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ORIGINAL ARTICLE

Research on the mechanism to break the barriers in information resource communication for school-enterprise cooperation in vocational colleges with a digital background: A qualitative inquiry based on grounded theory

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ABSTRACT

The digital wave is reshaping the ecosystem of vocational education, where deep collaboration between vocational colleges and enterprises has become a critical pathway for cultivating highly adaptable technical and skilled talents. Efficient information communication mechanisms now serve as core variables determining the effectiveness of such cooperation. This study focuses on vocational college teachers, enterprise managers, and internship students engaged in school-enterprise collaboration. Following the procedural grounded-theory paradigm, in-depth interviews, non-participatory observations, and digital document analyses were conducted to construct a "technical support-information interaction-goal alignment-effect feedback loop" theoretical model. The findings reveal that while digital technologies significantly enhance information transmission efficiency and resource-sharing breadth, they also introduce new barriers, such as information overload, delayed feedback, and system heterogeneity. The root causes lie in schools' and enterprises' divergent organizational goals and insufficient technological adaptability, as well as the absence of institutional incentives. Based on these insights, a three-dimensional (institutions-technology-culture) synergy optimization path is proposed, and the "demand-technology-institution" linkage mechanism is further refined, offering a transferable communication governance framework for the digital transformation of vocational education.

Key words: digital transformation, vocational colleges, school-enterprise collaboration, information communication mechanism, information barriers, grounded theory

INTRODUCTION

In recent years, enterprises have shown an increasing willingness to participate in school-enterprise cooperation with vocational colleges (Ran, 2021). Since the report of the 19th National Congress of the Communist Party of China put forward the initiative of "deepening the integration of industry and education, and school-enterprise cooperation", local colleges and universities across the country have actively carried out school-enterprise cooperation projects, which have promoted the organic connection between the education system and the industrial system (Xi, 2017). School-enterprise cooperation has been recognized and promoted by the government as an effective talent training model and has achieved remarkable results

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(Wang, 2009). As a key part of industry-education integration, cooperation between vocational colleges and enterprises has become increasingly important in the context of digital transformation. However, the communication situation in this cooperation is not promising. First, the problem of information asymmetry is serious. Colleges and universities often find it difficult to obtain the latest information held by enterprises comprehensively and in a timely manner, resulting in a disconnect between talent training and market demand. For instance, the "real-time data exchange protocol for production lines" from a smart manufacturing enterprise reached the vocational institute's training system two weeks later than scheduled due to cumbersome cross-departmental approval procedures, directly resulting in a misalignment between the students' practical training content and the enterprise's actual production environment. Second, communication channels are blocked, mostly relying on traditional methods, such as telephone calls, emails, or offline meetings, which are not only inefficient but also difficult to adapt to the collaborative needs of digital tools, such as enterprise resource planning (ERP) systems and college educational administration systems, resulting in the intensification of information silos. Moreover, traditional communication methods are easily restricted by time and space, hindering efficient communication and collaboration between the two parties (according to the interview data). These barriers have seriously restricted the deepening of school-enterprise cooperation and urgently need to be addressed. At the same time, teaching and enterprise practice resources are scattered on digital platforms, lacking systematic integration, making it difficult for students to obtain a coherent "theory-practice" resource chain. Thus, talent training could not be effectively connected to industrial needs. For instance, enterprise production process videos and college theoretical courseware are stored on different platforms, and students need to switch three to four systems to complete the coherent learning of "machining theory-practical operation specifications" (according to the interview data).

The above problems have seriously restricted the deepening of school-enterprise cooperation. In the first place, the information resources in school-enterprise cooperation refer to various types of information and their carriers involved in the process of school-enterprise cooperation between vocational colleges and enterprises in the digital context. These include basic information such as school-enterprise cooperation agreements and information of participating subjects, talent training-related information (*e.g.*, enterprise talent demand, college curriculum outlines, and enterprise training materials), communication and collaboration information (*e.g.*, communication records through telephone and WeChat, digital platform usage logs, and feedback from both parties), industry technical information (*e.g.*, industry trends, technological innovations, and the latest industry standards), and evaluation information (*e.g.*, communication costs and cooperation benefits). Therefore, exploring the optimization path of the information resource communication mechanism in the digital context has become a key proposition for improving the quality of vocational education.

As a bottom-up theory-building research method, grounded theory emphasizes starting from actual data and gradually inducing theoretical concepts and models through in-depth data mining and analysis. This method is highly suitable for exploring complex social phenomena, such as the school-enterprise cooperation communication mechanism in the digital context. It can help us deeply explore the key elements and internal logical relationships, and can provide theoretical support and practical guidance for solving the current communication problems in school-enterprise cooperation.

LITERATURE REVIEW

In the digital era, school-enterprise cooperation in vocational institutions is crucial for enhancing talent cultivation quality and meeting industrial demands (Kai, 2025). Many scholars have explored information resource communication mechanism issues within this cooperation in the digital context from various perspectives. Concerning communication models, Chen (2021), grounded in the digital era, reviewed and reflected on the historical background, foundation, core, and direction of reforms in Chinese higher and vocational education. He proposed two key tasks for the new stage (*i.e.*, deepening industry-education integration and accelerating digital transformation), outlining a future vision for higher and vocational education in the digital age. On the aspect of technological tools, Zhang (2022) identified key control points and effectiveness indicators for high-quality development of digitally empowered vocational education by sorting through the background of the era of digital empowerment of vocational education and expounding on change trends. However, this study was limited to a unidimensional enhancement of communication efficiency by digital tools and overlooked the "digital divide" arising from interface incompatibility between ERP systems and college educational administration systems. Such studies that only focus on the one—dimensional improvement of communication efficiency by digital tools often exhibit a techno-optimist orientation. Regarding the construction of digital teaching resources, Du (2017) proposed supply-side solutions to the problem of insufficient practical applicability of digital teaching resource products in vocational education. Xue and Wu (2021) systematically researched and elaborated on the reference framework, developmental trajectory, and enhancement strategies of the digital teaching abilities of vocational education teachers. Against the backdrop of rapid digital technology development, vocational institutions can leverage these technologies to build exchange and cooperation platforms (Xu & Deng, 2022).

With the widespread application of digital technology in education and industry, school-enterprise cooperation in vocational institutions presents new trends. First, digital technology not only transforms traditional educational models but also provides new opportunities and challenges for industry-education integration and school-enterprise cooperation (Yang & Yang, 2021). As a vital pathway for improving the synergistic development of education and industry, school-enterprise cooperation utilizes digital platforms and technological means to optimize the allocation of educational resources and deepen collaboration (Liu *et al*., 2020). Second, the construction of online learning platforms and resource libraries enables students to access abundant learning materials anytime and anywhere, facilitating personalized and self-directed learning, thereby improving learning efficiency and outcomes (Cheng *et al*., 2020). Online training and project cooperation allow enterprises to participate in curriculum design and the teaching process within colleges, providing practical cases and projects that help students integrate theoretical knowledge with real-world application, enhancing practical skills and professional competence (Gao & Zhao, 2024). However, this also introduces new challenges, such as data security and exacerbated information asymmetry, which hinder in-depth cooperation. There is academic consensus that efficient communication is key to addressing these challenges and advancing deep school-enterprise integration. Effective communication enables both parties to stay informed about each other's needs and dynamics and to collaboratively solve problems arising from digital transformation.

The communication mechanism, as a critical link in school-enterprise cooperation, directly impacts the effectiveness of collaboration. Existing research has analyzed this mechanism from multiple dimensions. Research emphasizes the need to clarify the roles and responsibilities of different entities—schools, enterprises, government, and industry associations—as communication actors and stresses the importance of multi-stakeholder collaborative participation for enhancing communication effectiveness. Scholars like Li *et al.* (2022) pointed out that in the school-enterprise cooperation communication mechanism, the government should take the lead in building platforms to promote information and resource sharing, while enterprises, schools, and industry associations need to undertake the responsibilities of providing practical resources, formulating training programs, and offering professional guidance respectively. Wang (2021) suggested that enterprises should promptly communicate their technological-development direction to schools so that student technical training and innovation research can align with future enterprise development, strengthening teaching in these areas. Effective communication content should be closely and precisely aligned with industrial needs and the practical teaching context of schools. Communication content also involves various aspects, such as talent cultivation program design, internship and practical training arrangements, and technological research and development collaboration. Shi (2020) proposed regularly organizing career and entrepreneurship education events, such as forums and career planning sessions, to guide students in sharing their related experiences and doubts and in gaining more information, and to foster mutual understanding through exchange. Scholars like Zhang *et al.* (2022) noted that in the content alignment of the school-enterprise cooperation communication mechanism, schools and enterprises need to jointly develop talent training programs, enterprises should deeply participate in internship and practical training arrangements, and both parties should jointly establish research teams to conduct technological R&D cooperation for achievement transformation.

Communication channels encompass traditional face-to-face exchanges, telephone conferences, and emerging digital communication platforms (*e.g.*, Vocational Education Cloud and Enterprise WeChat). However, studies have indicated that while digital channels improve efficiency, they also bring drawbacks, such as information overload, a lack of emotional exchange, and system compatibility issues. In particular, there is a lack of discussion on the dynamic relationship between technology empowerment and barrier regeneration (the phenomenon where the original information communication barriers that were intended to be broken through technical means, due to new problems arising from technology application, such as information overload and system compatibility conflicts, form new communication obstacles again). In addition, although scholars highlight the importance of multi-stakeholder collaboration, a systematic analysis of the differing information needs of institutions, enterprises, and students in the digital context is lacking, resulting in insufficiently targeted collaborative strategies. The application of grounded theory has injected new vitality into this field. Future research could further expand multi-case studies based on grounded theory to enhance the generalizability of the findings. It could also delve into the impact mechanisms of digital technology on various elements of communication mechanisms to propose more practical optimization strategies, and simultaneously focus on the application of emerging digital technologies (*e.g.*, artificial intelligence [AI], blockchain) in innovating communication mechanisms. This would promote the high-quality development of school-enterprise cooperation in vocational institutions in the digital age. Proposing more targeted and actionable suggestions for information resource communication mechanisms can tangibly address the current problems in the digitalization of school-enterprise cooperation communication in vocational institutions, providing strong practical guidance and overcoming the disconnect between theory and practice.

RESEARCH DESIGN

Research method

Grounded theory is an inductive qualitative research approach primarily aimed at analyzing empirical data to construct theory (Urquhart *et al.*, 2010). At the outset of research, investigators typically do not presuppose theoretical hypotheses but instead commence directly from data gathered through practical observation, interviews, *etc*. Through means such as coding, categorization, and comparison, concepts and categories are extracted from the data, ultimately culminating in theory formation (Charmaz, 2006). Since its introduction in 1967, grounded theory has—based on its varying interpretations and applications—gradually evolved into three main schools: classical grounded theory, proceduralized grounded theory, and constructivist grounded theory. While all of these schools adhere to the fundamental principles of grounded theory, they differ in their coding techniques (Jia & Heng, 2020). The classical school argues that proceduralized grounded theory deviates from the core spirit of grounded theory, which is to generate theory naturally from data without any prior assumptions or verification (Glaser, 1992; Holton & Walsh, 2016). It also disapproves of the constructivist school's introduction of constructivist ideas into grounded theory (Glaser, 2012). Rooted in positivism, classical grounded theory emphasizes value neutrality and advocates the "objective" extraction of theory from data through a linear process of open coding, axial coding, and selective coding, requiring researchers to maintain "sensitivity" to the data (Mao & Pan, 2025). Proceduralized grounded theory was proposed based on classical grounded theory; its core still emphasizes that the induction and generation of theory should be rooted in specific practices, but it does not exclude the review and application of existing research literature (Wu & Li, 2020). It further strengthens the positivist tendency, places greater emphasis on the systematicity and operability of coding steps, clearly defines specific operational norms for various types of coding, and pursues the rigor and reproducibility of theory generation. Constructivist grounded theory, grounded in interpretivism, posits that theory is a co-constructed outcome of the interaction between the researcher and the data. It emphasizes the researcher's subjective initiative and situational embeddedness, adopts a more flexible coding process, and stresses the dynamic construction of theory tailored to specific contexts through constant comparison and theoretical sampling, without being confined to fixed coding steps (Charmaz, 2014). Strauss and Corbin's proceduralized grounded theory method was selected for the current study primarily due to its systematic coding procedures and capacity for the logically rigorous construction of categorical relationships (Strauss & Corbin, 1997). This approach effectively addresses the complexity and multidimensional characteristics of information resource communication mechanisms in school-enterprise cooperation in the digital context. Through its three-phase process of open, axial, and selective coding, it progressively refines core concepts and logical connections within the data. It is particularly suited to parsing dynamic issues arising from interactions among multiple actors (*e.g.*, institutions, enterprises, and students), such as technological adaptability, institutional disparities, and cultural cognition. Furthermore, this method emphasizes the paradigmatic analysis of causal conditions, strategies, and consequences, which aids in revealing the dual effects of technology empowerment-barrier regeneration. It also provides structured support for proposing an "institution-technology-culture" tripartite synergistic path, ultimately achieving the research objective of constructing an operable communication governance model from practical data.

Research sampling

The research subjects were personnel involved in school-enterprise cooperation at vocational colleges. Interviewees were selected through theoretical sampling, and raw research data were collected *via* in-depth, open-ended interview questions. Theoretical sampling is not used to verify or test hypotheses about concepts but to reveal relevant concepts, along with their attributes and dimensions. When researchers employ theoretical sampling, they seek out locations, individuals, and situations that can provide the information they need to understand these concepts (Corbin & Strauss, 2015). Adhering to the principle of theoretical sampling, this study conducted in-depth interviews with management personnel and faculty teams at vocational colleges, corporate decision-makers, human-resource specialists, and student interns. To ensure the comprehensiveness and diversity of the interview content, particular attention was paid to the typicality of business operations and the representativeness of relevant majors, thereby enabling the collection of detailed interview data from various perspectives and levels. All interviewees possessed excellent cognitive, comprehension, and communication abilities, highly aligning with the research requirements. The study was based on a Chinese context, and all participants were from China. Through recommendations from academic communities and social networks, 30 key informants were ultimately selected from nine institutions and six enterprises. The sample comprised 10 school-enterprise cooperative student interns (A01-A10); 10 institutional representatives, including liaison teachers, course instructors, and practical training teachers (A11-A20); and 10 enterprise representatives, including project leaders, liaison specialists, and internship mentors (A21-A30). The sample covered six enterprises (including four small and medium-sized enterprises [SMEs] and two large enterprises) in the manufacturing, information technology, and services sectors, as well as three types of vocational colleges (*e.g.*, comprehensive, science and engineering, and finance and economics). This ensured the sample's representativeness in terms of industry type, institutional characteristics, and stakeholder roles, avoiding industry bias in the theoretical construction.

Data collection

Pilot sampling for the interviews was conducted in July-August 2024. Initially, interviews were carried out on a small scale with school-enterprise cooperative student interns, resulting in valid interviews with seven students majoring in marketing, financial engineering, logistics management, computer science and technology, engineering management, and hotel management. However, an analysis of the initial interviews with students participating in university-industry collaborations revealed potential concerns and issues requiring deeper investigation. For instance, the discussions around questions such as "How did you learn about enterprise-related information through your university?" and "Do you find the current communication methods between the university and enterprises helpful for your understanding of university-industry collaboration?" deviated from the core focus of this study. The interviewees did not contextualize their responses within the digital context, presenting complex frameworks and multiple influencing factors. Thus, the initial interviews failed to fully explore the aspects relevant to this research, yielding non-utilizable results. In addition, upon reflection, it was found that for some open-ended questions, no follow-up inquiries were made to elicit details, and effective guidance to prompt the interviewees to elaborate on their answers was not given. This led to the insufficient depth and breadth of the relevant data, resulting in incomplete information acquisition.

From the perspective of sample selection, the representation across different majors was insufficient, and the number of interviewees was too small. This may have caused one-sidedness in the theoretical construction and failure to cover a broader range of phenomena and perspectives. Thus, in the subsequent interviews, the scope of the interviewees was expanded. The sample selection criteria were re-evaluated, and targeted supplements were made to samples with insufficient representativeness. Specific participants were also reselected for follow-up interviews. This was done to ensure the sample's diversity and comprehensiveness, allowing the theory to more broadly reflect real-world scenarios. For ambiguous responses, timely follow-up questions were asked to obtain more accurate and detailed information. All of these efforts were made to further analyze the newly emerging key issues, thereby deepening the understanding of the research topic and enhancing the theoretical construction.

After refining the approach to be employed to address the issues identified during the initial interviews, a final round of interviews was conducted from September to November 2024. The basic information of the respondents is presented in Table 1. Throughout the research process, data collection and coding analysis were carried out concurrently rather than sequentially. The data collection was organized into three stages. First, in-depth interviews were conducted with vocational school administrators, teachers, corporate executives, human-resource personnel, and student interns. In cases where in-person meetings were not feasible due to specific circumstances, interviews were conducted *via* WeChat voice calls or text-based communication. These interviews aimed to capture the subjective experiences, pain points, and expectations of the participants, providing a preliminary framework for subsequent observations and document analysis. The interview results helped the researchers focus on key issues (*e.g.*, the use of communication tools and delays in information exchange) and guided the direction of the following stages. The second stage involved on-site observations of work environments in vocational schools and enterprises engaged in digital collaboration. A total of 40 h of observations were conducted, covering the operational processes of digital teaching platforms at three vocational schools and digital internship management systems at two enterprises. The specific scenarios observed were the digital onboarding process for interns and the use of online systems for training courses by both schools and enterprises. Behaviors related to information and communication practices were documented. Building on the interview findings, these observations helped verify whether the described behaviors aligned with actual practices (*e.g.*, platform usage and intern management) and uncovered

Table 1: Demographic profile of final interviewees

Interviewee	Role	Major/field of expertise	Role description/position
A01	Student 1	Mechanical design	Student
A02	Student 2	Marketing	Student
A03	Student 3	Computer programming	Student
A04	Student 4	Hospitality management	Student
A05	Student 5	E-commerce	Student
A06	Student 6	Civil engineering	Student
A07	Student 7	Accounting and finance	Student
A08	Student 8	Animation design	Student
A09	Student 9	Logistics management	Student
A10	Student 10	Early childhood education	Student
A11	Teacher 1	E-commerce	Industry-academia collaboration liaison
A12	Teacher 2	Mechanical manufacturing	Industry-academia course instructor
A13	Teacher 3	Marketing	Industry-academia teaching faculty
A14	Teacher 4	Computer programming	Industry-academia Practicum instructor
A15	Teacher 5	Logistics management	Industry-academia project instructor
A16	Teacher 6	Hospitality management	Industry-academia curriculum developer
A17	Teacher 7	Animation design	Industry-academia teaching faculty
A18	Teacher 8	Accounting	Industry-academia teaching faculty
A19	Teacher 9	Architectural engineering	Industry-academia practicum instructor
A20	Teacher 10	Electronic information engineering	Industry-academia course instructor
A21	Corporate 1	Information technology	Industry-academia project leader
A22	Corporate 2	Artificial intelligence	Industry-academia liaison specialist
A23	Corporate 3	General industry	Industry-academia project team member
A24	Corporate 4	Manufacturing	Industry-academia administrative staff
A25	Corporate 5	General industry	Industry-academia internship mentor
A26	Corporate 6	General industry	Industry-academia liaison officer
A27	Corporate 7	Environmental protection	Industry-academia office member
A28	Corporate 8	General industry	Industry-academia project manager
A29	Corporate 9	General industry	Industry-academia liaison specialist
A30	Corporate 10	Electronic information	Industry-academia internship supervisor

previously unmentioned details (*e.g.*, implicit obstacles in system operation). The third stage entailed collecting digital documents from schools and enterprises generated during their collaboration: cooperation agreements, online training materials, records from communication platforms, and email correspondence. A total of 12 school-enterprise cooperation agreements, three months of digital platform logs, and 28 online training course materials were collected to ensure the diversity and timeliness of the data sources. These documents were analyzed to understand the types and flow of information resources. Objective data from agreements and logs helped supplement formal processes or systemic issues that might have been overlooked in the interviews and observations (*e.g.*, information update frequency and enforceability of agreement terms).

The progressive approach described above—moving from subjective accounts to behavioral observations and finally to objective documentation—enabled a deeper understanding of the issues and formed a triangulation mechanism, thereby enhancing the study's validity. Grounded theory emphasizes the gradual abstraction of theory from data. The initial interviews helped identify core categories (*e.g.*, "information silos"), while the data obtained from the subsequent observations and document analyses were used to examine and elaborate on the attributes and dimensions of these categories. For instance, the notion of "fragmented communication *via* WeChat", raised in some interviews, was quantitatively validated through chat logs and platform records (*e.g.*, repetitive messages accounted for 43% of the content).

All interviewees responded positively and cooperated fully. The discussion topics were clear, and communication proceeded smoothly. Each interview lasted 30-60 min. The key interview questions were: How do both schools and enterprises integrate and utilize communicated information resources? Are there mechanisms or measures in place to promote the effective application of these resources to improve talent development and corporate productivity? Does the communication mechanism facilitate two-way interaction between schools and enterprises? Can enterprises provide timely feedback to schools regarding talent development opinions and suggestions? Do you feel that the industry updates and technological development information provided by enterprises are timely? Do they meet your learning needs for new knowledge and skills? Have you encountered obstacles in online communication with enterprises, such as in language expression or professional understanding? How were these resolved? All interviews were audio-recorded, resulting in 30 valid samples. These recordings were transcribed into 70,000 words of text for coding. Because interviewing and coding were conducted simultaneously, no new conceptual categories emerged. In accordance with the principle of theoretical saturation, a randomly selected subset of samples (accounting for 2/3 of the total) was used for coding analysis and theory building, and the remaining seven samples (1/3 of the total) were reserved for theoretical saturation testing.

Research process and model construction

Open coding

This study utilized NVivo 12.0 to conduct line-by-line coding of raw interview transcripts and textual data, extracting meaningful concepts and categories. For instance, phrases such as "vocational colleges exchange information on talent demand with enterprises *via* online platforms" were coded into concepts such as "online communication platform" and "talent demand information exchange". When the respondents mentioned "using WeChat work groups to promptly communicate project progress", the initial concept "use of instant messaging tools" was identified. During field observations, specific digital methods employed in document transfer and data sharing were also recorded and conceptualized accordingly. After numerous similar concepts were reviewed and consolidated, they were grouped into broader categories, such as "application of digital communication tools". Similarly, expressions such as "industry associations provide feedback on enterprises' practical skill requirements for talent" were coded as "talent demand feedback". Given the diverse nature of information exchange—including industry trends and technological updates—such content was classified under the category "information communication content". Through a rigorous coding process, 50 initial concepts were identified and subsequently integrated into 15 categories. These concepts covered various dimensions, including communication tools, channels, objectives, content, collaboration processes, outcomes, and information sharing. The resulting categories included but were not limited to digital communication platform development, communication frequency and timing, collaboration goal setting and understanding, and cost-benefit considerations of communication. This structured analysis provides a solid foundation for further investigation. Based on relevance and coherence, concepts belonging to the same type were further synthesized into subcategories. The correspondence between subcategories and concepts is presented in Table 2.

Axial coding

While open coding generates a series of subcategories, axial coding further synthesizes and integrates these subcategories. It groups related codes based on their conceptual-level logical relationships and refines them into main categories through clustering. For example, categories such as "communication tools", "communication platforms", and "communication frequency" are grouped under the main category of "Communication and Collaboration Infrastructure". Similarly, "talent needs" and "collaboration goal setting" are classified under "Collaboration Needs and Objectives". Through axial coding, a systematic network of categorical relationships is constructed.

This study was based on a repeated review and in-depth reflection on the process from labeling and conceptualization to the integration of subcategories. Using paradigms such as causal conditions, phenomena, strategies, and outcomes, a deep relational analysis was conducted on the 15 categories initially identified. Taking "Digital Communication Platform Development" as an example, in the current collaboration between vocational colleges and enterprises, frequent business interactions and urgent communication needs exist, while traditional communication methods, such as phone calls and emails, are inefficient and fail to meet real-time and convenience requirements. This constitutes the causal condition of urgent communication needs and the low efficiency of traditional communication methods. Against this backdrop, digital communication platform development is proposed and implemented as a targeted strategy. By establishing a digital platform integrating multiple functions, both parties achieve rapid information transfer and sharing during communication, significantly improving communication efficiency and yielding positive outcomes, such as enhanced communication efficiency and timely information delivery. Furthermore, considering the relationship between "information-sharing content" and "talent demand information exchange", enterprises, with their deep industry insights and extensive connections, can accurately convey the latest industry standards, actual enterprise needs, and cutting-edge technological innovations to vocational colleges. This falls under the

Table 2: Example of open coding (excerpt)

Raw data statements and tagging	Conceptualization & node count	Categorization & node count
A10-4. Although both academic materials and corporate practical resources are available on the platform, they lack effective categorization and integration. The content is poorly organized, making it difficult to locate suitable materials.	Online communication platform (17)	Digital communication tool application (42)
A15-1. We use WeCom and Tencent Docs for collaboration. Instant messaging is stable, but the search function is not very accurate. A04-6. I use Tencent Meeting for video communication with corporate mentors, which facilitates the sharing of my work progress.	Instant messaging tool usage (8)	
A14-5. Response time is generally slow, typically taking 4-5 days to receive a reply. The feedback is also not very effective. A23-2. Timeliness and accuracy are both satisfactory. Enterprises and institutions have established efficient information-sharing channels.	Resource updates and feedback effectiveness (10)	
A05-4. Integration is relatively high, making it very convenient to connect theory and practice. The platform uses an intelligent recommendation system that automatically suggests relevant corporate resources based on my current courses. A18-10. Students and instructors can complete all cooperation-related tasks on a single platform, improving communication efficiency, reducing cumbersome processes, and facilitating both education and career development.	Resource integration and sharing (15)	Communication content (31)
A21-11. I hope that big data and artificial intelligence can be used to build an intelligent matching platform. This would help academic institutions tailor teaching content to better align with corporate needs, thereby improving the relevance of talent development.	Talent demand feedback (6)	
A22-9. The frequency of digital communication is moderate, with interactions occurring approximately every 2-3 days. A04-6. I use Tencent Meeting for video communication with corporate mentors, typically two to three times a month.	Communication frequency (10)	Communication mechanism (35)
A07-3. Communication content is generally clear; both schools and companies emphasize developing skills that meet market demands. However, I hope to gain deeper insight into corporate training systems regarding new technology applications.	Communication content (18)	
A30-7. We evaluate communication effectiveness by comparing improvements in corporate benefits and student competency before and after cooperation. If there is significant progress, the communication is considered successful.	Consideration of communication benefits (12)	Cost-benefit (24)
A11-5. In response to students' lack of practical ability, we proposed increasing internship duration and diversifying practical experiences. Through online collaboration platforms, we jointly developed teaching and practical plans with enterprises, reducing communication costs.	Consideration of communication costs (12)	

category of "information interaction content". Based on this accurate and timely information, vocational colleges can closely align their talent training objectives with market demands and develop more practical curricula, thereby effectively promoting joint talent cultivation. This fully demonstrates the close intrinsic connection between the two. Ultimately, five main categories were refined. The definitions of the categories and the correspondence between the main categories and the subcategories are presented in Table 3.

Selective coding

Following an in-depth exploration of the logical relationships among various categories through axial coding, the research entered the stage of selective coding. The core task at this stage was to identify the central category of the entire study. Through repeated examination and comprehensive consideration of the preliminary analytical results, the "information resource communication mechanism in school-enterprise cooperation in vocational colleges with a digital background" was ultimately determined as the central category. A comprehensive and systematic theoretical model centered on this core category was constructed. In this model, the establishment of a digital communication platform serves as the foundation. It acts like a bridge, breaking down communication barriers between vocational colleges and enterprises, providing efficient and convenient channels for information exchange, and strongly promoting information sharing and feedback. During information sharing and feedback, colleges and enterprises can promptly understand each other's needs and dynamics. Based on this, both parties can collaboratively set cooperation goals and make dynamic adjustments according to actual circumstances, such as changes in the market environment or policy adjustments, ensuring that the cooperation consistently moves in the right direction. The ultimate focus of goal collaboration and adjustment is joint talent cultivation and evaluation. Through close cooperation, both parties jointly develop scientific and rational talent training programs, strengthen communication and collaboration between teachers and enterprise mentors during the training process, provide joint guidance for student practice, and finally establish a scientific talent evaluation system

Table 3: Examples of axial coding

Main category	Subcategory	Connotation of the category
Foundations of communication and collaboration	Communication tools and platforms Communication frequency and scheduling	Digital tools and platforms encompass the various technologies and systems that facilitate communication and collaboration among stakeholders, such as online communication platforms, instant messaging tools, and specialized digital means for file transfer and document sharing. These tools and platforms serve as the material foundations for collaborative efforts. The temporal attributes of communication refer to the frequency of communication occurrences and the specific timing at which communication takes place. These factors directly influence the timeliness of information delivery and the overall efficiency of collaboration.
Collaborative needs and objectives	Talent demand collaborative goal setting and understanding	Information on enterprises' talent demands, including practical competency requirements, along with the feedback mechanism for talent demand information, is one of the key driving factors for collaboration between vocational institutions and enterprises. The mutual setting of goals that both parties aim to achieve through collaboration, as well as their shared understanding of these goals, ensures that the common goals serve as directional guides for the partnership.
Digitalization construction and application	Application of digital communication tools Development of digital communication platforms	The practical application of various digital communication tools is emphasized. For example, online communication platforms are used for the exchange of talent demand information, and instant messaging tools are used to communicate the progress of cooperative projects and others, reflecting the actual functional role of digital tools in cooperation. It focuses on the process of building a digital communication platform from scratch and the relevant planning, which is the basic construction part to ensure the application of digital communication tools and information interaction.
Content of information interaction	Talent demand exchange Content of information sharing	The communication and exchange of information on talent demand between vocational colleges and enterprises is the information interaction regarding human-resource elements in the cooperation. It covers the transmission and sharing of diversified information, such as industry trends and technological innovations. This is another important information interaction, in addition to talent demand information during the cooperation process, which helps both parties in the cooperation grasp industry trends.
Evaluation of collaborative benefits	Cost-benefit considerations in communication	During the cooperation process, the communication costs (*e.g.*, the time and technical costs) and the benefits generated through communication and collaboration (*e.g.*, the benefits brought by information sharing) are measured to evaluate the value and sustainability of the cooperation.

based on communication and feedback. This system enables objective and fair assessment of the quality of talent cultivation, providing critical references for subsequent improvements in talent training, thereby forming an organic and interconnected communication mechanism. The model uses the digital communication platform as the foundational carrier, facilitates a bidirectional information sharing-demand feedback flow, drives collaborative adjustment of cooperation goals, and ultimately culminates in joint talent cultivation and evaluation, forming a complete chain of technical support-information interaction-goal collaboration-closed-loop effects, as shown in Figure 1.

Theoretical saturation test

Saturation is a key indicator of whether the research data meet the requirements for theoretical construction, helping to determine the adequacy of data collection and the sufficiency of the theoretical framework.

Scholars of grounded theory have provided core bases for the definition and analysis logic of saturation: Glaser (2001) and Strauss and Corbin (1997) proposed that theoretical sampling should continue until category saturation, and its logic replaces the consideration of sample size; Charmaz (2009) pointed out that saturation analysis can be applied to the early and late stages of research, and a theoretical category reaches saturation when the collected data no longer generates new theoretical insights or new attributes of the core category. She also noted that member checking (feeding back results to research subjects for confirmation or conducting follow-up visits to refine categories) is a feasible method; Albas and Albas (1993, 1998), in the later stage of their research, obtained new categories and achieved good data saturation by explaining the main categories to previous subjects and inquiring about the degree of consistency with their cognition and experience. In accordance with common practices for saturation testing, this study reserved seven interview transcripts for this purpose. These transcripts were conceptualized and categorized using the three-level coding method. The results revealed no new concepts or categories, indicating that the core category (*i.e.*, "information resource communication mechanism for school-enterprise cooperation in vocational colleges in the digital context") effectively encompasses the entire model. The internal relationships within the model are well constructed, demonstrating that the communication framework for school-enterprise cooperation has been thoroughly explored and represented. Thus, the conceptual model developed in this study can be considered theoretically saturated.

RESEARCH FINDINGS AND DISCUSSION

Core barrier dimensions to information resource communication in school-enterprise cooperation

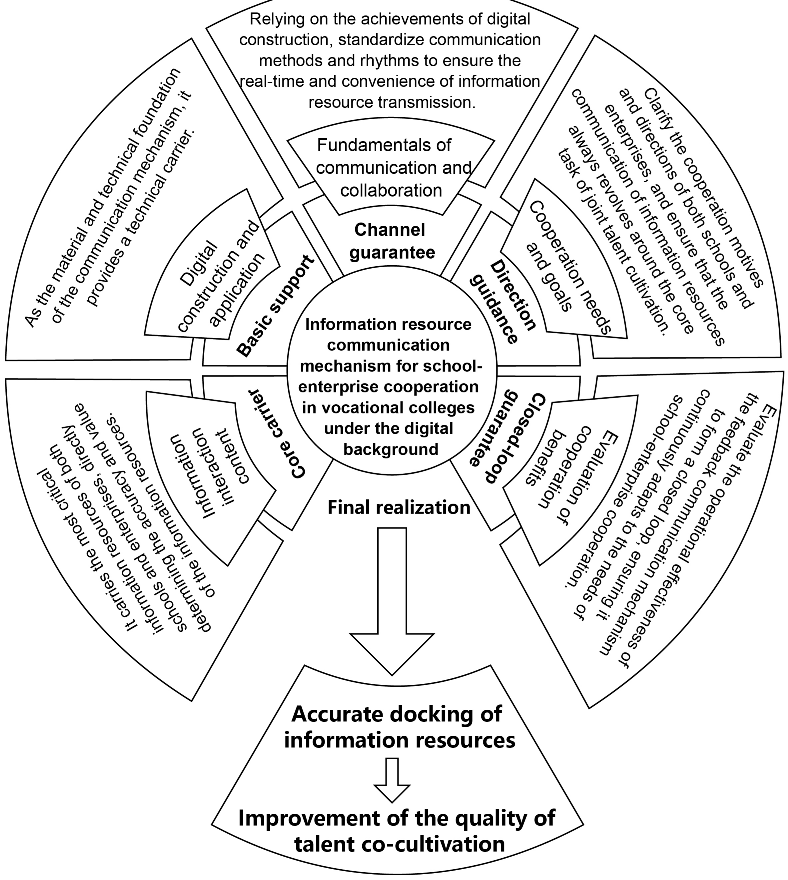

Figure 1. Model of information resource communication mechanisms for school-enterprise cooperation in the digital context.

Through a three-level coding analysis of the interview data with school-enterprise cooperation personnel, it was found that the barriers to information resource communication can be categorized into three dimensions: structural barriers, technical adaptability, and cognitive differences. Structural barriers manifest as differences in organizational structures and management processes between schools and enterprises, leading to redundant information transmission hierarchies. This issue reflects the significant differences in organizational management models between enterprises and vocational institutions: the hierarchical information transmission mechanism in enterprises contrasts sharply with the flat management structure in vocational institutions, highlighting the urgent need for both sides to optimize collaboration mechanisms, streamline information delivery processes, and enhance communication efficiency. These measures are essential to ensure effective alignment between teaching and practical needs. Enterprise personnel A24 mentioned, "The latest operation standards from the enterprise's technical department require layer-by-layer transmission through the administrative department and the school-enterprise cooperation office. By the time they reach the school, they are already 15 days late, directly affecting the updating of teaching plans" (A24—Manufacturing Administrative staff). Technical adaptability barriers are specifically reflected in the inconsistent standards of digital platforms and the absence of data interfaces between schools and enterprises. Teacher A12 pointed out that "[t]he data interfaces between the ERP system and the school's educational administration platform are incompatible. Student grades and enterprise internship records cannot be synchronized automatically, requiring manual export and import, which is highly inefficient" (A12—Mechanical Manufacturing teacher). Student A03 added, "When learning programming, the enterprise's code repository conflicts with the school's development environment, consuming a significant amount of time on debugging" (A03—Computer Science student), highlighting the issue of heterogeneity in school-enterprise digital platforms. Cognitive differences stem from schools' and enterprises' divergent views on the value of information resources. Enterprises focus more on commercial secrets and short-term benefits, while schools lean toward long-term talent cultivation needs,

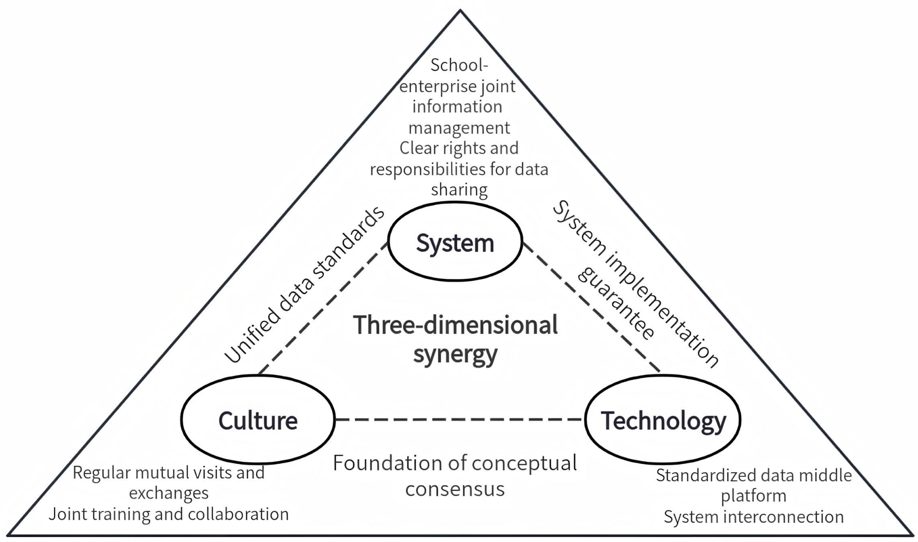

Figure 2. The three-dimensional synergy optimization model.

leading to an insufficient willingness to share information. There is a contradiction between the enterprise's protection of the commercial value of information resources and the institution's educational needs. Enterprise personnel A21 stated frankly, "technical materials involve commercial secrets; sharing requires approval, leading to delays in the school's access" (A21—IT project leader). Conversely, Teacher A15 emphasized that "[c]ases provided by enterprises often avoid core technical details, making it difficult for students to gain an in-depth understanding of industry practices" (A15—Logistics Management teacher).

Dual effects of digital tools on communication mechanisms

Research indicates that digital tools present both opportunities and new challenges. On the one hand, instant messaging software and cloud collaboration platforms significantly enhance the efficiency of information transmission, breaking through spatiotemporal constraints. Student A06 stated, "Because we can submit internship reports in real time through a DingTalk group, enterprise mentors can provide feedback on the same day" (A06—Civil Engineering student). Teacher A11 mentioned, "Cloud collaboration platforms increased the efficiency of jointly revising course syllabi by 50%" (A11—E-commerce teacher). On the other hand, fragmented communication not only induces information overload but also exacerbates redundancy due to the lack of a systematic integration mechanism. For example, while a certain vocational college and an enterprise used a WeChat group for daily communication, core information, such as key technical standards and talent training plans, was not systematically archived. An analysis of a three-month chat history from a specific school-enterprise cooperation WeChat group showed that out of 67 core messages, 29 involved repeated communication, accounting for 43%. Enterprise personnel A28 noted: "Discussions in the WeChat group are dispersed; important files get buried. Twenty-nine core messages were repeated within three months" (A28—project manager). Student A09 complained: "Platform materials are messy; searching for 'logistics distribution cases' brings up irrelevant content" (A09—Logistics Management student).

Optimization pathways for information resource communication mechanisms

Based on grounded theory, a three-dimensional synergy optimization model was developed, focusing on specific pathways to break down these barriers: institutional synergy, technical synergy, and cultural synergy. This model is illustrated in Figure 2.

Institutional synergy: rule anchors and responsibility cornerstones

Institutional synergy is the top-level framework of the three-dimensional synergy model. It establishes clear rules for information flow through mechanisms such as the "joint school-enterprise information management system", including uploading materials to the shared platform within the specified time. Enterprise personnel A30 illustrated: "After non-confidential technical data were uploaded within 72 h, student skill matching improved by 28%" (A30—Electronics Information manager). This delineates the boundaries of responsibility and standardizes processes for information sharing at the institutional level. Institutional synergy provides the "rule anchors" for both technical and cultural synergy. On the one hand, a clear division of responsibilities (*e.g.*, defined data-sharing duties) provides a "requirement list" for system development and data interoperability (*e.g.*, connecting educational administration systems with ERP) within technical synergy, ensuring that technological implementation follows established guidelines. On the other hand, the rigid constraints on information flow shaped by institutions guide both schools and enterprises into forming habits of information sharing, laying a foundation of institutional consensus for cultural synergy and fostering mutual trust and collaboration at the cultural level.

Technical synergy: efficiency engine and implementation support

Technical synergy acts as the efficiency engine of the three-dimensional synergy model, centered on a "standardized data middle platform and system interoperability". It breaks down the technical barriers between information systems by developing standardized interfaces (*e.g.*, enabling data exchange between educational administration systems and ERPs), facilitating cross-platform and cross-entity data flow. Teacher A14 reported: "After connecting the educational administration system with the ERP, the time required for internship arrangements dropped from 3 days to 1 h" (A14—Computer Science teacher). Technical synergy provides implementation support for institutional and cultural synergy. From an institutional perspective, the technical system serves as the "digital carrier" of institutional rules. It transforms the institutional requirement of uploading materials within a specified timeframe (*e.g.*, automatic reminders and data traceability) into system processes, thereby ensuring the rigid implementation of the institution. From the cultural dimension, the real-time information interaction and data transparency achieved through technical synergy tangibly strengthen both parties' perception of the value of information sharing, accelerating the development of a mutual trust ethos within cultural synergy. This provides data-driven evidence and an efficiency foundation for cultural collaborative activities, such as regular exchange visits and joint training.

Cultural synergy: conceptual foundation and ecological soil

Cultural synergy is the conceptual foundation of the model. It cultivates a shared value consensus and a collaborative culture around information sharing through activities such as regular mutual exchange visits and joint training collaborations. Student A07 observed: "After enterprise mentors participated in classroom teaching, they became more willing to share practical project experience" (A07—Accounting student). Cultural synergy provides the "ecological soil" for institutional and technical synergy. For institutional synergy, the recognition of the value of information sharing at the cultural level reduces the "resistance cost" of implementing rules, transforming the Joint Information Management System from a "mandatory constraint" into "active compliance". For technical synergy, the open and collaborative atmosphere fostered by cultural synergy stimulates proactiveness from both parties during technical integration, such as enterprises voluntarily opening their ERP data standards and institutions participating in system requirement design. This creates softer conditions for technical synergy to overcome departmental silos and technical monopolies, making the implementation of standardized data middle platforms and system interoperability easier.

Mutual reinforcement logic of three-dimensional synergy: closed-loop interaction and value multiplication

Collaboration among institutions, technology, and culture does not exist in isolation; instead, it forms an ecosystem of closed-loop linkage: institutional collaboration defines clear rules—technological collaboration enables implementation—cultural collaboration consolidates consensus, which in turn drives institutional optimization and technological iteration. Take the pilot case as an example: relevant indicators were compared before and after the implementation of the Joint Information Management System. Before implementation, the alignment between students' skills in the pilot vocational institution and the job requirements of enterprises was measured using quantitative metrics, such as enterprises' ratings of students' internship performance and the pass rate of skill assessments. Three months after implementation, the standardized interfaces realized process automation; data from the same dimensions were collected again, and the magnitude of the difference between the two datasets was calculated, ultimately showing a 28% improvement in skill alignment. The improvement in collaboration project response speed (35% increase) was calculated by recording the time gap between the proposal of a school-enterprise collaboration project and its actual implementation before and after the system was put in place. Specifically, the average time taken for enterprises to propose technical teaching needs and for the institution to respond to and advance such projects was counted before implementation. This was then compared with the average time required for similar projects after implementation (supported by the shared platform and data interconnection). The percentage reduction in time consumption represented the improvement in response speed, demonstrating the value of the technology. This tangible improvement allowed both schools and enterprises to truly perceive the benefits of information sharing, thereby strengthening the cultural recognition of proactive

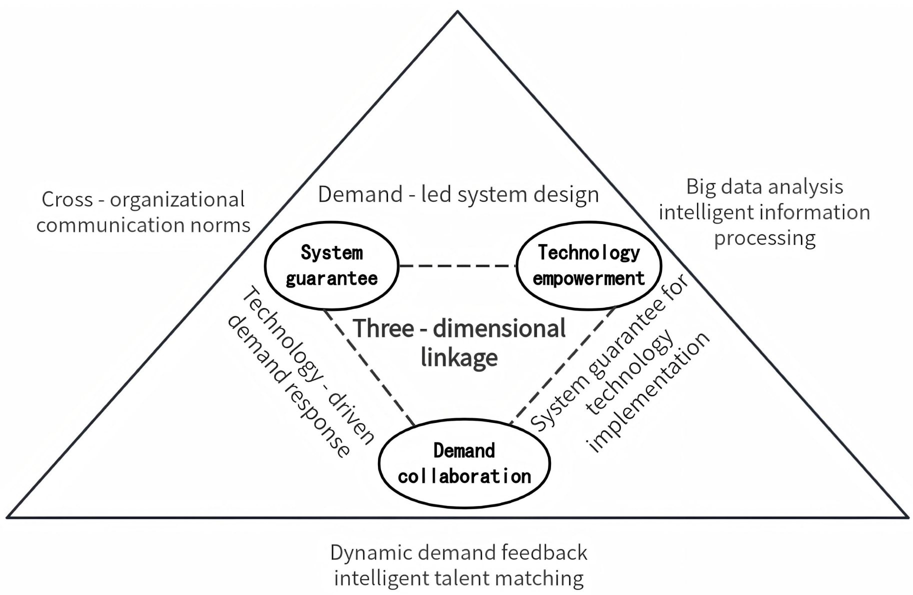

Figure 3. Three-dimensional linkage mechanism.

communication and collaborative education. In turn, the demand for in-depth collaboration generated by cultural collaboration drives further institutional improvement (*e.g.*, expanding classification rules for classified and unclassified information) and technological upgrading (*e.g.*, developing more intelligent skill-matching algorithms). This forms an institution-technology-culture collaborative closed loop with spiral improvement, continuously breaking down information barriers and unleashing the collaborative value of school-enterprise cooperation.

CONCLUSION

This study, based on the procedural methods of Straussian grounded theory, employed in-depth interviews and qualitative analysis of participants in vocational school-enterprise cooperation. Open coding enabled the extraction of 50 initial concepts, axial coding synthesized 15 subcategories, and selective coding formed the core category: digital school-enterprise cooperation communication mechanism. This category systematically reveals the core elements and operational logic of the information resource communication mechanism within school-enterprise cooperation in the digital context. It was found that although digital technology presents new opportunities for school-enterprise collaboration, challenges such as information asymmetry, inefficient communication channels, and fragmented resources persist. Their root causes lie in divergent organizational goals, insufficient technological application capacity, and a lack of institutional safeguards. Consequently, a "three-dimensional demand synergy—technology enablement—institutional safeguarding" linkage mechanism was constructed. The demand synergy mechanism establishes dynamic demand feedback and intelligent matching processes to precisely align institutional talent cultivation with enterprise job position requirements. The technology enablement mechanism utilizes digital tools, such as big data analytics and intelligent algorithms, to achieve efficient information collection, intelligent processing, and precise push. The institutional safeguarding mechanism provides institutional support by constructing cross-organizational communication norms, performance evaluation systems, and incentive-constraint mechanisms. The synergistic operation of these three mechanisms can significantly enhance the efficiency of information resource integration and promote the deep integration of the vocational education supply side with industrial demand. The model construction was consistently grounded in interview data. For instance, the demand synergy mechanism originated from enterprise personnel A22's appeal: "Hopefully, the platform can intelligently match enterprise job needs with institutional courses" (A22—AI specialist). The practical basis for the technology enablement mechanism came from teacher A18's feedback: "After analyzing student behavior with big data, the accuracy of pushing enterprise resources improved significantly" (A18—Accounting teacher), as shown in Figure 3.

Through grounded theory, this study theoretically revealed the dual effects of digital tools and constructed a three-dimensional synergy model alongside a demand-technology-institution linkage mechanism, addressing the current literature's gap regarding dynamic relationships and systemic solutions. Methodologically, the application of proceduralized grounded theory and data triangulation mitigated the limitations of relying solely on interview data, enhanced the research validity, and provided a rigorous qualitative research paradigm for vocational education studies. Practically, the translation of abstract theories into actionable pilot cases bridged the research gap at the practical level and promoted the implementation of industry-education integration. However, due to the inherent attributes of the grounded theory method and the limitations of the research design, the study's conclusions face significant challenges in terms of promotion and application.

From the perspective of sample and contextual adaptability, this study adopted theoretical sampling rather than statistical sampling. Although the samples covered multiple industries and vocational colleges, they did not include key collaborative entities, such as government vocational education management departments and industry associations, nor did they distinguish the differences in vocational education ecosystems between eastern and central-western regions, or between urban and county-level areas. This may lead to "acclimatization" when the conclusions are promoted across industries (*e.g.*, school-enterprise cooperation in low-digitalization traditional service industries and agriculture) and implemented across regions (*e.g.*, cooperation between county-level vocational schools in central and western regions and local SMEs). In future promotion and application, SMEs may struggle to build standardized data middle platforms due to high technology investment costs and weak data security protection capabilities. Additionally, differences in information resource types (*e.g.*, field practice data in agriculture and forestry, and creative project materials in art) and communication needs between specialized colleges and their corresponding industry enterprises may result in insufficient adaptability of the existing collaborative model. All of these factors may restrict the effective and wider promotion and implementation effects of the research conclusions.

Future research could be expanded and deepened across multiple dimensions. Theoretically, interdisciplinary perspectives, such as technology diffusion theory and collaborative governance theory, could be introduced to explore the dynamic evolution of communication mechanisms, validate applicability across different regions and industry contexts, and establish dynamic sharing rules, such as the "graded confidentiality system" proposed by Enterprise Employee A27 (A27—environmental protection industry staff). Methodologically, combining large-sample questionnaire surveys and experimental research could help validate the theoretical model, while longitudinal case studies could track the dynamic effects of mechanism implementation, as highlighted by Student A08 (Animation Design student): "Longitudinal tracking over 3-5 years is needed to evaluate the long-term effectiveness of communication mechanisms". Practically, the ongoing exploration of generative AI in intelligent talent demand matching could analyze corporate job descriptions and institutional course syllabi to automatically generate "skill gap reports", thereby shortening the demand cycle. Research on metaverse technology in "virtual joint training" could examine communication mechanisms in which institutional teachers and enterprise mentors co-guide students in virtual environments, annotating technical points in real time to enhance interactive practical teaching. Teacher A12 expressed anticipation of "using metaverse technology to simulate enterprise workshop operations" (A12—Mechanical Manufacturing teacher). Exploring new communication scenarios, such as intelligent interaction and virtual training, could advance industry-education communication modes toward greater intelligence and predictability. Simultaneously, efforts should be made to strengthen the practical translation of the research outcomes by transforming theoretical models into actionable policy toolkits and performance evaluation frameworks. These tools would provide decision-making references for educational administrators and industry-education collaboration entities, supporting the digital transformation and high-quality development of vocational education while improving the effectiveness and feedback efficiency of information resource communication in industry-education cooperation.

DECLARATIONS

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Author contributions
Hu YF: Conceptualization, Methodology, Data curation, Software, Validation, Formal analysis, Investigation, Writing—Original draft, Writing—Review and Editing. Wang HY: Resources, Writing—Review, Supervision, Project administration, and Funding acquisition. All authors have read and approved the final version.

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Not require.

Informed consent
This paper does not involve the privacy of interviewees such as their portraits and names. Only their remarks are recorded and anonymized. Informed consent has been obtained from all participating interviewees, who agree

that their remarks can be published in the journal. Meanwhile, all participants were informed that the interview data would only be used for research purposes, and their information would be anonymized when presenting the research results. In addition, participants are allowed to stop the recording at any time during the interview and can refuse to answer any questions asked during the interview.

Conflict of interest

The authors have no conflicts of interest to declare.

Use of large language models, AI and machine learning tools

None.

Data availability statement

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

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