcomes of entrepreneurship education, or the objectives of the courses, range from creating business value to creating "non-business" value.[48] As Lackéu stated, value creation refers to creating real-life social, cultural, or economic value for stakeholders beyond creators and teachers, including venture creation and sustainable entrepreneurship.[48] It is important to note that value creation presupposes student involvement in real-life practices, which aligns with the philosophy and principles of TVET. These findings underscore the importance of a flexible and inclusive framework to effectively guide the digital transformation of entrepreneurship education within TVET.

Content

Digital competences

Courses such as "Cross-border E-commerce Entrepreneurship", "Internet+ Entrepreneurship", "Maker Technology", and "Entrepreneurship Basics" are particularly rich in digital content, explicitly including advanced digital competences such as e-commerce platform operations, mobile internet, big data, cloud computing, 3D printing, laser processing, and robotics. However, some courses, such as "Entrepreneurial Quality Assessment and Team Building" and "Industry Entrepreneurship Practice", barely mention specific digital tools. Most courses adopt digital tools and platforms, indicating a consistent emphasis on equipping students with basic digital competence. Overall, while the use of digital tools and platforms is prevalent, the depth and specificity of digital competences vary from basic tool usage to advanced technical skills, depending on the course focus.

Entrepreneurship competences

Common competences across these courses include business planning and management (*e.g.*, "Entrepreneurial Management", "Entrepreneurship Basics"); innovation and creative thinking (*e.g.*, "Innovation Methods and Training", "Innovation Thinking"); market analysis and financial management (*e.g.*, "Entrepreneurial Simulation Training", "Opportunity Identification and Marketing"); and teamwork and leadership (*e.g.*, "Entrepreneurial Quality Assessment and Team Building"). This shows a broad range of entrepreneurial skills being covered. However, different courses emphasize specific entrepreneurial skills differently. For example, "Entrepreneurial Financing Practices" focuses heavily on financial strategies and risk management, while "Innovation Methods and Training" emphasizes creative problem-solving techniques. Additionally, the scope of these competences varies, with some courses providing comprehensive training in multiple areas (*e.g.*, "Entrepreneurship Basics"), while others concentrate on niche skills (*e.g.*, "Industry Entrepreneurship Practice").

Digital enterprise models

Several courses focus on understanding and implementing digital enterprise models. Common models discussed include e-commerce models like B2B and B2C (*e.g.*, "Cross-border E-commerce Entrepreneurship"); new business models emerging from the "Internet+" era (*e.g.*, "Internet+ Entrepreneurship"); and simulations of digital enterprises and markets (*e.g.*, "Entrepreneur Simulation Training", "Opportunity Identification and Marketing"). However, not all courses

explicitly address digital business models. Courses like "Innovation Methods and Training" and "Industry Entrepreneurship Practice" do not mention any digital business models, whereas courses like "Internet+ Entrepreneurship" and "Opportunity Identification and Marketing" include detailed discussions on emerging digital enterprise models. Overall, most courses focus on introducing and applying digital enterprise models, particularly emphasizing the practical implementation and understanding of e-commerce and Internet+ business models. However, the presence and depth of digital business models vary, with some courses deeply integrating these concepts and others lacking explicit mention.

Summary

Different courses emphasize various entrepreneurship and digital competences, reflecting the diverse needs of entrepreneurship education. Many courses focus on educational experiences that enhance both entrepreneurship and digital competence. These relevant competences can be found in the European Union's Digital Competence Framework for Citizens (DigComp 2.2) and the EntreComp Framework developed by the European Union. In designing the curriculum, it is advisable to systematically consider the content mentioned in these two frameworks, as both DigComp and EntreComp are widely recognized and extensively used, providing rich content that effectively supports education and training purposes.

By comparing and analyzing the 21 competences from DigComp and the 15 from EntreComp, it is evident that there are overlapping competences between them. These overlapping competences suggest that focusing on cultivating any of these competences within the curriculum can effectively integrate both digital and entrepreneurial teaching content. Given the limited capacity of each curriculum, focusing on these overlapping competences within the limited time allows for the most efficient achievement of curriculum objectives. In the actual implementation of the course, choosing the most appropriate competences to integrate into the curriculum according to the need is essential.

Regarding digital enterprise models, although their presence and depth vary across courses, and some courses lack explicit mention, it is essential to recognize that teaching students to understand, master, and develop digital enterprise models is not only a process of cultivating their digital and entrepreneurship competences but also a focal point of the teaching process. By teaching digital enterprise models, we can better cultivate students' entrepreneurship and digital competence, ensuring the comprehensiveness, practicality, and forward-looking nature of the curriculum content. Such courses aim to help students understand and master how businesses create, deliver, and capture value in the digital age. They ensure that curricula on digital enterprise models not only impart knowledge but also stimulate innovation and critical thinking. This approach aims to create value that supports global sustainable development and potentially cultivates future industry leaders.

Organization

Digital technologies

As previously mentioned, the courses incorporate various advanced digital technologies to enhance students' digital competence. Courses like "Cross-border E-commerce Entrepreneurship", "Internet+ Entrepreneurship", "Maker Technology", and "Entrepreneurship Basics" are rich in digital content, including e-commerce platforms, market research tools, advertising promotion tools, mobile internet, big data, cloud computing, 3D printing, laser processing, and robotics.

However, since we are discussing the use of digital technologies in the organization of classroom instruction, it is essential to focus more on educational technologies. We need to consider digital technologies from the perspective of instructional needs. Generally, the digital technologies and educational platforms mentioned in the courses have some relevance. For instance, the "Internet+ Entrepreneurship" course mentions using a smart TVET platform, which is a typical LMS. The "Innovation Thinking" and "Entrepreneurial Simulation Training" courses enhance the learning experience through gamified learning tools. The "Cross-border E-commerce Entrepreneurship" and "Entrepreneurship Basics" courses mention the use of mobile educational technologies, such as watching micro-course videos on smartphones. Regarding online collaborative learning tools, the "Entrepreneurial Quality Assessment and Team Building" and "Innovation Thinking" courses mention digital collaboration tools. Overall, these courses involve modern educational technologies and platforms, especially LMS and mobile educational technologies.

Nevertheless, these courses do not broadly mention the use of significant educational technologies, such as VR, AR, or adaptive learning. This omission could be due to the high development and maintenance costs of VR/AR and adaptive learning technologies, which not all TVET institutions can afford. Additionally, implementing these advanced technologies requires substantial technical support and infrastructure, which many TVET institutions might lack. From an acceptance perspective, teachers need time and resources to learn and adapt to these new technologies, and those who have not received appropriate training might find it challenging to

integrate these technologies effectively into their teaching. Although most students favor new technologies, some might be unfamiliar with immersive learning tools.

Resources

Human resources

Most courses involve teachers, entrepreneurs, and experts. The diversity of expertise in the field of entrepreneurship is evident in the human resources presented across different courses. For instance, the "Internet+ Entrepreneurship" and "Maker Technology" courses involve specific field experts like internet and industry experts. In contrast, courses such as "Entrepreneurial Quality Assessment and Team Building" mainly rely on teachers and entrepreneurial mentors. Courses like "Cross-border E-commerce Entrepreneurship" and "Entrepreneurial Simulation Training" involve entrepreneurial mentors who provide practical insights and real-world guidance, whereas other courses might not include such involvement.

Financial resources

All courses receive support for course development and implementation funding. Courses like "Cross-border E-commerce Entrepreneurship" and "Entrepreneurial Financing Practices" even provide financial support for practical projects and case analysis, aiding students in implementing actual business ideas. The level of financial support varies, with some courses receiving substantial funding for extensive practical projects, while others receive limited funding primarily for course delivery rather than practical implementation.

Knowledge resources

The knowledge resources involved in the courses typically include textbooks, online resources, and case libraries, reflecting the diversity of learning materials. Courses like "Entrepreneurial Management" and "Maker Technology" offer a wide range of learning materials, including textbooks, online resources, and video content. In contrast, courses like "Industry Entrepreneurship Practice" focus more on industry-specific knowledge and resources without a broad range of general learning materials. The depth and comprehensiveness of knowledge resources also vary, with some courses providing extensive libraries of case studies and examples, while others offer more limited collections.

Social resources

The social resources involved in these courses include networks of alumni, enterprise partners, and external practice bases. Courses like "Internet+ Entrepreneurship" and "Opportunity Identification and Marketing" provide extensive networking opportunities through partnerships with companies and access to industry networks. In contrast, courses like "Industry Entrepreneurship Practice" primarily connect students with industry-specific networks and resources. Some courses integrate community-based resources and networks, fostering broader social engagement, while others focus on more narrowly defined professional networks.

Experience

Practical experiences, such as internships, project tasks, and case studies, are integral to all courses. Courses like "Entrepreneurship Basics" offer comprehensive practical experiences, including enterprise management practice. "Cross-border E-commerce Entrepreneurship" and "Maker Technology" provide significant hands-on learning experiences, including internships and project-based learning. Other courses may offer less direct practical experience, focusing more on theoretical knowledge. Courses like "Entrepreneurial Simulation Training" extensively use role-playing and business simulations to provide practical experience, while others might rely more on case studies and classroom activities.

Culture

Entrepreneurship and innovation cultures are widely emphasized across courses, reflecting the diversity of cultural backgrounds. Courses like "Cross-border E-commerce Entrepreneurship" include cross-cultural understanding, communication, and integration, preparing students for the global business environment. In contrast, courses like "Industry Entrepreneurship Practice" focus more on specific industry cultures without broader cultural integration.

Summary

Regarding the organization of courses, the key is to innovatively use digital technologies and strategically utilize appropriate resources to achieve curriculum objectives. In discussing educational digital technologies, we see that LMSs, gamified learning tools, mobile educational technologies, and online collaborative learning tools are widely used across these 12 courses. This does not imply that all technologies must be experienced in a single course during the digital transformation process; instead, appropriate digital technologies should be selected and integrated into the teaching process based on specific needs.

How do we make these selections? The choice depends on which teaching methods are suitable for the specific instructional content. Entrepreneurship education has many applicable teaching methods, such as project-based learning, design thinking, case study methods, flipped classrooms, and experiential learning.[48] To effectively support these teaching methods, it is necessary to integrate corresponding digital technologies. For

example, immersive learning technologies can enhance students' experiences to help them understand real entrepreneurial projects more clearly. LMSs are ideal platform tools for implementing flipped classrooms, allowing teachers to track students' task completion in real time. Additionally, as AI plays an increasingly significant role in education, learners will rely more on self-directed learning than traditional teacher-led instruction. However, this does not negate the need for other teaching methods. Facilitating collaborative learning, whether virtual or in person, remains crucial.

When organizing educational experiences, how can we strategically utilize available resources? It is important to note that not all TVET institutions have access to extensive resources. For instance, it is common for some institutions to have limited financial resources. Therefore, knowing how to leverage the available resources to support teaching is essential.

Moreover, supporting necessary classroom activities and organizing essential educational experiences to achieve curriculum objectives are crucial. Therefore, supplementing and enhancing any lacking resources is also important. Not all educational experiences and classroom activities can create actual value for stakeholders. For instance, writing a business plan does not create value. Classroom activities should be extended to include real-life practices, such as pitching to externals, customer development, internships, and co-creation with partners. This requires TVET institutions to have tangible social and human resources to support these activities. Additionally, an open institutional culture can facilitate similar activities by educators and students.

Evaluation

Evaluation tools

Most courses employ online platforms and digital tools to evaluate student performance. For instance, "Cross-Border E-commerce Entrepreneurship" uses an online platform for task submission and assessment, while "Entrepreneurial Quality Assessment and Team Building" uses online collaboration tools to evaluate teamwork skills. Additionally, "Internet+ Entrepreneurship" utilizes a smart platform for task distribution and assessment, and "Entrepreneurial Simulation Training" employs simulation software and online platforms for project evaluation. Many courses also use data analysis and survey tools to assess student performance. For example, "Entrepreneurial Management" uses multimedia tools and electronic testing systems to evaluate students' management knowledge and application skills, while "Innovation Methods and Training" employs data analysis and online survey tools to assess innovation project performance.

Overall, the evaluation tools used in different courses are diverse. For example, "Maker Technology" uses specialized tools such as 3D printers, laser cutters, and robotics units for assessment, while "Entrepreneurial Financing Practices" utilizes online financing platforms and financial analysis tools. Some courses, like "Industry Entrepreneurship Practice", heavily integrate specific professional tools to evaluate industry practice performance, whereas other courses primarily rely on more general online tools and platforms.

Evaluation methods

Most courses combine formative and summative assessment methods. For example, "Entrepreneurial Quality Assessment and Team Building" evaluates teamwork skills through group projects and discussions, and "Innovation Thinking" conducts online tests and project evaluations *via* a massive open online course (MOOC) platform. Additionally, many courses employ methods such as project reports, case analyses, and scenario simulations. For instance, "Cross-Border E-commerce Entrepreneurship" uses case analysis and project reports to assess business plan and market analysis skills, while "Entrepreneurial Simulation Training" evaluates entrepreneurial practice skills through staged tasks and project defenses.

The evaluation methods vary among courses. Some courses, such as "Maker Technology", focus on project presentations and team collaboration outcomes to assess practical skills, while others, like " Opportunity Identification and Marketing", emphasize comprehensive assessment through project roadshows. Furthermore, some courses offer comprehensive evaluation systems. For instance, "Entrepreneurship Basics" combines formative and summative assessments to evaluate entrepreneurial skills and practical application capabilities, while other courses focus on specific aspects of assessment, such as "Industry Entrepreneurship Practice", which primarily uses industry case analysis and project presentations to evaluate practical skills.

Summary

A comprehensive evaluation system can more thoroughly and systematically assess the entire course by combining formative and summative assessments. This approach allows for timely insights into students' learning progress, effective adjustment of teaching methods and content, and improved teaching quality.

During formative assessments, the integration and selection of digital tools or platforms are crucial. These tools can monitor student progress in real time and promptly address student needs, and enhance engagement and participation. Additionally, the evaluation process should involve multiple assessment methods, such as peer assessments, stakeholder

assessments, expert reviews, and self-assessments. The involvement of multiple assessment methods imposes specific demands on digital technologies and resources. On one hand, the assistance of digital platforms and tools becomes essential, enabling assessors to conduct formative assessments anytime and anywhere. On the other hand, the ability to gather various assessors also indicates the availability of sufficient resources, such as financial and social resources, to support such assessment methods.

Regarding summative assessments, they can focus on the value creation objective of curriculum development, evaluating the effectiveness of students' task outputs in creating value for stakeholders.

Notably, in the context of digital transformation, the simplest method for evaluating entrepreneurship courses is to have students conduct online self-assessments using the DigComp and EntreComp frameworks. These frameworks are detailed and comprehensive, guiding instruction and assessing whether students' competences meet the required standards. However, relying solely on these frameworks for self-assessment is insufficient and does not fully support the achievement of curriculum objectives. As emphasized, a comprehensive and systematic evaluation using digital technologies and tools is crucial for entrepreneurship education courses during digital transformation.

CONCLUSION

This study, based on Vial's digital transformation conceptual diagram, constructs a conceptual curriculum development framework aimed at exploring the digital transformation of entrepreneurship education in TVET institutions. This framework integrates "digital transformation", "entrepreneurship education", and "curriculum development" into a coherent and rational whole, as these concepts share a process-oriented nature. Its construction is underpinned by a thorough and detailed literature review, encompassing key concepts and content modules related to "digital transformation", "entrepreneurship education", "curriculum development", and the impact of digital technologies on these domains.

Furthermore, this study compares 12 entrepreneurship courses across 14 dimensions: stakeholders, value creation, digital competences, entrepreneurial competences, digital business models, digital technologies, human resources, financial resources, knowledge resources, social resources, experience, culture, evaluation tools, and evaluation methods. Through this comparison, we identify significant insights from their commonalities and differences.

By analyzing the commonalities and differences across the four dimensions of objectives, content, organization, and evaluation, this study further solidifies and refines the conceptual curriculum development framework.

Regarding objectives, almost all courses list students and teachers as primary stakeholders, emphasizing their central role in entrepreneurship education. Additionally, many courses include enterprises and industry experts as stakeholders, highlighting the connection between education and real-world business practices.

In terms of content, the courses cover a broad range of digital and entrepreneurial competences. For example, courses like "Cross-border E-commerce Entrepreneurship" and "Internet+ Entrepreneurship" include advanced digital skills such as e-commerce platform operations, big data, and cloud computing. Simultaneously, entrepreneurial skills, such as business planning, innovation thinking, and market analysis, are evident in multiple courses.

In the organizational dimension, courses achieve their objectives through innovative use of digital technologies and strategic utilization of resources. Many courses employ LMSs, gamified learning tools, and mobile educational technologies to enhance the learning experience. Additionally, these courses integrate various human, financial, and knowledge resources, providing comprehensive support for achieving course objectives.

Regarding evaluation, most courses use online platforms and digital tools for assessment, combining formative and summative assessment methods. The participation of multiple evaluators, such as peer assessments, stakeholder assessments, expert reviews, and self-assessments, further enhances the quality and depth of evaluations.

In summary, the findings of this study not only partially confirm the effectiveness of the constructed framework but also further solidify it with insights from the Chinese context, ensuring that it can effectively guide the digital transformation of entrepreneurship education within TVET institutions in the future. The comprehensive integration of digital technologies, diverse resources, and effective evaluation methods enhances the educational experience while preparing students for the entrepreneurial challenges of the digital age and fostering innovation and sustainable development. Future research should focus on empirically testing this framework and exploring its applicability in different educational contexts to further enhance its effectiveness and reliability.

DECLARATIONS

Author contributions

Zeng XZ: Conceptualization, Writing—Original draft.

Chieng SL: Methodology, Software, Writing—Review and Editing. Liu HO: Writing—Review and Editing, Investigation. All authors have read and approved the final version.

Source of funding
This research was supported by 2024 research project "Research on the Collaborative Development of Higher Education in the Chengdu-Chongqing Area" funded by Chengdu-Chongqing Education and Socio-Economic Collaborative Development Research Center of China West Normal University (Project Number: CYJXF24004) and 2024 research project "Exploring the Path of Transformation in Translation Education through Digital Empowerment and Collaborative Construction between Schools and Enterprises" funded by Innovation Projects of Chengdu University.

Ethical approval
Not applicable.

Conflict of interest
The authors have no conflicts of interest to declare.

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

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