The Logic, Model and Pathways of Industry-Education Integration in Developing Secondary Vocational Teachers' Digital Literacy

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Abstract: In the digital transformation of vocational education, secondary vocational teachers' digital literacy has become a key factor affecting the quality of technical and skilled talent training. Policies have continued to promote the use of industry-education integration to enhance teachers' digital literacy. However, related studies have examined the impact of introducing digital technology on industry-education integration, but little attention has been paid to how the operation of industry-education integration affects the development of teachers' digital literacy. This paper studies the applicability of an ecological perspective to the development of digital literacy among secondary vocational teachers in industry-education integration. The underlying logic of this support is explained, and an analytical model of this support is presented with the four elements of educational actors, educational resources, educational environments, and educational relationships, at the four levels of input, process, conversion and feedback. Based on the above, and in the context of secondary vocational education, some practical paths have been proposed for teacher participation, industrial digital resources, industrial practice environments and mutually beneficial school-enterprise cooperation. The above paths can promote the cultivation and enhancement of digital literacy among secondary vocational teachers through industry-education integration.

Keywords: Industry-Education Integration; Secondary Vocational Teachers; Digital Literacy; Educational Ecology; Digital Transformation of Vocational Education

1. Introduction

With the rapid development of digital and intelligent technologies, new technologies such as artificial intelligence and big data are bringing major changes to the form of education and teaching methods. Teachers' literacy and abilities continue to develop in response to these changes, making teachers a key force in addressing the educational changes brought by new technologies. As a type of education with equal status to general education, secondary vocational education is a main setting for training highly qualified technical and skilled talent. It plays an irreplaceable role in serving industrial upgrading and promoting regional economic development [1]. Secondary vocational teachers are responsible for training technical and skilled talent. Digital literacy is a basic ability for adapting to teaching changes in the Education Informatization 2.0 era, as well as a condition for training talent that meets industrial needs. Improving secondary vocational teachers' digital literacy has therefore become an important issue in modern vocational education reform.

In 2022, the Department of Vocational and Adult Education under the Ministry of Education listed "promoting the digital upgrading of vocational education" as one of its key priority tasks. Concrete measures are needed to promote the high-quality development of vocational education through industry-education integration and school-enterprise cooperation. In 2024, the General Office of the Ministry of Education issued the Notice of the General Office of the Ministry of Education on Strengthening the Development of Municipal Industry-Education Consortia. Improve the practical skills, professional capabilities and digital literacy of teachers through school-enterprise cooperation and training in digital technology to cultivate "top-tier teachers" for vocational education. Therefore, it can be seen that industry-education integration will help promote the digitalisation of vocational education and enhance the digital literacy of teachers. Most of the existing research focuses on the topic of digitalisation and its

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promotion of industry-education integration. There is a relative lack of research on how industry-education integration functions and its impact on the development of teachers' digital literacy. To some extent, this reduces the role of industry-education integration in cultivating the digital literacy of secondary vocational teachers to that of technology input or resource addition. The formation of digital literacy is viewed as the outcome of external training, and the effects of its internal development in the actual settings of industry-education integration have been ignored. Therefore, it is necessary to begin with industry-education integration itself and investigate how the integration of industry and education supports the digital literacy of secondary vocational teachers. Ecologically speaking, this paper investigates the suitability of industry-education integration for cultivating the digital literacy of secondary vocational teachers and presents the reasons behind it. Then, it constructs a corresponding analytical system to provide theoretical support and a reference for teachers' development of digital literacy in the process of digitalisation of secondary vocational education.

2. The Internal Logic of Industry-Education Integration in Developing Secondary Vocational Teachers' Digital Literacy

2.1 The Suitability of Ecological Theory for Analyzing the Support Provided by Industry-Education Integration

Ecology is the study of the relationships among organisms, populations and their environment. With the worsening of the environmental problem, it has attracted the attention of scholars. Ecological theory studies the relationships among actors and their environments from the perspective of systems, balance and the whole, and is now widely used in education. In the 1970s, Lawrence Cremin, president of Teachers College, Columbia University in the United States, used the biological concept of the ecological niche to develop the theory of educational ecology. Based on ecological principles and ideas and methods, educational ecology studies the structure and functions of educational ecosystems and explores how to achieve a suitable educational ecological structure and the best ecological functions. It views education as an ecosystem, and various factors in the educational environment and other components affect the educational ecosystem and people involved in education [2]. The internal ecological factors of the secondary vocational education ecosystem include teachers, students, curriculum and teaching resources, etc.; the external ecological factors are policy orientation, industrial demands, and the technological environment.

Vocational education crosses boundaries and is in close cooperation with society, thus having a unique ecological system. Among the various educational ecosystems, that of secondary vocational education is relatively focused on the external environment of industries and enterprises. Therefore, industries and enterprises are necessary external factors in this ecosystem from an ecological perspective. They are the main reasons for its existence and the direction of development [3]. In this educational ecology, the impact of industry-education integration on the digital literacy of secondary vocational teachers can be seen as a process where external factors affect internal ones. On the one hand, industrial investment and support under industry-education integration constitute a form of bottom-up control. Here, bottom-up control is not used in the strict sense of trophic-level control. It is based on the ecological logic of resource supply driving system response. Resource subsidies in the form of industry tools and data improve teachers' access to digital resources and their usability. They improve the living conditions for digital teaching practice, reduce the obstacles to applying digital technology, and increase the frequency of teacher use of this technology. At the same time, under the external support of industries and enterprises, the internal factor of secondary vocational teachers' digital literacy is being progressively enhanced by resource support and positive feedback from the value of practice. Industries and enterprises provide the tools, data, platforms and real environments. With the help of these external factors, secondary vocational school teachers do not just learn a tool, but use digital technology more often, in greater depth and closer to real tasks. Their digital literacy is gradually increasing. At the same time, these gains are spread throughout the group via organisational mechanisms, and thus improvements in digital literacy gradually reach more people in the group. When the level of external support is high and it can work well with the positive feedback from the teacher group, the entire educational system may undergo a qualitative change. It may move from a relatively low level of digitalisation to a higher one,

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becoming more resilient and better able to adapt to changes in the environment and the industry. Therefore, in terms of industry-education integration, industrial tools and resources can be used to improve the operation of the educational system directly. They can also improve the structure and functions of the entire educational ecosystem by supporting and promoting the internal factor of teachers' digital literacy.

Ecological theory can therefore explain the internal logic of how industry-education integration fosters teachers' digital literacy. Its ability to explain interactions among factors also makes it a suitable theoretical tool for analysing this issue.

2.2 Four Aspects of the Logic of Industry-Education Integration in Developing Secondary Vocational Teachers' Digital Literacy

Based on the ecological theory of factor interaction discussed above, the mechanism through which industry-education integration develops secondary vocational teachers' digital literacy can be examined in four aspects.

First, according to the ecological niche theory, external factors extend the scope of digital resources, and internal factors promote the development of abilities. An ecological niche is the particular location of a species in an ecosystem. In educational ecology, it is the position of an educational actor in time and space, their functional role, and how they use resources in the educational ecosystem. The two main dimensions for measuring ecological niches are Niche Breadth and Niche Overlap. Niche breadth is the range of resources available to individuals or groups in a particular environment. Greater niche breadth is associated with greater resource possession and use [4]. The development of digital literacy among secondary vocational school teachers through industry-education integration can be viewed as an extension of resource boundaries. School-enterprise cooperation brings digital tools and real-life scenarios from the industry into the education system. Teachers can obtain and use digital resources in various task environments to expand the breadth of their ecological niche. Various digital resources help teachers be more flexible and creative in their use of technology for teaching. The improvement in abilities resulting from this broader niche will enhance the digital literacy of secondary vocational school teachers. Niche overlap is the intersection of resource use by different individuals or groups [5]. This overlap often means competition for resources in ecology. However, secondary vocational education is also a vocational type. When industry-education integration creates a reasonable overlap in the niches of industry and teachers for digital technology resources, this overlap will be cooperation rather than competition. In collaboration with experts from the industry, teachers develop niche overlap with industry in the application of digital skills. In this area of overlap, teachers are acquiring the digital abilities of industry through communication and learning to build their own literacy. Industry-education integration expands the ecological niche of teachers by increasing their niche breadth in digital resources and raising niche overlap between schools and enterprises. In light of the above changes, the utilisation of digital resources will be more efficient and better suited to the development of digital literacy for secondary vocational school teachers.

Second, according to the law of energy flow, external factors provide digital technology efficiently, and internal factors absorb and convert it with minimal loss. According to the ecological concept of energy flow, energy in an ecosystem is transferred in one direction through food chains and, in doing so, changes from a high-energy state to a low-energy state [6]. Advanced digital technology, data and practical applications provided by the industry can be considered an "energy source". When industry and education operate independently, these resources can only be brought into the education system as external materials. They are often reduced to simple textbook content or standardised materials and then reach individual teachers through courses or teacher training. Due to the one-way and declining flow of energy, some loss will occur in the transfer of knowledge and skills from industry to teachers. The Organisation of educational activities affects the transfer efficiency. If the transfer chain of enterprises' digital resources to secondary vocational teachers is too long, then the information and abilities carried will be reduced at each link. Organising the stages in close proximity will improve the convenience of connection and enhance the impact of learning for teachers' digital literacy. The thermodynamic phenomenon of "increasing entropy" can be considered an ineffective dissipation of educational resources, such as fragmented

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information, disorganized tool use, and disconnected learning environments. To avoid the loss of digital knowledge and skills during transmission, the governance of industry-education integration can shorten the transfer path through cooperation. It can avoid the loss of multiple transfer stages and directly meet the digital needs of secondary vocational teachers, fully converting the details of digital skills that might be lost along the way into teachers' reserves of digital ability.

Third, in light of the logic for overcoming the flowerpot effect, external factors alter the teaching environment, and internal factors enhance adaptability. The flowerpot effect is that although an ecological individual may thrive in a closed or semi-closed environment, such conditions can reduce its adaptability and flexibility in the face of changes in the external environment. As a result, the range of ecological tolerance is relatively narrow, and its ecological niche has decreased. It may not be able to adapt in the outside world and may lose some functions or even die. In the ecosystem of secondary vocational education, the "flowerpot effect" refers to teachers remaining in a stable "teaching comfort zone" for an extended period and thus lacking digital experience. Their Digital Adaptability to External Changes Gradually Declines. With the changes in the external environment and the progress of digitalisation in the industry, secondary vocational school teachers struggle to meet the industry's digital needs, and their digital literacy development lags behind [7]. Address the "flowerpot effect" through industrial-educational collaboration. Real-life scenarios in the digital industry can be used to introduce advanced technologies, such as enterprise cloud platforms, the industrial Internet and digital twins, in classrooms. Teachers should also participate in the enterprise's projects regularly. Enterprises open access to data assets, schools provide case-based courses, and then update the knowledge of secondary vocational teachers and apply this updated knowledge in teaching and practice. Thus, the digital literacy of secondary vocational teachers develops from "school greenhouse skills" into abilities that can be applied in various first-line industrial scenarios.

Fourth, in accordance with the principle of mutualism, external factors offer support and internal factors, in turn, provide benefits. Vocational Education and Industrial Development are naturally interdependent [8]. Mutualism in ecology is a stable, long-term coexistence and interdependence of different species that is beneficial to both. It is not only necessary for life; it is also a form of cooperation in the course of evolution. According to this theory, the symbiotic relationship in the secondary vocational education ecosystem under industry-education integration is a form of "mutual empowerment through symbiosis". The industry offers high-end digital tools, industrial data and application environments; in turn, schools and teachers provide excellent technical and skilled talents and research results. Both enterprises and teachers are recipients and givers of support in this network of relations. It is a type of mutualism in ecology; thus, the relationship is not about a one-time input of resources but stable, long-term support in both directions. The digitalisation of jobs in the industry requires secondary vocational teachers with technological literacy who can train others. Teachers can also use teaching research to help the industry solve some small-scale technical problems. To cultivate talent meeting market needs in secondary vocational education, teachers need to be more digitally literate. Teachers find it hard to overcome practical difficulties through learning in schools alone. These needs cannot be addressed by short-term cooperation. A long-term connection is required for teachers to consolidate their learning through regular practice. With the deepening of interaction, this mutual-supportive relationship of shared interests will gradually evolve into a community with a common future. Industry and education are no longer loosely connected partners, and the support becomes deeper and more precise. It changes from "learning what is offered" to "filling gaps in what is needed". Thus, the digital literacy of secondary vocational teachers will be enhanced by this close cooperative relationship.

3. A Model Framework for Industry-Education Integration in Developing Secondary Vocational Teachers' Digital Literacy

3.1 Four Elements of Industry-Education Integration in Developing Secondary Vocational Teachers' Digital Literacy

The development of the educational system at the level of ecology is the result of the interaction among various factors. Based on the previous

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discussion of the internal logic of this support, this paper proposes a support model with four components: educational actors, educational resources, educational environments, and educational relationships. Under the ecological approach, these four elements have ecological features in industry-education integration [9,10]. "Ecological" is not merely a figure of speech in this context. It indicates that the way these four factors exist and function is suitable for the ecological system of explaining interactions among factors.

3.1.1 An ecological approach to educational actors: the internal driving force for digital literacy development

Educational actors are the core element of the support model for industry-education integration. Secondary vocational teachers organise digital teaching and directly experience improvements in digital literacy through this support process. In this model, the ecological concept of educational actors is implemented through the expansion of their functions and changes in work patterns. Under the framework of industry-education integration, teachers are members of the school-enterprise cooperation network and connect industrial resources with teaching activities. Teachers actively absorb digital resources supplied by industry in open practical settings. They use these resources to develop their own digital abilities through teaching and practice, and then spread these abilities throughout the organisation. Teachers translate industrial logic into teaching logic in practice, and educational actors can also develop by participating in activities within the educational ecosystem. In this ecological view, educational staff are no longer passive recipients of digital resources but actively develop their own digital literacy through application and continuously disseminate these skills.

3.1.2 An ecological approach to educational resources: the external supply for digital literacy development

Digital Resources are the foundation for enhancing teachers' digital literacy. To bring in industrial digital resources and effectively utilize them for education, we need to break down the boundaries between education and industry. High-end industrial resources can provide the necessary support for developing the digital literacy of secondary vocational school teachers. Ecological approach to educational resources refers to shifting the focus from accumulating resources to making them usable and easy to use. In the past, many schools have sought to increase the richness of their resources by purchasing platforms and building resource libraries. However, these resources were often "visible but out of reach". Teachers did not have an effective way to use them and thus were unable to achieve the desired results with the resources. What secondary vocational teachers need is practical resources that can be used directly in class, not just seemingly plentiful resources. In industry-education integration, an ecological approach to resources is used to bring enterprises' advanced digital achievements directly to the classrooms and practical training. Teachers then use real industrial data that can be applied in practice, simulation environments for exercises, and intelligent tools that can be used directly. There are many such resources, and they are also suitable for teaching. Teachers can learn how to use them quickly, make them "useful", and apply them flexibly according to the teaching needs to make "good use" of them. They can be adapted and improved by practice to create new resources [11]. Therefore, the basic problem that an ecological approach to educational resources addresses is whether teachers can use these resources and use them well to make industrial digital resources a real external source for teachers' development of digital literacy.

3.1.3 An ecological approach to educational environments: a shared setting for digital literacy development

The formation of digital literacy among secondary vocational education teachers is being promoted by the joint efforts of education and industry. At the foundation of an ecological approach to educational environments is the construction of an "open environment" connecting the school with the outside world. Virtual simulation platforms and digital laboratories offer some support for the construction of teaching spaces incorporating digital technology. These spaces are not bound by physical space and can provide a convenient location for teachers to engage in learning-by-doing activities for digital technology. An open-environment also links the interaction networks of teachers, students and enterprise technicians. Communication and cooperation in the educational community create a social environment for mutual assistance and joint development. Problems that teachers encounter in their actual use of technology can be solved

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quickly through community cooperation, and ideas for applying digital skills are continuously improved by interacting. Teachers are no longer restricted to learning theory at school or passively observing in enterprises. Based on their learning needs, they can choose between virtual exercises and real-life applications freely, and smoothly transfer skills learned in simulated environments to actual work and develop digital literacy.

3.1.4 An ecological approach to educational relationships: institutional support for digital literacy development

Actors, resources and environments are the "hard conditions" for the development of digital literacy, and educational relationships provide the "soft mechanisms" to support a stable operation of the ecosystem. Ecological approach to educational relationships in this paper refers to constructing a stable symbiotic relationship between schools and enterprises. Unlike previous short-term cooperation based on agreements or projects, ecological school-enterprise relationships focus on institutional integration and cultural recognition. Cooperation is not based on single opportunities. The above relationships are long-term collaborations between enterprises and education. Through curriculum design, practical teaching and joint research involving enterprises, teachers can learn about new digital production tools and applications. They can turn the knowledge of advanced industries into teaching materials and skills. Enterprises are also in a good place. They can train talent in line with their requirements better and boost their sense of educational participation and social responsibility through interaction with teachers. Through such a mutually beneficial, long-term interaction, the enhancement of teachers' digital literacy is no longer confined to one-off training or fragmented experiences. It is improved by institutional arrangements.

3.2 Four Levels of Industry-Education Integration in Developing Secondary Vocational Teachers' Digital Literacy

At the level of process, the development of digital literacy for secondary vocational teachers through industry-education integration can be divided into four stages: input, process, conversion and feedback. These four stages focus on the basic questions of this support. The first is the entry of industrial digital resources into secondary vocational schools. Secondly, how to deliver digital resources to secondary vocational school teachers effectively. Thirdly, there are practical applications of how teachers turn digital resources into digital literacy in different environments. Fourthly, there is the issue of sustainability: what kind of relationships can maintain the supply and operating environment?

3.2.1 Input level: industry-education overlap expands access to digital resources

An "area of overlap" has emerged for enterprises' actual business activities and schools' teaching tasks, and consequently, there is an intersection in the use of digital resources. Thus, industrial tools, data and platforms can be brought into the school teaching system via school-enterprise cooperation. Due to the similarity of tasks, teaching activities and actual work have matching goals and processes. Digital resources originally used by enterprises for production and operation are now applied in education. Enterprises' internal digital resources can be utilised for educational purposes and applied directly by teachers in courses and teaching. Therefore, the industrial digital resources enter the teaching environment in their original form. Joint school-enterprise development and project practice build a "shared resource area" integrated into the school's teaching environment and provide digital support for teachers. It increases the scope of resources and the space for application available to teachers in the secondary vocational education system. It provides a stable foundation of digital resources to help teachers continuously access and use new digital technologies for the development and accumulation of their digital literacy.

3.2.2 Process level: making transfer routes more direct for efficient digital resource transfer

At the intersection of industry and education, the effective transfer of digital resources is key to enhancing teachers' digital literacy. Too many transfer steps will lead to the dispersion of resources due to repeated processing and formalisation. The content teachers finally obtain may be different from actual industrial practice. The value of industry-education integration is to use institutions and relationships to enhance the directness of transfer at this level, thus meeting the needs of teachers for enterprise tools, data and settings more directly. Enterprises can open platform accounts, provide project datasets, or establish a "dual-mentor system" for one-on-one communication and guidance between industry experts and teachers, etc. Thus, the loss of a traditional conversion into textbooks or training

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materials can be avoided. Direct Supply reduces the path of resource flow and helps teachers learn about digital resources better and use them more frequently. Industrial digital abilities can be added to the teachers' literacy with little loss. In other words, through industry-education integration, a shorter transfer path and a closer alignment with actual needs can help the high-energy digital resources of industry retain more of their original value in educational institutions. Teachers can better absorb them as digital literacy and increase the conversion rate of external information into internal learning for teachers.

3.2.3 Conversion level: industrial settings drive the conversion of digital resources into literacy and abilities

Under the umbrella of industry-education integration, the development of digital literacy for secondary vocational teachers shifts from relatively closed and controlled classrooms to open environments close to the industrial sector. Enterprises bring real production processes, project cases and digital platforms to schools to create teaching environments of simulation and practice. Teachers are not limited to textbooks and demonstrations. Given that the tasks are close to industrial work, training needs to cover data processing and tool use, etc., and address the impact of technological updates directly. Practical Scenarios in Front-line Industries Move Teachers Out of Their "Teaching Comfort Zone". The restricted digital experience in schools is continuously tested and corrected by external demands. Through many rounds of joint school-enterprise practical training, teachers have adapted their use of technology under real constraints and turned scattered operating experience into transferable digital skills. Continuous adaptation to a changing environment has enabled the development of practical digital literacy for new-era industrial technology changes. This is a shift from greenhouse skills to adaptive literacy.

3.2.4 Feedback level: mutual benefits ensure sustainable digital literacy development

Industry-education collaboration establishes a long-term relationship based on practical benefits. It is based on the mutual needs for talent cultivation and industrial development. The Digital Transformation of Industry Demands Talents with Strong Digital Literacy and Technical Knowledge. Training such talent requires secondary vocational teachers with high digital literacy. At the same time, the improvement of these teachers' digital literacy also requires the digital resources and practical conditions provided by industry. Therefore, the two sides are in harmony in function. Their stable, long-term support has enabled the continuous introduction and improvement of industrial digital resources in schools and the educational environment through digital technology. As a result of investment in industrial resources, teachers' digital literacy has been enhanced and can now support the development of the industrial system by improving technical and skilled talent training. It will encourage more collaboration between enterprises and schools. Through this interaction, industrial digital resources are integrated into the educational process and become a permanent feature of the learning environment. A positive cycle of mutual benefits has emerged from the improvement of teachers' digital literacy and industrial development.

4. Practical Pathways for Industry-Education Integration to Develop Secondary Vocational Teachers' Digital Literacy

The previous parts have presented the reasons for and analytical model of how industry-education integration fosters the digital literacy of secondary vocational teachers. Next, we will address the problem of how this integration can enhance the digital literacy of secondary vocational teachers.

4.1 Use Teachers' Deep Participation to Develop Digital Literacy in Industry-Education Settings

An ecological approach to educational actors is shown in the development capabilities of teachers through industry-education integration practice. Secondary vocational school teachers are the links connecting industry and education in the educational ecosystem. Their development of digital literacy requires full participation in the industry-education system.

First, have teachers participate in industrial practice regularly and do not treat the enterprise practice as a one-time placement or short-term experience. On the one hand, joint school-enterprise projects should involve teachers in the digital production, management or service processes of enterprises to enable them to experience and use digital tools, data platforms and business systems in actual work. At the same time, teachers' industrial practice should be integrated into their teaching responsibilities and

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included in the overall process of teaching design and course implementation, rather than being an "additional activity" outside of teaching. Through repeated practice and use of digital technology, teachers have developed stable digital literacy and operating skills. Second, integrate teaching tasks and production tasks to accumulate experience through repeated application in both teaching and industrial practice for teachers [12]. Digital experience obtained in industrial practice can be directly converted into teaching cases, teaching tasks or practical training projects to make the teaching content more authentic and current. At the same time, problems that arise in teaching can be brought into industrial practice for real-world problem-solving by teachers. Through several cycles of teaching and industrial practice, teachers have gained more knowledge of and applied digital technology. Third, teachers should join the industry-education integration environment as a participant. Teachers of the projects and tasks in practice should have clear roles and responsibilities, such as participating in the improvement of the digital process, helping enterprises provide technical training, or assisting in solving real production problems. Compared with passive reception, active participation in the set-up activity can enable teachers to learn about digital technologies in more depth and apply them frequently. They can continuously adjust and improve the structure of their digital skills in the process of problem-solving.

4.2 Use Direct Resource Supply to Improve the Efficiency of Converting Industrial Digital Resources into Teachers' Abilities

The Function of educational resources is not limited to increasing their quantity. The first is to strengthen the integration of industrial digital resources in education and to expand the scope of teachers' application of these resources. From an ecological perspective, whether teachers can effectively use industrial digital resources, whether they are familiar with the digital technologies actually employed by enterprises, and whether this leads to an improvement in their digital literacy, depends on two factors: whether the resources enter teachers' practical environments in a form close to their original state, and whether the supply of resources meets teachers' teaching and practical needs.

First, shorten the transfer path of industrial digital resources to teachers' work and avoid losses due to multiple translations. In the old system, these resources often had to be prepared by textbooks, courses or central training before they could be used in teaching. Repeated processing simplifies or even distorts the resources, so what teachers receive differs from actual industrial practice. Direct school-enterprise cooperation can eliminate the middleman and allow teachers to access the digital platforms, business systems and data resources of enterprises directly. For example, the jointly built practical training platform and shared enterprise system accounts and real project data can be used directly by teachers for industrial digital resource applications. It keeps all the information and application logic of the resources, helps teachers learn about digital technology, and improves their operating proficiency. Second, turn industrial digital resources into resources for the development of teachers' abilities. Focus on the actual needs of teachers for improving their own digital literacy and stop focusing on how to turn resources into teaching materials. Schools and enterprises can jointly form resource development teams to help teachers solve problems in digital teaching, such as the use of tools, data processing, and platform operation and maintenance. Collect relevant content from industrial digital resources, develop digital ability resource packages for teachers specifically, and provide supporting operating guides and application case libraries. It can help teachers apply what they have learned in their teaching. Third, match resources with the actual teaching and other needs of teachers for more targeted resource conversion. The development of digital literacy for secondary vocational school teachers depends on digital resources closely linked to their teaching tasks, subject areas and practical work. In matching resources, schools and enterprises can use course development, practical training projects, and teaching reform to identify teachers' digital needs at various stages of teaching. Then, enterprises can provide tools, data and application settings according to their needs. Industrial digital resources are directly used as tools for teachers' teaching design and practice, so they are used more frequently and the results of conversion are improved.

4.3 Use Industrial Settings to Turn Digital Experience into Transferable Abilities

The Settings where secondary vocational teachers use digital technology in the relatively closed teaching environment of schools are quite

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limited. They often focus on the existing teaching platform and regular teaching activities. Most of the digital experience for teachers is used in class teaching and has a limited number of applications. Over time, repeated use of the same tools in limited environments can lead to teacher dependence on specific technologies and operating modes, exhibiting characteristics of the "flowerpot effect". At present, teachers have some experience with digital operations but have seldom tested this experience in real production settings. It is difficult for them to meet the new technical demands and application requirements of industrial digitalisation. Therefore, teachers' digital literacy needs to be cultivated through open and changing practices in line with the logic of real production.

First, create practical environments close to the production process based on real industrial projects. Through school-enterprise cooperation, the enterprise's current digital projects and specific production tasks can be incorporated into teachers' practice, and teachers can participate directly in the project implementation. Given the actual production constraints and task requirements, teachers need to continue adjusting their use of digital tools and deepen their understanding of the logic of technology through repeated practice. Teachers are learning about the application of digital technology in manufacturing. The previous dispersion and disconnection of operating experiences have been connected, and now digital experience is changing from simple use to all-encompassing understanding. Second, create combined industrial environments to connect simulation with actual operation and enhance the transferability of digital experience. Along with real production environments, virtual simulation platforms and digital practical training systems can be employed to break down and simulate industrial production processes for practice. In a relatively controlled environment, teachers can repeatedly perform the main operations and become familiar with the steps and functions of digital tools. This reduces the pressure of operating directly in real production. Teachers can then go to a real production or service site and use what they have learned. Connect simulation training with actual work and, in various environments of different difficulties, conduct tests and corrections for existing experiences. Digital experience becomes stable across different settings and develops into transferable abilities. Thirdly, bring industrial problems into teaching practice to turn digital experience into teaching ability. Teachers' digital practical experience in industrial environments can be introduced to classroom teaching through case development, task design, and practical training projects to create reusable teaching resources. At the same time, teachers need to restructure their digital knowledge and operating logic according to students' learning characteristics and teaching goals, deepening their understanding of digital technology. Thus, teachers' digital experience has been repeatedly applied and tested in classroom teaching and other applications to develop a form of digital literacy suitable for various teaching circumstances and industrial demands.

4.4 Use Mutually Beneficial Relationships to Build a Long-Term Pathway for Teachers' Continued Digital Literacy Development

In industry-education integration practice, if school-enterprise cooperation is limited to individual projects or one-off tasks, teachers' opportunities for practice and resource support will typically cease after the completion of the project. Their digital experience may not be continuously updated, and thus, there will be no progress made after some time of use. For teachers to continue participating in industrial practice and repeatedly using industrial digital resources, schools and enterprises need to maintain a relatively stable cooperation. In terms of mutualism, for school-enterprise cooperation to continue in the long run, both parties need to obtain stable benefits from the interaction. Therefore, the improvement of teachers' digital literacy needs to be achieved through cooperation, and enterprises and schools should work together to share benefits from long-term collaboration. Enhancing Teachers' Digital Literacy Will Benefit the Education System. However, for enterprises focused on economic returns, the willingness to participate will naturally be lower in the absence of clear returns from the work or practical benefits.

First, directly assign teachers to the tasks of the enterprise's digital development according to their actual needs. In cooperation, the school can have teachers participate in some tasks that have moderate technical demands but still require a considerable amount of effort, such as data organisation, system testing, operating procedure optimisation and feedback on platform use.

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Generally, these tasks take up much of enterprise technicians' time and do not contain sensitive business information; thus, they are suitable for teachers. Teachers' participation reduces the workload of enterprise staff and improves the efficiency of digital projects. Through repeated participation in certain activities, teachers will learn about the digital system and business process and improve their use of technology. Embed teachers' participation in the enterprise's work to allow the company to enjoy the benefits of collaboration. Second, turn the results of teachers' digital practice into teaching and training materials for enterprises. Teachers can learn from enterprises' digital practice and gather a large number of operating cases. Schools and enterprises can use this content to develop operating guides, case manuals or training materials for new-employee orientation and job-skill improvement. Reduce the company's training costs and help employees get used to the new digital system. Teachers also learn about digital technology in their preparation for and teaching of classes. Third, involve teachers in trials and feedback on enterprises' digital tools or system applications. In the process of building new digital systems, platforms and tools need to undergo several rounds of testing and application checks. In school-enterprise cooperation, some system trial and application feedback work can be given to teachers of industry-education integration. Under the direction of enterprise technicians, teachers try operating procedures, function settings and effects of digital systems, record problems that occur during use, and provide improvement suggestions. Teachers' trial feedback help the enterprise find problems with the operation or workflow before the full-scale deployment of the system and reduce subsequent adjustment costs. After repeated trials and feedback, teachers have learned the operating logic and application settings of these digital tools. With continuous use in practice, the digital experience will be enhanced.

5. Conclusion

From an ecological perspective, this paper explores how industry-education integration empowers secondary vocational teachers' digital literacy. It argues that industries act as critical external factors, and the improvement of teachers' digital literacy hinges on endogenous development rather than simple technology introduction or resource accumulation. Based on niche theory, the law of energy flow, solutions to the flowerpot effect, and the principle of mutualism, this paper elaborates the four-fold logic underpinning the empowerment effect of industry-education integration. Accordingly, an empowerment model is constructed, which takes educational actors, educational resources, educational environments and educational relationships as its four core elements, and features four process-oriented levels: input, process, conversion and feedback. On this basis, situated in the real-world context of secondary vocational education, practical pathways are proposed from four dimensions: deep-level teacher participation, direct resource supply, transformation driven by industrial scenarios, and mutually-beneficial school-enterprise symbiosis. This study introduces the factor-interaction perspective of ecology into research on secondary vocational teachers' digital literacy, breaking free from the limitations of prior scholarship that over-emphasises digital technology per se. The proposed practical pathways are grounded in the realities of secondary vocational school operation. They not only take objective constraints on teacher participation into account, but also attach importance to whether industrial digital resources can be genuinely digested and internalised by teachers. Furthermore, they give full consideration to practical difficulties in constructing real-world practice scenarios and pursue the long-term sustainability of school-enterprise cooperation. This research provides certain reference value for schools and teachers engaged in relevant practical work.

References

[1] Wang Jingjie. The Development Index and Direction of Modern Vocational Education from the Perspective of Building a Leading Country in Education. Journal of Vocational Education, 2023, 39(10):31-41.

[2] Zhang Huiqing, Wu Yonghe. The Meaning, Challenges and Pathways of Digital Transformation in Higher Education from an Educational Ecology Perspective. Journal of Southwest Minzu University (Humanities and Social Sciences Edition), 2024, 45(09):204-214.

[3] Bai Ling, Li Guiting, Sun Yating. Practical Barriers and Solutions to Developing Vocational Teachers' Digital Literacy from an Ecological Perspective. Vocational and Technical Education, 2025, 46(04):52-58.

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[4] Sun Liwen, Ren Xiangwei. Evaluating the Development of China's Cultural and Creative Industries Based on Ecological Niche Theory. Journal of Beijing Jiaotong University (Social Sciences Edition), 2020, 19(01):64-76.

[5] Shang Naiyan, Li Donghai, Yang Xiaobo, et al. Niches and Interspecific Associations of Dominant Tree Species in Different Forest Layers of Communities Containing the Endangered Plant Heritiera parvifolia. Acta Ecologica Sinica, 2025, 45(07):3389-3400.

[6] Yu Guangming, Li Xinmin. On Energy Flow in Ecosystems. Journal of Central China Normal University (Natural Sciences Edition), 1992, (02):125-129.

[7] Gu Cuifeng, Chen Lan. Improving Primary and Secondary School Teachers' Digital Literacy from an Educational Ecology Perspective. Theory and Practice of Education, 2024, 44(14):41-46.

[8] Peng Guanglei, Zhou Duanming. Development Pathways for Industry-Education Integration in Vocational Education from a Symbiosis Perspective. Journal of Heilongjiang Institute of Teacher Development, 2025, 44(06):88-92.

[9] Zhu Jun. Pathways for Building an Industry-Education Integration Ecosystem for New Business Education in the Digital Economy. Investment and Cooperation, 2022, (10):193-195.

[10] Wu Chaoyang, Lyu Qing, Wu Xiancong. Practical Challenges and Development Pathways for the "Three Teaching Elements" Reform in Secondary Vocational Education. Education Science Forum, 2023, (15):19-23.

[11] Zheng Shuo, Du Dechang. Pathways for the "Classroom Revolution" in Vocational Education in the Context of High-Quality Development. Chinese Vocational and Technical Education, 2022, (02):19-23.

[12] Yang Runhui. Exploring a New School-Enterprise Partnership Model for Developing On-Campus Production-Based Practical Training Bases. Vocational and Technical Education, 2012, 33(05):72-75.

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