

A study on the application and empowerment of hierarchical analysis in the digital competence assessment system for teachers in vocational colleges and universities

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Abstract

The purpose of this study is to explore the application of Analytic Hierarchy Process (AHP) in the assessment of teachers' digital competence in Chinese vocational colleges and universities. Through in-depth analyses of the Digital Literacy for Teachers standard and related digital competency theories, this study constructs a comprehensive assessment model containing three primary indicators and ten secondary indicators. The model uses hierarchical analysis to assign weights to each evaluation indicator, thus providing a scientific and systematic methodological framework. The results of the study show that digital pedagogical competence is the most critical component of teachers' digital competence, especially in digital content creation, teaching and assessment. This study not only provides theoretical and practical support for the professional development and digital teaching practice of teachers in vocational colleges and universities, but also provides a scientific decision support tool for educational management.

Keywords: hierarchical analysis; vocational institutions; teachers' digital competence; assessment models; digital literacy

1. Preface

In the context of the global digital transformation of education, the digital competence of teachers has become a key factor affecting the quality of teaching and the effectiveness of student learning (Wannapiroon et al., 2022). Especially in vocational colleges and universities, teachers' digital skills not only need to meet the basic educational technology application needs, but also have the ability to use digital tools to teach and practice vocational skills (Jubaedah et al., 2022). China's Ministry of Education has therefore developed the Digital Literacy for Teachers standard, which aims to improve the digital teaching skills of the nation's teaching force and promote the modernisation of education (Yu & Jung, 2023).

With the implementation of this policy, how to accurately assess the digital competence of teachers in vocational colleges and universities to ensure the relevance and effectiveness of teacher training and resource allocation has become a focus of attention for educational administrators and policy makers (Agustina et al., 2022). This study aims to provide a scientific and systematic methodological framework for the assessment of teachers' digital competence by constructing a model for assessing teachers' digital competence in vocational colleges and universities based on the Analytical Hierarchy Process (AHP) (Wahyuni et al., 2022).

AHP is a widely used tool for multi-criteria decision analysis, which can effectively deal with mixed qualitative and quantitative decision problems (Agustina et al., 2022). By comparing the theoretical frameworks of digital competence for teachers in vocational colleges at home and abroad, and combining with the standard of Digital Literacy for Teachers, this study will explore how to use the AHP to empower the assessment model of digital competence for teachers in vocational colleges, so as to put forward an assessment system with both theoretical and practical value.

The purpose of this study is to construct and validate an assessment model of teachers' digital competence applicable to Chinese vocational colleges and universities through in-depth analyses of the Digital Literacy of Teachers standard and related digital competence theories, and ultimately to use AHP to assign weights to the evaluation index system of the model. This research can not only provide a scientific decision support tool for the education administration, but also provide guidance and reference for the professional development and digital teaching practice of teachers in vocational colleges and universities.

This study can provide a new perspective and methodology for assessing and improving the digital competence of teachers in vocational colleges and universities, and thus promote the digital transformation and development of vocational education.

2. Theoretical Framework and Literature Review

2.1 Digital Literacy Standards for Teachers

The Education Industry Standard on Digital Literacy for Teachers, issued by the Ministry of Education of China, aims to identify the core competencies that teachers should possess in digital teaching and learning environments (Wang, 2022). The standard covers teachers' skills in the use of digital tools, their ability to design and implement digital teaching and learning activities, as well as their ability to manage teaching and student guidance in virtual environments. In addition, the standards emphasise the importance of continuous learning and professional development for teachers in digital environments (Gu, 2022). The establishment of these competencies provided the initial theoretical foundation for the assessment model of this study.

2.2 Theoretical Framework of Digital Competence for Teachers in Vocational Colleges and Universities in China and Abroad

Digital competence is a key indicator of a teacher's ability to effectively integrate technology into the teaching and learning process (Cabero-Almenara et al., 2023). At the international level, the

DigCompEdu framework published by the European Commission systematically describes the digital competences that educators should possess (Mattar et al., 2022). The framework divides teacher competencies into six categories, including information and data literacy, communication and collaboration, digital content creation, safe use, problem solving, and use of technology (O'Dwyer, 2023). In November 2022, China's Ministry of Education published Digital Literacy for Teachers, which defines teachers' digital literacy in terms of five dimensions: digital awareness, knowledge and skills of digital technology, digital application, digital social responsibility, and professional development (Gu, 2022).

Vocational education needs to emphasise vocational skills, professionalism, practical training and pay more attention to the needs of students' career development (Barboutidis & Stiakakis, 2023). Compared with other types of teachers, teachers in vocational colleges and universities, as the main bearers of vocational education, are faced with the special nature of the vocational environment, the student population and the curriculum, which makes it necessary for them to have higher vocational literacy, more in-depth professional knowledge and richer teaching experience (Lores-Gómez, 2023).

- First, highlighting the training of vocational skills. The educational goal of vocational colleges is to provide students with practical vocational skills training, so teachers in vocational colleges need to have certain professional skills and a wealth of practical experience, be able to teach students practical application skills, and focus on practical teaching and skills training.
- Secondly, emphasis is placed on the development of vocational literacy. Vocational literacy refers to the moral, psychological and social qualities that students need to possess in their professional careers, and is one of the important goals of vocational education.
- Thirdly, focus on the characteristics of practical teaching. Teaching methods in vocational colleges and universities need to focus on practicality and help students master practical skills.

By analysing and comparing these theoretical frameworks, this study identifies the key components of teachers' digital competence that will be incorporated into the constructed assessment model. Such comparative analyses help to ensure the comprehensiveness and applicability of the assessment model.

2.3 Application of Hierarchical Analysis in Education

The Analytic Hierarchy Process (AHP), introduced by Saaty in the early 1970s, is a mathematical tool for solving complex decision-making problems (Krenický et al., 2022). In the field of education, AHP is widely used in a variety of contexts, including curriculum design, educational policy evaluation, and teacher evaluation (Yüksel et al., 2023). By decomposing a decision problem into smaller, more manageable parts, decision makers can more systematically assess the importance of factors and make more scientific decisions accordingly (Baydar, 2022). In this study, AHP will be used to assign weights to each evaluation index in the digital competence assessment model for teachers in vocational colleges and universities, and this process will be based on expert opinions and empirical data.

2.4 Synthesis of the theoretical framework

Synthesising the standards of Digital Literacy for Teachers, the theoretical frameworks of digital competence at home and abroad, and the application of the hierarchical analysis method, this study constructs a multi-level assessment model. The model will analyse teachers' digital competencies in detail from macro to micro and assign weights to the evaluation indicators of these competencies through the hierarchical analysis method. This approach not only promotes the scientific and practical nature of the assessment tool, but also provides theoretical support for subsequent teacher training and development policies.

3. Constructing an evaluation index system

3.1 Methodology for the construction of the assessment model

This study constructed a comprehensive assessment model based on the educational industry standard of "Digital Literacy for Teachers" issued by the Ministry of Education of China, as well as the theoretical framework of digital competence for teachers in vocational colleges and universities at home and abroad.

Firstly, the assessment dimensions are defined, and the key dimensions affecting teachers' digital competence, such as technology operation ability, digital content creation, instructional design and implementation, online teaching management and digital ethics and safety, are identified according to the standards of Digital Literacy for Teachers. Secondly, theoretical framework integration is carried out to incorporate domestic and international research results and theoretical frameworks, adjust and improve each assessment dimension to ensure the comprehensiveness and adaptability of the assessment model. Finally, indicator selection is carried out to choose specific measurement indicators for each dimension, which are defined based on the specific performance of teachers in applying digital technology in actual teaching.

3.2 Evaluate the contents of the model

By combining the theoretical frameworks, components and digital teaching case studies of digital competence in vocational colleges and universities at home and abroad, as well as in-depth analyses of the education industry standard of "Digital Literacy for Teachers" issued by the Ministry of Education, and combining the interviews with 20 vocational college and university teachers conducted by the research group, this study constructs a general framework of the connotative elements of digital competence for teachers in vocational colleges and universities, which contains three primary indicators and 10 secondary indicators (Table 1) of digital competence, digital teaching competence, and digital learning competence including basic digital competence, digital teaching competence and digital learning competence.

3.2.1 Basic digital competence

Basic digital competence refers to the minimum digital skills and knowledge that vocational teachers need in a digital teaching and learning environment, including the use of digital platforms, digital

ethics, digital security and digital society (Yu & Jung, 2023).

- "Use of digital platforms" means that teachers should master the ability to use various digital platforms and tools, such as teaching management platforms, online classrooms and online learning systems (Feoktistov et al., 2020). These platforms can help teachers better manage student information, conduct online lectures, organise student activities and monitor student learning.
- "Digital ethics" refers to the code of conduct and moral norms to be followed in digital environments, such as protecting students' privacy, preventing plagiarism, respecting intellectual property rights, and avoiding illegal and illicit content (Campo, 2020). Digital ethics can help teachers to use digital technology wisely in the digital teaching environment.
- "Digital security" means that teachers should be aware of the need to protect personal privacy and the security of digital information, and should understand and implement the basic principles and techniques of digital security, such as password protection, network security, data security and data backup (Latorre-Medina, 2023). Digital security protects the privacy and security of personal and digital information of teachers and students and prevents unnecessary risks and losses.
- "Digital society" means that teachers should be aware of and actively participate in the development of a digital society (Efthymiou et al., 2023). Digital society involves various aspects such as digital development, digital divide and digital culture. Teachers should be aware of the latest developments in digital technology, promote the development of digital culture and digital citizenship, and guide students to use digital technology correctly. As the audience groups of vocational education have a weak learning foundation, these groups often lack digital skills and knowledge, making it easier for them to fall into the plight of the digital divide. Therefore, teachers in vocational colleges and universities need to strengthen their understanding and management of the digital divide, pay attention to digital education for disadvantaged groups, actively promote digital teaching and resource sharing, and take practical measures to improve the digital divide.

3.2.2 Digital pedagogical competence

Digital pedagogical competence encompasses three areas: digital content creation, digital teaching and digital assessment.

- "Digital content creation" refers to teachers' proficiency in using digital tools and software to integrate, edit, improve, share and reconstruct existing knowledge and content (Kovačević, 2023). Teachers need to understand a wide range of digital software, such as image, audio and video editing software, as well as online teaching platforms. At the same time, teachers need to organically combine digital technology and subject knowledge to create digital educational resources with practicality.
- "Digital teaching" refers to the processes and activities that enable teachers to use digital technologies and tools to achieve education and teaching. Teachers need to make effective use

of digital teaching resources, design and implement digital teaching programmes that meet the requirements of teaching according to the characteristics of different subjects, different grades and different students, and carry out digitally minded teaching activities in a digital teaching mode (Zhang, 2022). For example, teachers can use online courses, multimedia teaching materials, virtual laboratories and other digital teaching tools to improve teaching effectiveness and students' interest and motivation in learning.

- "Digital assessment" refers to the ability of teachers to use digital technologies and tools to assess and provide feedback on students' learning processes and outcomes (Jurane-Bremane, 2023). For example, teachers can use digital assessment tools such as online micro-teaching progress, homework submission, online tests, interactive quizzes, etc., apply digital assessment tools to effectively monitor students' learning behaviours and, through critical analysis and interpretation of students' learning performance and progress, provide students with personalised and immediate feedback and learning support, and formulate targeted and dynamic learning programmes for students. Digital assessment can reflect students' learning situation and level more objectively and accurately, and provide teachers with scientific and accurate teaching assessment data.

3.2.3 Teacher Digital Learning Competencies

Teacher digital learning competence refers to the ability of teachers to learn and develop in digital environments and encompasses three aspects: online learning and reflection, digital collaboration and digital innovation. This aspect of competence is particularly important for teachers in vocational colleges and universities, who need to continually update their knowledge and skills in order to adapt to the changing needs of education and technological development.

- "Online learning and reflection" refers to the ability of teachers to use digital technology for online learning and self-improvement. Teachers can acquire new knowledge and skills through various online learning platforms and digital learning resources to continuously improve their teaching and professionalism. Digital technology provides teachers with more ways to learn and reflect on their own, such as using learning record tools to reflect on their learning and participating in teaching seminars (McLachlan & Tippet, 2023).
- "Digital collaboration", on the other hand, refers to the ability of teachers to work together and collaborate across time and space through digital technologies and tools. Digital collaboration includes not only remote collaboration using tools such as online conferencing and email, but also the use of cloud-based storage and sharing of teaching and learning resources, collaborative editing tools and project management tools to improve the efficiency and effectiveness of collaboration. In addition, digital collaboration also includes collaborative approaches in education such as teacher communities, which aim to improve the quality of teaching and professional development of teachers. Digital Collaboration Modern teaching has increasingly emphasised teamwork, and the emergence of digital technology has provided a convenient way for teachers to collaborate with each other, which can help teachers to work together to complete their tasks, and at the same time promote knowledge sharing, communication and learning (Jurane-Bremane, 2023).

- "Digital innovation" refers to the ability of teachers to use digital technologies to innovate and improve in a digital environment, and encompasses the awareness, ability and vision to transform the future of digital education. Teachers need to continuously learn and master new digital technologies and apply them to their teaching practice to create richer, more effective and lively teaching methods and approaches (Jurane-Bremene, 2023).

Table 1: Digital Competency Assessment Model for Teachers in Chinese Vocational Colleges and Universities

Level 1 indicators		Secondary indicators	descriptions
Basic Digital Competency		Use of digital platforms	Teachers should acquire the ability to use a variety of digital platforms and tools.
		digital ethics	Codes of conduct and ethics to be followed in the digital environment.
		digital security	Have an awareness of the need to protect personal privacy and the security of digital information, and understand and implement basic principles and techniques relating to digital security.
		digital society	A sense of social participation, the ability to understand and actively participate in the development of the digital society, and to actively contribute to the development of digital culture and digital citizenship.
Digital Teaching Competency		Digital content creation	Skilled in using digital tools and software to integrate, edit, improve, share and reconstruct existing knowledge and content.
		digital teaching and learning	Ability to use digital technologies and tools to realise processes and activities of education and teaching.
		Digital assessment	Ability to use digital technologies and tools to assess and provide feedback on student learning processes and outcomes.
Digital Learning Competencies		Online learning and reflection	Ability to use digital technology for online learning and self-improvement.
		Digital collaboration	The ability to cooperate and collaborate together across time and space through digital technologies and tools.
		Digital Innovation	Ability to utilise digital technologies for innovation and improvement in a digital environment.

4. Assessment model empowerment

4.1 Selection of the team of experts

In this study, 10 experts in the field of vocational education in China (**Table 2**) were invited to determine the relative importance of the indicators at each level of the evaluation model using the 1-

9 scale method. The selection of experts included three basic conditions: first, they had the title of associate professor or above; second, they were experts and scholars working in Chinese vocational colleges and universities; and third, they were teachers who had made certain achievements in the field of digital research. All experts were required to participate in the study on a voluntary basis.

Table 2: Descriptive Statistics of Expert Information

No.	Gender	Age	Years of work experience	Educational background	Professional title
1	Male	51-60	≥ 20	PhD	Professor
2	Female	41-50	16-20	PhD	Professor
3	Male	41-50	16-20	PhD	Professor
4	Male	41-50	16-20	PhD	Associate Professor
5	Female	41-50	16-20	Master's degree	Associate Professor
6	Female	41-50	16-20	Master's degree	Associate Professor
7	Male	41-50	16-20	Master's degree	Associate Professor
8	Female	41-50	16-20	Master's degree	Associate Professor
9	Female	41-50	16-20	Master's degree	Associate Professor
10	Female	41-50	16-20	Master's degree	Associate Professor

4.2 Application of Hierarchical Analysis

The Analytic Hierarchy Process (AHP) is the main tool used in this study for empowering assessment models by building a hierarchical structure that defines the goal of the problem (assessing teachers' digital competence), the criterion level (key dimensions), and the programme level (specific indicators) (Nuraini et al., 2023). In this study, a judgement matrix was constructed to assess the relative importance of the elements of the criterion and programme levels by comparing them two by two by collecting the opinions of the expert group, and then the normalised eigenvector w corresponding to the maximum eigenvalue $\lambda_{\max}$ of the judgement matrix was firstly derived by the sum-product method, and then a consistency test was conducted to calculate the consistency ratio (CR) of the judgement matrix to ensure the consistency and reliability of the assessment (Du, 2023). the CR value needs to be less than 0.1 to accept the assessment results. Finally, weights are calculated to extract local and global weights from the judgement matrix, which indicate the relative

importance of each indicator in the overall assessment.

After calculation, it is determined that the CR value of all judgement matrices of each level in the evaluation model is less than 0.1, which indicates that they have good consistency, and can be based on which the weights can be calculated, and then further calculated to obtain the comprehensive weights. That is to say, the weight value of the secondary indicators is calculated first, and then averaged together to get the weight of the first-level indicators, and the weight of the first-level indicators is multiplied by the weight of the second-level indicators to get the final integrated weight, which is the final weight of each second-level indicator in the evaluation system. The final indicator system with the weights of the indicators is obtained (**Table 3**).

Table 3: Weighting values for the overall objectives of the evaluation model

Level 1 indicators	weights	Secondary indicators	weights	Combined weights
Basic Digital Competency	0.3124	Use of digital platforms	0.3154	0.0985
		digital ethics	0.2243	0.0701
		digital security	0.2132	0.0666
		digital society	0.2471	0.0772
Digital Teaching Competency	0.4621	Digital content creation	0.3148	0.1455
		digital teaching and learning	0.4315	0.1994
		Digital assessment	0.2537	0.1172
Digital Learning Competencies	0.2255	Online learning and reflection	0.3824	0.0862
		Digital collaboration	0.3454	0.0779
		Digital Innovation	0.2722	0.0614

5. Conclusion and discussion

The improvement of digital competence is the result of a combination of individual subjective initiative and external support for teachers in Chinese vocational colleges and universities. Subjective initiative requires continuous improvement of one's digital awareness, digital skills and teaching competence through independent learning and practical experience to adapt to the digital teaching environment and teaching needs. External support, on the other hand, includes digital training, resources and technical support provided by the school, as well as assessment and incentive mechanisms. Subjective initiative and external support are interdependent and mutually reinforcing, and together they form the basis of digital teaching. Therefore, to enhance the digital competence of teachers in vocational colleges and universities, it is not only necessary to strengthen teachers' individual subjective initiative, but also necessary to actively guide and make use of external support, such as technology and resources, to build a digital education ecosystem and promote the sustainable development of digital education.

The digital competence assessment model for teachers in Chinese vocational colleges constructed in this study contains 3 level 1 indicators and 10 level 2 indicators, which are assigned weights

according to the hierarchical analysis method, and we can find that "digital teaching competence" occupies the highest weight in the level 1 indicator, with a weight value of 0.4621, which indicates that the most important digital competence of teachers in vocational colleges is in "digital content creation", "digital teaching" and "digital assessment". Digital competence is most importantly embodied in "digital content creation", "digital teaching" and "digital assessment"; "digital teaching" in the second-level indicator has the highest weighting, with a value of 0.4621, indicating that the digital competence of vocational college teachers is most importantly embodied in "digital content creation", "digital teaching" and "digital assessment". Among the secondary indicators, "digital teaching" has the highest weight, with a weight value of 0.1994, indicating that teachers in vocational colleges and universities need to integrate digital technology with education and teaching in depth, and that information technology application ability is changing to the development of systematic and higher-order digital competence of teachers.

The study found that digital content creation, digital teaching and digital assessment in "digital pedagogical competence" are important directions for improving teachers' digital competence. The enhancement of these competencies is the result of both individual teacher initiative and external support. Teachers need to continuously enhance their digital awareness and skills to meet the changing needs of education. At the same time, schools and education departments should provide the necessary technical support and resources to build a supportive digital education ecosystem for the sustainable development of vocational education. In addition, the construction of the methodological framework and assessment model of this study provides feasible references and application prospects for similar studies in other fields.

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