Multiple-role perspective on assessing teaching ability: reframing TVET teachers' competency in the information ageMultiple-role perspective on assessing teaching ability

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Abstract: *In the information age, technology has changed people's lives as well as working and learning styles. The teaching competency of vocational teachers' is facing new challenges. Based on the modernization of vocational education, "Internet + Vocational Education", and "reform of teachers, teaching materials and teaching methods", the study intends to enrich the research on vocational teachers' teaching competency theoretically by establishing the framework, criteria and assessing instrument. In practice, the study aims to provide benchmarks and tools for the diagnosis and assessment of vocational teachers' teaching competency. Furthermore, the study wishes to provide guidelines for vocational teachers' professional development and improve the quality of the ICT teaching practice.*

Keywords: Information age; Digital citizen; Teaching competence; TVET teacher; Delphi; AHP

Introduction

Vocational education has contributed to the rapid development of global manufacturing and service industries, and TVET (Technical and Vocational Education and Training) teachers are starting to play an increasingly important role in the modernization and globalization of vocational education. Vocational education is striving to push through reforms in its teachers, teaching resources and teaching methods, all of which rely on building a team of distinguished teachers (Han & Chen, 2019). However, the status quo of TVET teachers' teaching competency is not commensurate with the demands of the digital era. There is an urgent need for TVET teachers' teaching competency framework and standards in the information age.

Teachers' teaching ability evaluation is one of the core contents of vocational education evaluation. It is also a difficult problem concerned by both the theory and practice of vocational education. The establishment of the TVET teachers' teaching competency evaluation standard based on the needs of schools and industries in the information age can help achieve learning objectives, find out the strengths and weaknesses and improve the teaching quality. The information age has opened up important opportunities for every aspect of our life, and vocational education is no exception. Therefore, it is necessary to clarify TVET teachers' teaching competency standard in the information age.

Based on a study conducted in China to guide the teaching training programs for distinguished TVET teachers, this article adopts a multiple-role perspective to contribute to the further development of an evaluation framework.

Literature review

Relevant literature and studies have defined TVET teachers' teaching competency in three different perspectives: teaching activity perspective, iceberg model perspective and comprehensive perspective.

From the teaching activities perspective, Hopf (1985, Diep & Hartman 2016) proposed a four-dimensional model of vocational teachers: (1) professional competence: abilities to master the professional knowledge to be learned and taught; (2) method competence: abilities to organize teaching content, to establish specific teaching content to improve teaching quality, to master the diversity of teaching methods and to provide diagnostics; (3) relational competence: abilities to build and maintain the relationship with learners; and (4) controlling competence: ability to

guide the learners. Some researchers (Oni, 2007; Okoye & Michael, 2015; Oluwasola, 2014) held the opinion that TVET teachers should be able to manage classroom and workshop, handle teaching aids, evaluate students' performance, apply teaching methods, recognize students' learning styles, meet the needs of students in the classroom, and impart necessary technical knowledge and vocational skills, etc. Likewise, Grosch (2017) discovered that TVET teachers' competency comprised three modules: planning/preparation, implementation and evaluation.

Following the iceberg model, Lai et al. (2017) conducted an exploratory factor analysis and three first-level items emerged: thinking competency, organizational competency and application competency. Andersson and Köpsén (2015), Arifin and Rasid (2017) believed that competencies of TVET teachers include skills, knowledge, attitudes, values, tasks and appreciations related to teaching and training.

In a more comprehensive perspective, Yunos et al. (2010) claimed that TVET teachers should have six competencies: skills, knowledge, ethics and professionalism, social process, social accountability and entrepreneurship.

The fact that scholars adopted different perspectives when analyzing the meaning of TVET teachers' competence indicated that multiple identities of vocational education teachers were already recognized, especially their roles as teachers and technicians/engineers. In fact, in countries like China and Germany, a TVET teacher is encouraged to be "dual professional". These studies provided us with a good theoretical support when analyzing the roles of TVET teachers and the construction of their teaching competence. However, to some extent, insufficient attention has been paid to the changes brought by the

information age to TVET teachers. Existing studies either neglected a TVET teacher's fundamental part as a digital citizen, or diminished the role of ICT ability as a key teaching competency of TVET teachers in the information age.

Although few of TVET teachers standards laid emphasis on information technology and aspects enabled by IT, some well-recognized general teacher standards have attached great importance to the application of ICT in education. UNESCO (2018) has developed ICT-CFT (the ICT Competency Framework for Teachers) as a guidance for teacher training, which clearly highlighted the importance of the widespread use of ICTs in the educational scenarios and emphasized its great potential in supporting teachers' lifelong learning. Similarly, ISTE standards for educators (International Society for Technology in Education, 2017) advocated that teachers should embrace seven roles, each of which embody the use of information technology. The International Board of Standards for Training, Performance and Instruction proposed the Instructor Standards: Competencies and Performance Statements (IBSTPI, 2004), which were designed for both instructors in traditional face-to-face settings, and those in online and blended environments in the 21st century. In these standards, new requirements brought by the changes of technologies and teaching approaches were taken into consideration. In China, a national standard was also released concerning primary and secondary school teachers' ability of applying information technology. It pointed out that information technology has the potential to optimize and even transform education, and that information literacy and ability in lifelong leaning are vital for all teachers in primary and secondary schools (The Ministry of Education of PRC, 2014).

Therefore, to highlight the multiple roles of TVET teachers in the current era, this study adopts a comprehensive perspective to investigate the issue of "what abilities do TVET teachers need in the information age". Finding the answer to this question will help improve the teaching competency of TVET teachers.

Conceptual framework

Multiple roles of TVET teachers in the information age

TPACK (Technological Pedagogical and Content Knowledge) framework (Koehler et al., 2013) reveals all the roles of teachers, such as digital citizens, tutors, and professionals. The elements that constitute the framework of TVET teachers' teaching competency tend to have the role hypothesis behind them. TVET teachers form multiple social relations in their social practice, including the relations between them and other stakeholders within education and outside society. This social relationship can be grouped into two dimensions. One dimension is within the education, including the TVET teacher-student relationship and the TVET teacher-teacher relationship. The other dimension is related to the external society, including the relationship between TVET teachers and industry enterprises, and the relationship between TVET teachers and information society. Based on the above relationships between TVET teachers and internal education and external society, this research identifies four roles for TVET teachers: teachers, lifelong learners, technicians/engineers, and digital citizens.

There are some similarities bewteen TVET teachers and general teachers. As for TVET teachers, they have basic skills of curriculum development and curriculum

teaching that all teachers need to have. Besides the role of teachers, TVET teachers in the information age are supposed to play three more roles: technician/engineer, digital citizen and lifelong learner.

Role of TVET teachers as technicians/ engineers

Compared with general education, the research on the teaching competency structure of TVET teachers pays more attention to theoretical and practical competency (Jafar et al., 2020). At present, there are a large number of cases summarizing the "dual professional" teachers from the perspective of teacher team construction, but few cases exploring the "dual professional" teaching competency structure from the perspective of individual TVET teachers. Compared with teachers of compulsory courses, teachers of elective courses have stronger professional features and are more characteristic of "dual professional" teachers in vocational education. Therefore, the research on teachers' teaching competency of vocational education mainly focuses on the teachers of elective courses. For example, it has been suggested that TVET teachers' teaching competency in vocational education include three first-level components: activity-related component, personality-related component, and social-communicative adaptability (Symanyuk & Pecherkina, 2016). The teaching competency model of pre-service TVET teachers established by Wagiran et al. (2019) includes core competence, hard skills and soft skills. Among them, the core competence mainly refers to teachers' pedagogical knowledge, subject content knowledge and technical knowledge. Hard skills refer to the teaching ability of teachers' practical operation and professional theory courses as well as their mastery of practical operation and professional course content. Soft skills refer to the integrity, reliability, discipline and exemplary character of

teachers. Rofiq et al. (2019) believe that teachers of pre-service vocational education should have abilities in pedagogy, expertise, management, personality and society. Diep and Hartmann (2016) combined perspectives of working process, psychological cognition, competency and teaching activities to construct a framework of vocational education teachers' teaching competence aimed at meeting the goals of sustainable development, including six competence dimensions. From the dialectical relationship between social practice and philosophy, the scenarios of vocational education teaching activities are transboundary, that is, they extend from colleges to enterprises, industries or society. Therefore, higher requirements are put forward for TVET teachers' individual competency.

Vocational education aims at serving social development and promoting employment, cultivating students' professional skills and spirit, enabling them to act correctly in different fields and assume personal and social responsibilities. Vocational institution take school-enterprise cooperation as the mode of school running, combine work with study as the mode of training, and develop the teaching and learning of single school form into school-enterprise cooperation, which leads to the profound reform of vocational education. "High-level colleges and high-level majors" is one of the four pillars to implement the "National Vocational Education Reform Initiative of China" aiming to create a group of leading and supporting higher vocational colleges and specialty groups with Chinese characteristics (China Education Daily, 2019).

Role of TVET teachers as digital citizens

The information age has put forward new requirements for all people. Teachers, as digital citizens, should also posess corresponding information literacy, especially the ability to optimize teaching

in the information environment. Emerging technologies such as mobile internet, cloud computing, big data, IoT(Internet of Things), and artificial intelligence have had a profound impact on vocational education. The popularization of information technology has changed communication, work and life, knowledge structure, information acquisition, and behavior and thinking mode. Teachers need information literacy to take full advantage of the potential of technology and prepare students for the future.

In the information age, the interaction between human development and social development is more obvious, which is reflected in the following aspects: First, the division of labor leads to the transformation from single type of progress work to compound work; Second, technology has led to the development of simple occupations to comprehensive ones; Third, the information explosion has promoted the shift from schooling to lifelong learning. The integration of information technology and education includes three aspects: experience application, strategic innovation, and human reflection. Based on the higher requirements of technological development, it is necessary to construct new teaching environment and adopt new teaching methods to achieve the acquisition of skills and knowledge. In the past two decades, the development of teachers' teaching competency based on technology instrumentalism has been of limited help to improve the teaching quality, and the thinking paradigm of "education + information technology" has been confined to a narrow subject category. It is pointed out that teachers' ICT competency should not be restricted by technologies, and should be deeply integrated with teaching, in order to integrate and reorganize the components of teaching abilities in the information age. The concept and extension of "teaching and learning" are increasingly diversified. New technologies and new models have redefined the requirements of teaching capacity of all teachers, including TVET teachers as well. The TVET teachers' ICT competency are not subordinate to their teaching competency, but is integrated with it. In addition, the information age not only provides a broad space for teachers' international communication and cooperation, but also puts forward new requirements for teachers' international vision and communication ability.

Role of VET teachers as lifelong learners

With the surge of new technological revolution and industrial reform, the pedagogical knowledge, professional skills and information literacy of vocational education teachers are constantly updated. Many once-popular majors, especially in the traditional manufacturing and processing fields, have gradually shrunk from a major to a course or even disappeared, which has brought a great challenge to teachers' professional development. Mass production emphasizes obedience consciousness of employees, that is, each employee is only familiar with one skill. While the team operation represented by lean production emphasizes that every employee is omnipotent, and employees need to constantly improve their current technical and management skills to give full play of their potential, so it is best for TVET teachers to improve their pedagogical knowledge, professional skills and information literacy constantly. UNESCO regards vocational education as part of lifelong learning, involving professional knowledge, skills and attitudes relate to professional production and livelihood, education, training and skills development, etc. (Latchem, 2017). As the core driving force of vocational education reform, TVET teachers should embody the concept of lifelong learning in vocational education in their professional development.

"Dual professional" TVET teachers in the information age

To sum up, TVET teachers in the information age are expected to play four roles: teacher, technician/engineer, digital citizen, and lifelong learner. As is illustrated in Figure 1, TVET teachers fall into seven categories: (1) TVET teachers without information literacy or research & development competency; (2) TVET teachers with research-development competency but lack information literacy; (3) TVET teachers with information literacy but lack research & development competency; (4) technicians/ engineers with research & development competency but lack information literacy; (5) technicians/engineers with information literacy but lack research & development competency; (6) technicians/engineers with information literacy and research & development competency; (7) "dual professional" TVET teachers in the information age. The seventh category is the goal and direction of TVET teachers' teaching ability development.

Figure 1. Multi-role characteristics of "dual professional" TVET teachers in the information age
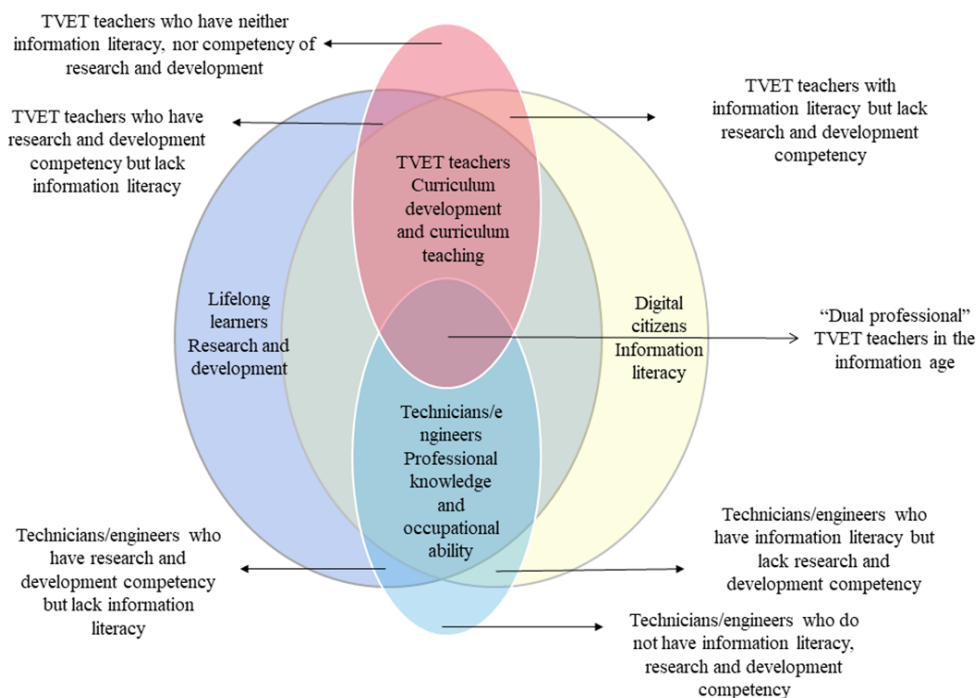
The framework of TVET teachers' teaching competency

Based on the literature review, the first-level criteria is determined, consisting teachers' competency (curriculum development and curriculum teaching), technicians/engineers' competency(professional knowledge and occupational ability); digital citizens' competency information literacy) and lifelong learners' competency (research &

development).

After a careful study of the literature, the preliminary criteria were established, as shown in Table 1. Researchers chose these criteria because they are organized according to the process of teaching activities and working processes. These criteria are derived from research with high recognition and consensus. The review provides a conceptual framework for assessing TVET teachers' teaching competency.

Table 1. First-level indicators evaluating TVET teachers' teaching competency

First-Level Indicator	Main Reference Sources
Curriculum development	Wahba, 2006; Research group, 2010
Curriculum teaching	Peterson, 2003
Professional knowledge	Ally, 2019
Occupational ability	Rofiq et al., 2019
Information literacy	The Ministry of Education of PRC, 2020
Research and development	The Ministry of Education of PRC, 2020

Research questions

According to the literature, the preliminary evaluation indicator system of TVET teachers' teaching competency are established, including sixty-six first-level indicators, twenty second-level indicators and sixty-eight third-level indicators , but the validity still remains to be verified. Therefore, this study proposed a questionnaire survey to obtain the expert group's feedback on the evaluation indicators:

1. What is the evaluation framework to assess TVET teachers' teaching competency?

2. What is the weight of each indicator?

It is expected that the evaluation framework could provide a reference for the evaluation and improvement of TVET

teachers' teaching ability.

Methods

Delphi method

The Delphi method, which aims to obtain consensus among experts, is a multi-stage research process, and each stage is based on the results of the previous stage. A series of repeated questionnaires are collected to gather feedback from a panel of experts in particular field (Sharkey & Sharples, 2001). The research assumptions of Delphi method are: first, group judgment is superior to individual judgment; Secondly, experts and scholars, with their professional knowledge, are able to judge or predict the overall development trend of the industry; Third, the valid information gathered by experts is more accurate than that

provided by other groups; Fourth, anonymity enables participants to avoid disturbing the occurrence of correct information; Fifthly, the modification of multiple questionnaires can gradually integrate the views of the experts.

In previous studies, it was been found that different experts have expressed different views on the evaluation indicators for TVET teachers' teaching competency. Therefore, to establish reliable evaluation indicators, it is necessary to investigate the opinions of TVET experts and scholars on the criteria and reach consensus. Thus, the Delphi method is considered as an appropriate method for this study.

In general, the Delphi method needs a group of experts to reach consensus by giving answers to the same questions at least twice, and from the second round, experts can compare their answers to those of other experts and make necessary adjustments to their own answers (Hasson et al., 2000).

Traditionally, the Delphi method requires to conduct an open questionnaire on a specific topic and collect extensive expert opinions, which is time-consuming and complicated. However, the modified Delphi method starts with the first-round questionnaire based on the framework initially constructed by the investigators, and the opinions of experts on the framework are collected in each round. In this way, the revised Delphi method is more likely to achieve better efficiency and greater enthusiasm of the experts, avoiding excessive emotional interference caused by too many surveys or questions.

In view of the preliminary evaluation system had already been established in this study, considering the actual situation of time and manpower, the modified Delphi method was adopted in this research and two rounds

of questionnaire survey were conducted.

Sampling

The members of the expert group should be representative, diverse and professional. Therefore, it is necessary to investigate the academic background, professional background and professional experience of the experts. Experts selected should also have extensive knowledge and practical experience in the field of investigation.

There is no specific standard as to the number of experts in the Delphi method. Some scholars believe that if experts can invest sufficient time and energy, 15 to 25 experts are enough to achieve high reliability of conclusions (Hsu & Sandford, 2007).

Experts selected should be those who have high academic achievement, broad vision and foresight in the fields of vocational education theory and practice, ICT facilitated teaching and teacher development. Therefore, in this study, all members invited were experts engaged in relevant teaching and research work in vocational education. To ensure the heterogeneity of the participants, demographic information of experts(gender, educational background, professional title, working years, etc.) was also an important factor.

Questionnaire

The first-round questionnaire consisted of three parts: (1) demographic information (age, years of working, highest education level, teaching discipline/subjects, contact information, etc.); (2) evaluation indicator system with first-, second- and third-level indicators and modification space (considering the size of the questionnaire, the researcher distributed paper questionnaires to experts in the first round, so that participants could

highlight changes on the questionnaire conveniently. This proved sensible and the researcher received instant and constructive feedback from the participants.) (3) Theoretical basis and the literature sources. In addition, the researcher presented the framework of the evaluation indicator system with the help of mind maps, and verbally explained the underlying logic face to face. In this way the members deepened their understanding of indicators and increased their willingness to participate.

The questionnaire adopted a five-point Likert scale (1 = Not at all important, to 5 = Very important) to obtain experts' evaluation scores on every indicator. A study from a European perspective suggested a 5-point scale to provide better data quality than 7 or 11 points. (Revilla et al., 2013)

Survey design

Pilot survey

Before the formal Delphi survey, the researcher conducted a pilot study within the Institute of Education of Tsinghua University. Altogether four PHDs, eight doctoral students and five postgraduate students gave suggestions on the framework.

Afterwards, twenty-five experts from two higher vocational colleges and a secondary vocational college participated in the pilot study and answered the questions. A group interview with seven participants and one hour one to one interview with each of the seven participants were conducted.

Results of the pilot study: through the qualitative analysis of experts' open feedback in the questionnaires and interview data, it was found that opinions can be divided into four categories: deletion, supplement, modified expressions and questioning responses.

The researchers carefully reflected on the questions raised by experts, discussed within the research team, made modifications and adjustments, and added fourth-level indicators as specific observation points. Then, the framework of the TVET teachers' teaching competence (expert consultation draft) was ready for the Delphi study.

First-round Delphi

First-round Delphi survey

Researchers distributed paper questionnaires to experts attending the 47th Tsinghua Conference of Information Technology in Vocational Education. The conference invited TVET scholars, principals, academic leaders, deans of academic affairs, directors of information centres, etc. Of the 150 questionnaires sent out, 59 were returned (35.3% response rate). All respondents worked in the field of teacher development in vocational education. Another consideration in designing a Delphi study was the homogeneity or heterogeneity of the panel. Therefore, researchers took the experts' biographical information into consideration, such as the experts' gender, educational background, professional title, position, age, years of service, discipline or courses taught, enterprise work experience, etc. to ensure that the diverse group had a broader perspectives and better performance.

In the end, a total of 30 experts were invited (Table 2). The first round of the Delphi questionnaire was used as a creative strategy to reveal questions related to the research topic, and to encourage members to submit as many questions and comments as possible.

Table 2. Information of experts in the first-round Delphi survey

	Category	Number	Percentage
Position	Principal/Vice Principal	3	10%
	Director/Deputy Director of Academic Affairs	9	30%
	Director/Deputy Director of Information Center	9	30%
	Dean	9	30%
Professional title	Professor	5	16.7%
	Associate professor	17	56.7%
	Lecturer	3	10%
	Senior engineer	2	6.7%
	Expert teacher in middle school	2	6.7%
	Senior teacher in middle school	1	3.3%
Level of education	Doctor	2	6.7%
	Master	16	53.3%
	Bachelor	12	40%
Years of teaching	Under 10	6	20%
	10–19	15	50%
	20 and above	9	30%
Working experience in the industry/enterprise	Yes	8	26.7%
	No	22	73.3%
Type of college	Tertiary vocational school	26	86.7%
	Secondary vocational school	4	13.3%

Statistical data analysis of the first-round Delphi survey

Reliability test. Data from 30 valid questionnaires were imported into SPSS 26 for reliability test. Reliability is used to measure the internal consistency and stability of the measuring instrument. The Cronbach Alpha test is most used if the questionnaire is developed in the form of the Likert scale.

Therefore, the Cronbach alpha test was conducted in this research. Generally, the acceptable reliability value is 0.7 and if a questionnaire's reliability result is more than 0.8, it is considered "very reliable" (Zhou, 2017).

The value of the Cronbach alpha of each dimension of this questionnaire was above 0.7, indicating that the reliability of this questionnaire was acceptable (Table 3).

Table 3. Results of questionnaire reliability analysis

Dimension	Number of Items	Cronbach Alpha
First-level indicator	6	0.736
Second-level indicator	18	0.879
Third-level indicator	57	0.960
Fourth-level indicator	81	0.971

Validity test. In Delphi research, validity refers to the ability to characterize the properties and characteristics of the concept under test. Three aspects of the evidence can guarantee the content validity of the Delphi study. First, the results of this research were derived from the opinions of a relatively large group of participants (N=30), which is more valid than the opinion of a small group. Additionally, the first-round survey included open-ended questions that gave all participants opportunity to fully express their opinions Thirdly, all participants are experienced practitioners, deeply involved in the teaching, management and/or research of vocational education. Obviously, the questionnaire meets the above conditions and is considered to have good content validity.

Criterion for item selection. In Delphi research, there is no consensus on how to define consensus (Elizabeth, 2009). Some scholars believe that the median is the best measure of central tendency to determine the level of consensus in small groups when scales are used in studies, because it reduces the effect of extreme scores and skewed data (Underwood, 2020). Some suggest that interquartile range (IQR) reflects the difference between the upper quartile (75% of the data) and lower quartile (25% of the data), and the middle half of the answer is also regarded as one of the criteria for testing consistency in Delphi research. Previous studies have proved

that if the median is greater than or equal to 4 (five-level Richter Scale), IQR is less than or equal to 1, and the coefficient of variation is less than 50%, it is safe to draw conclusions with strong expert consensus. (Ramos & Arezes, 2016; Nasmyth, 2007; Williams et al., 2004)

The frequency of choices also indicates the degree of consensus. Some researchers suggest a consensus of 60% or greater among expert respondents, while others suggest a consensus of 70% to 80%. However, it is important to note that as the diversity of experts increases, the chances of a strong consensus will decrease. If the degree of consensus is set too high, it is possible that some important items may be deleted. (Nasmyth, 2007)

Considering the overall situation, 80% is selected as the standard of consensus degree in this study, that is, if more than 80% of the experts rated the indicator as 4 (important) or 5 (very important), the item would be retained, otherwise it would be modified or deleted.

The researchers used Excel and SPSS 26 to analyze the data, mainly considering the five indicators. They were the median, the mean, coefficient of variation, IQR and rate of consensus. The results of the first-round Delphi are shown in Table 4.

Table 4. First-round of Delphi expert feedback

Criteria	Median	Standard Deviation	Mean	Variable Coefficient	Quartile 1	Quartile 3	IQR	Rate of Consensus
A	5	0.594	4.68	0.127	4.625	5	0.375	93.3%
B	5	0.409	4.78	0.085	5	5	0	100%
C	5	0.346	4.87	0.071	5	5	0	100%
D	5	0.520	4.72	0.110	4.625	5	0.375	96.7%
E	5	0.571	4.53	0.126	4	5	1	96.7%
F	4	0.669	4.37	0.153	4	5	1	90.0%
A1	5	0.556	4.63	0.120	4	5	1	96.7%
A2	4.25	0.675	4.40	0.153	4	5	1	90.0%
A3	5	0.556	4.63	0.120	4	5	1	96.7%
A4	5	0.407	4.80	0.085	5	5	0	100%
B1	5	0.305	4.90	0.062	5	5	0	100%
B2	5	0.379	4.83	0.078	5	5	0	100%
B3	5	0.626	4.57	0.137	4	5	1	93.3%
C1	5	0.407	4.80	0.085	5	5	0	100%
C2	5	0.498	4.60	0.108	4	5	1	100%
D1	4	0.651	4.30	0.151	4	5	1	90.0%
D2	5	0.621	4.60	0.135	4	5	1	93.3%
D3	4	0.761	4.20	0.181	4	5	1	80.0%
E1	4.5	0.675	4.40	0.153	4	5	1	90.0%
E2	5	0.563	4.60	0.122	4	5	1	96.7%
E3	5	0.572	4.50	0.127	4	5	1	96.7%
E4	4.5	0.828	4.27	0.194	4	5	1	80.0%
F1	4.5	0.718	4.37	0.164	4	5	1	86.7%
F2	4.5	0.626	4.43	0.141	4	5	1	93.3%
A1a	5	0.817	4.43	0.184	4	5	1	93.3%
A1b	5	0.855	4.40	0.194	4	5	1	83.3%
A1c	5	0.724	4.60	0.157	4	5	1	93.3%
A1d	**4**	**1.098**	**3.97**	**0.277**	**3**	**5**	**2**	**70.0%**
A2a	4	0.750	4.30	0.174	4	5	1	83.3%
A2b	4	0.728	4.23	0.172	4	5	1	83.3%
A3a	5	0.568	4.77	0.119	5	5	0	93.3%
A3b	5	0.681	4.53	0.150	4	5	1	90.0%
A3c	5	0.615	4.63	0.133	4	5	1	93.3%
A3d	5	0.681	4.47	0.152	4	5	1	90.0%
A3e	5	0.606	4.67	0.130	4.25	5	0.75	93.3%
A4a	5	0.820	4.50	0.182	4	5	1	90.0%
A4b	5	0.675	4.60	0.147	4	5	1	90.0%
A4c	5	0.563	4.60	0.122	4	5	1	96.7%
A4d	5	0.596	4.70	0.127	5	5	0	93.3%

A4e	5	0.535	4.70	0.114	4.25	5	0.75	96.7%
A4f	5	0.521	4.73	0.110	5	5	0	96.7%
B1a	4	0.379	4.83	0.078	5	5	0	100%
B1b	4	0.346	4.87	0.071	5	5	0	100%
B1c	5	0.563	4.60	0.122	4	5	1	96.7%
B1d	5	0.682	4.50	0.151	4	5	1	90.0%
B1e	5	0.606	4.67	0.130	4.25	5	0.75	93.3%
B2a	5	0.606	4.67	0.130	4.25	5	0.75	93.3%
B2b	5	0.434	4.87	0.089	5	5	0	96.7%
B2c	4	0.925	4.20	0.220	4	5	1	80.0%
B3a	5	0.629	4.53	0.139	4	5	1	93.3%
B3b	5	0.571	4.53	0.126	4	5	1	96.7%
B3c	5	0.568	4.77	0.119	5	5	0	93.3%
C1a	5	0.450	4.73	0.095	4.25	5	0.75	100%
C1b	5	0.379	4.83	0.078	5	5	0	100%
C2a	5	0.571	4.53	0.126	4	5	1	96.7%
C2b	5	0.490	4.63	0.106	4	5	1	100%
D1a	4	0.747	4.17	0.179	4	5	1	80.0%
D1b	**4**	**0.776**	**4.13**	**0.188**	**4**	**5**	**1**	**76.7%**
D2a	5	0.626	4.57	0.137	4	5	1	93.3%
D2b	5	0.626	4.57	0.137	4	5	1	93.3%
D2c	5	0.809	4.37	0.185	4	5	1	80.0%
D3a	4	0.747	4.17	0.179	4	5	1	80.0%
D3b	**4**	**0.834**	**4.17**	**0.200**	**3.25**	**5**	**1.75**	**73.3%**
E1a	4.5	0.758	4.33	0.175	4	5	1	83.3%
E1b	5	0.571	4.53	0.126	4	5	1	96.7%
E1c	5	0.724	4.40	0.165	4	5	1	86.7%
E2a	5	0.765	4.37	0.175	4	5	1	83.3%
E2b	5	0.629	4.53	0.139	4	5	1	93.3%
E3a	5	0.571	4.53	0.126	4	5	1	96.7%
E3b	4.5	0.571	4.47	0.128	4	5	1	96.7%
E4a	4	0.740	4.27	0.173	4	5	1	83.3%
E4b	4.5	0.718	4.37	0.164	4	5	1	86.7%
E4c	5	0.679	4.43	0.153	4	5	1	90.0%
F1a	**4**	**0.785**	**3.93**	**0.200**	**3.25**	**4**	**0.75**	**73.3%**
F1b	4	0.785	4.27	0.184	4	5	1	86.7%
F1c	5	0.730	4.47	0.163	4	5	1	86.7%
F2a	5	0.535	4.70	0.114	4.25	5	0.75	96.7%
F2b	4.5	0.718	4.37	0.164	4	5	1	86.7%
F2c	4	0.691	4.27	0.162	4	5	1	86.7%
F2d	5	0.621	4.60	0.135	4	5	1	93.3%
F2e	5	0.568	4.57	0.124	4	5	1	96.7%

Note: The values in bold failed to meet the standard and were to be modified.

Researchers comprehensively used median, mean, coefficient of variation, IQR and consensus degree (option frequency), and combined with the qualitative feedback of experts to select and reject the items in Delphi survey.

The median score of the six first-level items (A–F) were higher than four. The coefficient of variation of the six items was between 0.071~0.153, less than 0.5, indicating that experts had formed a strong consensus on first-level indicators. IQR was between 0 and 1, which met the standard of consistency test in the Delphi study. The degree of consensus was higher than 90%.

The median scores of eighteen second-level items (A1–F2) were all higher than 4. The coefficients of variation of the 18 items were between 0.062~0.194, less than 0.5, indicating that experts had formed a strong consensus on the second-level items. IQR was between 0 and 1, which met the criteria of consistency test in the Delphi study. The rate of consensus was higher than 80%. The median scores of 57 third-level items (A1a–F2e) were higher than 4. The coefficients of variation of those 57 items ranged from 0.078 to 0.277, less than 0.5, indicating that experts had formed a strong consensus on third-level items. Among them, five third-level indicators, A1d, B2c, D1b, D3b, and F1a, did not meet the standard and needed to be reconsidered.

After the first-round Delphi study, researchers added, deleted and modified the items. At this stage, the framework included 6 first-level indicators, 19 second-level indicators and 56 third-level indicators.

Second-round Delphi

Second-round Delphi survey

The second-round of the Delphi questionnaire was based on the results of the first-round of Delphi survey. The questionnaire contained filling-in instructions, the first-round questionnaire feedback and modified questionnaire. Among which, four third-level items of A1d, B2c, D1b, D3b were modified. A second-level item of F3 "Professional ethics education" was added to the first-level item of "Research and Development" along with two third-level items of F3a and F3b. In addition, two third-level items A4e and A4f were integrated into A4d. Besides, F2d was deleted, as it's similar to D2c.

The revised indicator system adopted five-point Likert scale (1 = not at all important, 2 = slightly important, 3 = neutral, 4 = importantand 5 = very important. The deletion of items was agreed upon by experts. The same 30 experts participated in the second-round survey.

Statistical data analysis of the second-round Delphi survey

Median, coefficient of variation, IQR and consensus rate were the main reference for the second-round questionnaire analysis. See Table 5 for results.

Table 5. Second-round Delphi expert feedback

Items	Median	Standard Deviation	Mean	Variable Coefficient	Quartile 1	Quartile 3	IQR	Rate of Consensus
F3	5	0.305	4.90	0.062	5	5	0	100%
A1d	5	0.615	4.63	0.133	4	5	1	93.3%
B2c	5	0.860	4.47	0.192	4	5	1	83.3%
D1b	4	0.626	4.23	0.148	4	5	1	90.0%
D3b	5	0.571	4.53	0.126	4	5	1	96.7%
F3a	5	0.346	4.87	0.071	5	5	0	100%
F3b	5	0.305	4.90	0.062	5	5	0	100%

The median score of the F3 was 5, and the coefficient of variation was 0.062, less than 0.5, indicating that experts had formed a strong consensus on F3. IQR is 0, which met the criteria of consistency test. The degree of consensus is 100%.

The median scores of the six third-level items were more than 4, and the coefficient of variation was between 0.062~0.192, indicating experts had formed a strong consensus on these six third-level items . IQR was between 0 and 1, and the degree of consensus was higher than 80%. All 30 experts agreed on the reduction of three third-level items.

The first-level indicators of the index system have not been revised or supplemented by experts in the two rounds of Delphi study. Therefore, curriculum development, curriculum teaching, professional knowledge, occupational ability, information literacy, research and development were taken as the first-level indicators in this study. All experts reached consensus on 19 second-level indicators and 56 third-level indicators retained. Therefore, this report finally determines the evaluation index system of the teaching ability of TVET teachers in the information age, thus ending the consultation of expert opinions

AHP weight analysis

The Analytical Hierarchy Process (AHP) model is a decision-making tool to solve multi-factor complex decision problems (Bachman, 2012). Firstly, the hierarchical structure is established according to the nature of the problem and literature review, then, the experts judge the relative importance between the indicators of each level according to their own experience and knowledge, and finally researchers draw a reasonable decision

through a bottom-up weighted calculation. The calculation steps are:

(1)To establish pairwise comparison matrices (PCMs). A pairwise comparison is a numerical representation of the relationship between any two elements that discerns which element is more important(Shayannejad & Angerabi, 2014) . Saaty (1987) proposed a scale of 1–9, in which 1 represents equal importance; that is, the two elements contribute equally to the objective, while 9 represents extreme importance one element over another one. If the element has a weaker impact than its comparison element, the score range varies from 1, indicating indifference, to 1/9, an overwhelming dominance by a column element over the row element. The results of all factor comparisons were placed in a matrix to form a PCM.

2) To calculate the eigenvalues and eigenvectors. The maximum eigenvalue λ_{MAX} and its corresponding eigenvector CI were calculated and normalized.

3) Consistency test. The random consistency ratio (CR) was used to judge whether the PCM formed by the results of the questionnaire survey was consistent. When $CR<0.1$, the PCM has a satisfactory consistency or the degree of inconsistency is considered to be within the allowable range; when $CR>=0.1$, the PCM is considered to have no satisfactory consistency and it needs adjustment until satisfactory consistency is achieved.

Previous expert ratings (second-round Delphi) were used as the main data source. Then, after internal discussion and induction of the scoring results, the pairwise judgment matrix was obtained as Table 6.

Table 6. Pairwise judgment matrix

	A	B	C	D	E	F
A (Curriculum Development)	1	1/3	1/4	1/2	2	3
B (Curriculum teaching)	3	1	1/2	2	5	6
C (Professional knowledge)	4	2	1	2	5	7
D (Occupational ability)	2	1/2	1/2	1	3	5
E (Information literacy)	1/2	1/5	1/5	1/3	1	2
F (Research and Development)	1/3	1/6	1/7	1/5	1/2	1

First, the maximum eigenvalue of the judgment matrix was calculated $\lambda_{MAX}=6.0920$. Then the consistency indicator CI was calculated:

$$CI=(\lambda_{MAX}-n)/(n-1)=(6.0920-6)/(6-1)=0.0184 \qquad (1)$$

The average random consistency indicator $RI=1.24$. Then we calculate the random consistency ratio:

$$CR=CI/RI=0.0184/1.24=0.0148<0.10 \qquad (2)$$

Since CR was less than 0.1, it could be considered that the construction of the judgment matrix was reasonable. Therefore, the weights of the criteria were given, as shown in Table 7.

Table 7. Determination of level 1 indicator weight

indicator	Weight
A (Curriculum Development)	0.0986
B (Curriculum teaching)	0.2665
C (Professional knowledge)	0.3624
D (Occupational ability)	0.1737
E (Information literacy)	0.0607
F (Research and Development)	0.0381

The above research results were integrated to form the weights of the indicators for TVET teachers' teaching competency in the information age.

Discussion and conclusions

In this study, the dimensions of TVET teachers' teaching competency in the information age are explored and the multiple roles of "dual professional" teachers are emphasized. The research findings have some similarities with teachers' TPACK framework (Koehler et al., 2013). For example, T is the dimension of information literacy in the information age, P is the dimension of vocational education teaching, including curriculum development and teaching, and C is the dimension of professional knowledge and occupational ability. In addition, this paper focuses on the research and development competency, which is also reflected in the UNESCO ICT-CFT framework (UNESCO, 2018) as well as China's Norms for Vocational Digital Campus (The Ministry of Education of PRC, 2020).

In contrast to general education that pays more attention to the teaching competency of teachers, researchers of the TVET field attach much importance to curriculum development (Zhao & Rauner, 2014). Researchers combine the curriculum development theory to highlight the curriculum development ability of TVET teachers, that is, professional competency.

It is find from the above table that the weight of curriculum development competency is low (0.0986). In interviews with administrators and teachers of vocational colleges, researchers found that curriculum development competency is relatively urgent, but it is difficult for teachers to complete it independently at present. Although there is still a long way to go, both theoretical and practical experts have reached a considerable consensus that with the progress of information technology, curriculum development can be realized with the help of digital tools, and it will also be an important content and trend for teachers to implement blended teaching reform in the near future and in addition, information literacy, as a basic ability, has also become a necessity for TVET teachers in China. However, experts give a relative low score to curriculum development competency when they consider the certain distance between research ability of TVET teachers and that of general education because of the diverse and relative low educational backgrounds of TVET teachers in China. The curriculum teaching dimension has the second highest weight, which is 0.2665. The professional knowledge dimension is 0.3624 with the highest weight, which indicates experts believe the most important for TVET teachers is professional knowledge and teaching competency.

In the second level items, E4 "information social responsibility" was considered relatively unimportant by experts (0.0863). F3 "Professional ethics education" is considered to be the most important, with a weight of 0.701.

In third-level items, several items have a lower comprehensive weight. "Make sure students have equal opportunities in information technology applications" (0.00066), F1a "Apply the scientific research achievement to the production practice of enterprises" (0.000344), F2c "Participate in activities on continuing education" (0.000701). In contrast, some have high comprehensive weights. They are C1b "Apply basic professional knowledge" (0.161083), C2b "Apply professional knowledge of new technology" (0.090591), C1a "Have basic professional knowledge" (0.080529). Experts generally agree that professional knowledge is more important for TVET teachers.

The objective of this study is to construct the evaluation index system to assess TVET teachers' teaching competency with a qualitative and quantitative process. This study has put forward a new conceptual framework of the four roles of TVET teachers in the information age, namely teachers, technician/engineer, digital citizen and lifelong learner. Based on this, the evaluation index system is constructed and further confirmed using a Delphi method. Furthermore, the weight of each specific indicator is determined by AHP. The participants invited in this research have different backgrounds, including expert researchers, experienced in-service teachers and senior administraors in vocational colleges and schools, which therefore increased the reliability and validity of the evaluation indicator system. However, the study found that the weights allocated to a few indicators were relatively low. Subsequent studies will be conducted to explore the reason and the implication. With the indicators, researchers

intend to further develop a scale to classify TVET teachers, and to provide concrete competency improvement schemes according to the TVET teachers' stages and competency levels.

The "dual-professional" attribute of a vocational teacher is an important issue in evaluating the professional competency. The evaluation indicator system based on "dual professional" provides a sound basis for accurate training, lifelong learning and sustainable development of teachers. Through this index system, teachers will gain agility in learning and implementing up-to-date skills, improve the quality of educational output, and further promote the sustainable development and digital transformation of vocational education. If applied in a broader context, the index system will contribute to formulating generalized guidelines for the sustainable development of teachers.

Limitations

The evaluation index system in this study shows the potential to be a useful instrument in assessming TVET teachers' teaching competency, but there are still some limitations to be considered while using and interpreting the results. First, the research is conducted in China and it should be borne in mind that this study does not attempt to be globally representative. Second, there is a lack of participation of TVET theory experts and international vocational education scholars. To test the validity of the index system, experts in relevant fields will be invited in the future.

Funding

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