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Research on Evaluation Indicators for Digital Literacy of University Teachers

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Abstract

This article reviews relevant literature on the connotation of teachers' digital literacy, typical frameworks, evaluation tools and methods for digital literacy. According to the roles and responsibilities of university teachers, an evaluation indicator system for digital literacy of university teachers is constructed based on six dimensions: technological competence, teaching ability, professional development, digital security and ethical awareness, adaptability to digital environments, and digital thinking and innovation. Considering the specific contexts of different disciplines, positions, and developmental stages of university teachers, a method for identifying group weights based on individual cognitive structures is proposed for different user groups, to be used in conjunction with the evaluation indicator system.

Keywords

Digital Literacy; University Teachers; Evaluation Indicators; Individual Cognitive Structure; Group Identification.

1. Introduction

With the rapid development of information technology, the field of education is experiencing unprecedented changes. Especially during the COVID-19 pandemic, global higher education has had to quickly adapt to online teaching, which has not only profoundly impacted students' learning methods, but also presented new challenges for teachers' teaching methods and digital skills[1]. Teacher digital literacy not only involves mastering basic technological skills, but more importantly, it encompasses comprehensive literacy in various aspects such as information acquisition, processing and dissemination, critical thinking, innovation awareness, and problem-solving abilities. It involves how teachers utilize digital tools and resources to optimize the teaching process, enhance learning experiences, and promote knowledge innovation and dissemination. As important forces for knowledge transmission and innovation in higher education, the digital literacy of university teachers has become a key factor in ensuring the quality of higher education.

Despite the increasing importance of digital literacy, existing research on teacher digital literacy frameworks and assessment tools mostly target the entire teacher population and training personnel, without distinguishing between university teachers and K-12 teachers, as well as subject specialties and position differences. Additionally, the few frameworks and assessment tools for digital literacy among university teachers each have their own emphases, and consensus on content dimensions has not been reached. Therefore, in order to better understand and evaluate the roles and responsibilities of university teachers in the digital age, and to provide a solid foundation for cultivating a high-quality teacher workforce that can meet future educational needs, it is necessary to conduct in-depth research on the construction of an evaluation indicator system for the digital literacy of university teachers.

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2. Literature Review

2.1. Connotation of Teacher Digital Literacy

In the 1990s, the rapid and sustained development of digital technology made the ability to use digital technology to complete tasks and solve problems a basic literacy requirement. Gilster (1997) was one of the earliest to discuss the concept of digital literacy and considered it as the key ability to understand and use the complex information presented by computers[2]. Since then, the concept of digital literacy has received widespread attention and dissemination worldwide, but the terminology for digital literacy has not been unified in various academic literature and national policy documents. In terms of conceptual content, digital literacy includes digital skills, digital competence, digital capability, and even cases of mixed wording[3]. In terms of research subjects, existing studies have focused not only on national populations or the general public, but also on specific groups such as teachers, government officials, library managers, auditors, the elderly, students, and farmers in the research of digital literacy.

In specific studies on the connotation of teacher digital literacy, Krumsvik (2011) suggests that teacher digital competence refers to the proficiency of teachers in using ICT in a professional environment, demonstrating good teaching judgment and awareness of its impact on learning strategies and student digital education[4]. Basantes-Andrade et al. (2022), based on a review of past research, define teacher digital competence as the ability of teachers to integrate ICT with teaching, key standards, and safety within a professional context[5]. The digital literacy guide for educators produced by the University of Cambridge indicates that digital literacy consists of sections such as using tools to retrieve and create digital content, problem-solving and innovation, online sharing and interaction, and online safety and health[6]. The *Teacher Digital Literacy* standards released by the Chinese Ministry of Education define it as the consciousness, ability, and responsibility of teachers to appropriately utilize digital technology to acquire, process, use, manage, and evaluate digital information and resources, discover, analyze, and solve educational problems, and optimize, innovate, and transform educational activities[7]. Liu and Yi (2024) summarize past concepts, stating that teacher digital literacy refers to a series of knowledge, skills, awareness, and ethical attitudes that teachers use digital technology for educational purposes, aiming to enhance both their own digital literacy and that of their students. They emphasize that the digital literacy of university teachers should be integrated with the educational environment and functions of teachers. The digital literacy of university teachers refers to their consciousness, ability, and responsibility to utilize digital technology to acquire, use, manage, evaluate, and create digital information, resources, and data, to optimize, innovate, and transform educational and evaluation activities through research, to construct a digitized collaborative educational field to meet the personalized and professional needs of students, and to promote their own development and that of the teaching community[8].

In general, although different institutions or scholars have differing interpretations of digital literacy, they all emphasize that its connotation extends from digital technology skills to attitudes, knowledge, abilities, ethical awareness, and other aspects required to solve problems in the digital age[9]. In other words, teacher digital literacy is a multidimensional concept, including technological competence, pedagogical ability, cultural and ethical awareness, digital environment, training opportunities, critical thinking, and innovation[10, 11]. The term *digital literacy of university teachers* in this paper refers to the collection of knowledge, skills, awareness, and ethical attitudes that enable university teachers to effectively use digital technology to carry out professional activities and achieve goals such as teaching, research, talent cultivation, social services, and their own continuous development.

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2.2. Framework of Teacher Digital Literacy

To clarify the development direction of teacher digital literacy, numerous international organizations, countries, and research institutions have provided representative frameworks for teacher digital literacy that can be referenced. For example, in 2017, the European Union released the *European Framework for the Digital Competence of Educators* (DigCompEdu), which consists of six areas of digital competence and 22 specific skills, including professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. It also uses six role descriptions –Newcomer, Explorer, Integrator, Expert, Leader, and Pioneer – to depict the levels of teachers' digital competence at different stages of development[12]. In the same year, the Norwegian Centre for ICT in Education released the *Professional Digital Competence Framework for Teachers*, covering seven competence areas, including subjects and basic skill, school in society, ethics, pedagogy and subject didactics, leadership of learning processes, interaction and communication, and change and development. It classifies and explains the professional digital competence that teachers should possess in each competence area from the perspectives of knowledge, skills, and abilities[13]. In October 2017, the National Institute of Educational Technologies and Teacher Training (INTEF) in Spain released the *Common Digital Competence Framework for Teachers*, which covers five competency domains including information and data literacy, communication and collaboration, digital content creation, safety, and problem solving, comprising a total of 21 specific capabilities[14]. In 2017, the International Society for Technology in Education (ISTE) in the United States introduced the *ISTE Standards for Educators: A Guide for Teachers and Other Professionals*, which outlines seven social roles for modern educators: learner, leader, citizen, collaborator, designer, facilitator, and analyst. It provides conceptual clarifications, indicator explanations, and action guidance for each role, thereby specifying the norms for teachers' information technology application in teaching processes and activities, and revealing the direction for the development of teachers' information technology application capabilities[15]. In 2018, the United Nations Educational, Scientific and Cultural Organization (UNESCO) released the *UNESCO ICT Competency Framework for Teachers*, which includes six aspects of digital competence: understanding ICT in Education, curriculum and assessment, pedagogy, application of digital skills, organization and administration, and teacher professional learning. It explains the detailed capabilities in each aspect from the perspectives of knowledge acquisition, knowledge deepening, and knowledge creation[16]. In 2022, the Chinese Ministry of Education released the *Teacher Digital Literacy* standards, establishing a five-dimensional, three-level framework for teacher digital literacy, encompassing digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development. This framework provides strong support for enhancing the high-quality professional development of teachers[7]. In 2023, the Joint Information Systems Committee (JISC) in the UK published the *Digital Literacy Framework (Higher Education Teacher Edition)*, which includes six key elements: ICT proficiency, information, data and media literacies, digital creation, problem solving and innovation, digital learning and development, digital communication, collaboration and participation, and digital identity and wellbeing[17].

Overall, these frameworks emphasize the abilities and roles of teachers in digital environments, each with its own emphasis. The frameworks from the EU and Norway focus more on professional development and ethics. The frameworks from Spain and China highlight information security and digital social responsibility. The frameworks from UNESCO and ISTE cover various aspects of educational technology application comprehensively. The framework from the UK's JISC places more emphasis on innovation and the digital wellbeing of teachers. Although the content dimensions of these frameworks are not uniform, each has its strengths,

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providing valuable insights and references for understanding and evaluating teacher digital literacy, as well as guiding teachers to adapt to digital education.

2.3. Assessment Tools for Teacher Digital Literacy

To scientifically assess the digital literacy levels of educational professionals, relevant organizations and scholars have developed and tested various assessment tools and methods. There are two main assessment methods: self-report evaluation, which uses structured questionnaires to assess participants' knowledge and skills, and performance-based evaluation, which examines participants' mastery of knowledge and skills as well as the development of higher-order abilities such as problem-solving, communication, collaboration, and critical thinking. Additionally, there is a third mixed evaluation method that combines self-assessment and performance-based evaluation. These methods provide valuable approaches for evaluating teacher digital literacy[18, 19]. When it comes to the sources of assessment tools for teacher digital literacy, there are mainly three categories[20]: (1) Direct use of existing frameworks, such as DigCompEdu, UNESCO, INTEF, and ISTE, which scholars have used as a basis for developing related assessment questionnaires. (2) Modification and improvement of existing frameworks and tools. For example, Qiu and Xiao (2021) conducted a comparative analysis of typical teacher digital competence frameworks using text analysis methods. They found that the existing frameworks mainly encompass four competency domains: technological, pedagogical, ethical, and attitudinal competencies[21]. Wang and Baek (2023) analyzed relevant literature on digital literacy of higher education teachers and identified technical competence, teaching ability and professional development, cultural moral consciousness, digital situation, training opportunities and lifelong learning, critical thinking, and innovation as the main components of digital literacy for university teachers[22]. Liu and Yi (2024) compared various typical teacher digital literacy frameworks and proposed that the framework for digital literacy of university teachers should emphasize digital teaching practices, digital leadership, digital well-being, digital awareness, and the cultivation of students' digital employ ability skills. They also suggested modifications to the teacher evaluation standards of the Chinese Ministry of Education, emphasizing the cultivation of comprehensive digital literacy in students, inclusion of research data security management, and the use of digital technology resources to support reflection and improvement not only in teaching but also in scientific research, industry-academic-research collaboration, and social services[8]. (3) Creation of new assessment tools tailored to either overall teacher digital literacy or specific types of teachers and positions. For example, Yang and Zhou (2019) developed an evaluation indicator system for digital literacy of university teachers based on five dimensions: digital technology usage, digital information management, digital content creation, digital community building, and digital security capabilities. They utilized exploratory factor analysis and confirmatory factor analysis methods to construct this system, comprising 18 indicators[23]. Similarly, He (2021) focused on the dual-teacher characteristics of vocational college teachers and proposed a *314* structural model, analyzing the constitutive elements of digital literacy from the perspectives of foundation, profession, and identity. This model includes eight dimensions, such as digital office, digital socialization, digital security, professional digitization, digital teaching, digital technician, digital social worker, and digital scientific worker, tailored to vocational college teachers[24]. Fang and Xu (2023) conducted a comprehensive study using literature analysis, expert consultation, and questionnaire analysis methods to construct an international Chinese teacher digital literacy indicator system based on five dimensions: digital basic knowledge, digital technology capabilities, digital teaching abilities, digital learning abilities, and digital awareness attitudes[25].

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202408_7(8).0017

3. Construction of Digital Literacy Indicator System for University Teachers

Based on the research of [8, 22], this study follows the principles of comprehensiveness, hierarchy, and development. It integrates various classic teacher digital literacy frameworks and considers the important functions of university teachers, such as teaching, scientific research, professional talent cultivation, management, and social service[5, 8]. Focusing on six dimensions including technological competence, teaching ability, professional development, digital security and ethical awareness, adaptability to digital environments, and digital thinking and innovation, this paper constructs an evaluation indicator system for digital literacy of university teachers (see Table 1).

Table 1. Evaluation Indicator System for Digital Literacy of University Teachers

Primary Indicator	Secondary Indicator	Contents	Measurement Method
Technical competence	Basic operational skills in information and communication technology (ICT)	Teachers' basic operational abilities with ICT tools such as computers, networks, and mobile devices	Evaluation of teachers' proficiency with ICT tools through practical operation tests or questionnaire surveys
	The effective use of digital teaching tools	Teachers effectively utilizing digital tools in their teaching, such as smart classroom systems and online assessment tools	Observing teaching practices, collecting peer and student feedback on teachers' use of digital tools
	The latest trends in educational technology	Teachers' awareness and understanding of emerging educational technologies, such as the application of artificial intelligence in education	Understanding teachers' awareness of the latest educational technologies through surveys or interviews
Teaching ability	Digital presentation of course content	Teachers digitally present course content, such as using multimedia teaching materials	Evaluate the digitalization level of teaching materials and student satisfaction
	Guidance and support for students' online learning	Teachers guide students in using online learning platforms and provide support for their online learning	Evaluate based on student feedback and usage data from the online learning platform
	Digital integration and innovation of teaching resources	Teachers integrate and innovate the creative and effective use of digital teaching resources	Peer review the innovation and effectiveness of teaching resources
	Fostering students' digital literacy	Develop students' communication and collaboration skills in the digital environment, as well as their problem-solving abilities, digital employability skills, critical thinking skills, and self-development capabilities	Assess students' digital literacy development through project outcomes, competition results, and self-evaluations
Professional development	Continuous learning and knowledge updates within the professional field	Teachers continuously learning and updating knowledge within their professional field	Assessment through continuing education certificates, academic publications, and professional qualifications

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	Mastery and application of digital teaching methods	Teachers master and apply digital teaching methods	Assessment through classroom observation and student learning outcomes
	Engagement in educational technology and professional community interaction	Teachers participate in professional communities and activities related to educational technology	Assessment based on participation, influence, and community feedback
Digital security and ethical awareness	Academic integrity and copyright awareness in the digital environment	Teachers maintaining academic integrity and respecting copyright in the educational environment	Assessment through teachers' publication records, teaching cases, and self-declarations
	Protection of student and parent data and respect for privacy	Teachers' awareness of privacy protection when handling student data	Assessment through policy compliance and student feedback
	Identification and management of ethical issues in digital education.	Teachers' identification and handling of ethical issues in digital teaching	Assessment through case studies and self-reports from teachers
	Awareness of research data security in the digital environment	Teachers' awareness of data security when handling and presenting research outcomes in a digital environment	Assessment through research project data management and protection measures
Adaptability to digital environments	Proficient use of online teaching platforms	Teachers proficiently using online teaching platforms for instructional activities	Evaluation based on platform usage frequency, instructional activity quality, and student satisfaction
	Remote teaching and collaborative skills	Teachers' ability to conduct remote teaching and online collaboration	Evaluation of participation and effectiveness in remote teaching
	Application of digital tools in emergency teaching situations	Teachers' ability to use digital tools for teaching in emergency situations	Assessment through performance in simulated scenarios and peer evaluation
Digital thinking and innovation	Critical thinking skills for addressing educational technology Issues	Teachers' critical thinking skills in addressing educational technology issues	Assessment through case studies and problem-solving tests
	Innovative thinking and practices in teaching	Innovative thinking and practices demonstrated by teachers in teaching activities	Assessment through review of innovative teaching projects and student feedback
	Anticipating and applying educational technology trends	Teachers' predictive analysis and application skills in educational technology Trends	Assessment through research projects, published papers, and professional lectures
	Industry-academia-research collaboration and social service innovation	The application and influence of digital technology in teachers' industry-academia-research collaboration and social service	Assessment through project reports, social impact, and partner evaluations

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4. Method for Determining Weight of Digital Literacy Indicators for University Teachers

Table 1 only provides a general refinement of digital literacy indicators for university teachers, without considering the differences in digital literacy among teachers in different disciplines, positions, and developmental stages.

To address the above-mentioned issue, this study has given new significance to the weighting of indicators. Despite using a common evaluation indicator system, different indicator weights are used to characterize the digital literacy of university teachers in different disciplines, positions, and developmental stages. This breaks the traditional *one-size-fits-all* evaluation approach of using a set of indicators with a set of weights and assigns different indicator weights to evaluation objects of different attribute categories to highlight individual differences in the evaluated objects. For example, compared with STEM teachers, humanities and social science teachers are influenced by the requirements and advantages of their disciplines, and have different emphases on the indicators in Table 1. These differences can be characterized by the differences in indicator weight values. The larger the weight value, the higher the attention on the corresponding indicator, or it indicates individual strengths in that corresponding indicator. Therefore, how to determine these differential weights becomes the key to distinguishing the digital literacy of teachers in different disciplines, positions, and developmental stages.

4.1. Methodology

We draw inspiration from big data mining thinking to propose a new weighting method. In order to obtain the weight of digital literacy indicators for teachers in different disciplines, positions, and developmental stages, we can take a certain type of subdivided teacher group as the observation object, and gather opinions from different observers to obtain the corresponding weights. Although each observer may have certain cognitive limitations and differences, following the fable of the blind men and the elephant, as long as we can extract the *true insights* of each observer, i.e., the correct part of their cognition, and ensure a sufficient number of participating observers, we can obtain the approximate weights for this type of teacher group.

Considering the hierarchical nature of the indicator system, this study draws on literature [26] and introduces the method of recognizing individual cognitive structure groups, in order to identify and integrate the individual cognitive characteristics of each observer to form collective cognition, thereby obtaining the evaluation indicator weights for digital literacy of a certain type of university teachers.

From a quantitative identification perspective, the term *individual cognitive structure* refers to an essential structure that corresponds to the indicator dimensions within a certain range of indicator content, and can best reflect the observer's level of cognition based on established values. Among the various utility functions, the distance function has a clear objective-oriented role, and its general expression is given by:

$$d_q(f, f^*) = \left(\sum_{j=1}^{m} \omega_j^q \left| f_{ij} - f_j^* \right|^q\right)^{\frac{1}{q}} \tag{1}$$

Formula (1) depicts the difference between the observer's individual cognitive level and the public's actual cognitive conclusion. Here, f_{ij} represents the observer i's observation value for indicator j, $f^* = (f_1^*, f_2^*, \cdots, f_m^*)^\tau$ represents the ideal value, which is the public's actual

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cognitive conclusion for that indicator, and $w=(\omega_1,\omega_2,\cdots,\omega_m)^\tau$ represents the value parameter vector, also known as the weight vector. Formula (1) characterizes the weighted distance between the observer and the ideal result based on the weight w under the q-norm. A smaller distance indicates a smaller observation error and better observation utility. To consistently retain the impact of the weight coefficients, the value parameter w appears in the form of the q th power.

4.2. Identification of Individual Cognitive Structure

Due to the hierarchical structure of the evaluation indicator system as shown in Table 1, following the logic of Formula (1), the identification model of individual cognitive structure here can be identified layer by layer from bottom to top.

(1) Identification and solution of the bottom-level individual cognitive structure. According to the digital literacy evaluation indicator system for university faculty in Table 1, for the sub-indicator $Y_i=(x_{i1},x_{i2},\cdots,x_{ip_i})^\tau$ at the N th level under Y_i, let $r_i=(r_{i1},r_{i2},\cdots,r_{ip_i})^\tau$ be the standardized indicator value vector, $r_i^*=(r_{i1}^*,r_{i2}^*,\cdots,r_{ip_i}^*)^\tau$ be the ideal value for the corresponding sub-indicator, and $\omega_i=(\omega_{i1},\omega_{i2},\cdots,\omega_{ip_i})^\tau$ be the value parameter vector. If using the weighted distance under the 2-norm to measure each observer j $(j=1,2,\cdots,n)$'s digital literacy cognitive level on indicator Y_i, then:

$$d_j(r_i(j),r_i^*)=\sqrt{\sum_{k=1}^{p_i}\omega_{ik}(j)^2(r_{ik}(j)-r_{ik}^*)^2} \tag{2}$$

The smaller the distance value represented by formula (2), the closer the indicator value is to the ideal value, indicating better cognitive performance of observer j on indicator Y_i. Therefore, based on formula (2), from the perspective most favorable to observer j, a goal programming model can be constructed to determine their cognitive structure characteristics on the bottom-level sub-indicators under indicator Y_i.

$$\min\{d_{\omega(j)}(r_i(j),r_i^*)\}=\sqrt{\sum_{k=1}^{p_i}\omega_{ik}(j)^2(r_{ik}(j)-r_{ik}^*)^2} \tag{3}$$

$$s.t.\begin{cases}\sum_{t=1}^{p_i}\omega_{ik}(j)=1\\ \omega_{it}(j)\geq 0,\quad i=1,2,\cdots,m;\quad k=1,2,\cdots,p_i\end{cases}$$

Model (3) states that for observer j, when the values and ideal values of the bottom-level indicators under Y_i are determined, the optimal solution for the value parameter vector $w_i(j)$ can be sought to obtain the individual cognitive structure of the bottom-level indicators under Y_i. Denote $\omega_i^*(j)=(\omega_{i1}^*(j),\omega_{i2}^*(j),\cdots,\omega_{ip_i}^*(j))^\tau$ as the optimal solution of Model (3), it is known from the properties of bounded closed interval continuous functions that the solution of Model (3) exists. According to the Kuhn-Tucker optimality principle, the optimal solution is: ① when there are no variable coefficients equal to 0 in the objective function, i.e., $r_{ik}(j)\neq r_{ik}^*$.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202408_7(8).0017

$$\omega_{ik}^{*}(j)=\frac{1}{(r_{ik}(j)-r_{ik}^{*})^{2}\sum_{k=1}^{p_i}\frac{1}{(r_{ik}(j)-r_{ik}^{*})^{2}}} \quad (4)$$
$$i=1,2,\cdots,m;\ j=1,2,\cdots,n$$

②When there are variable coefficients equal to 0 in the objective function, then the sum of the variables corresponding to the coefficients equal to 0 is set to 1, and the variables corresponding to the other coefficients are all set to 0.

The above process is applied to the sub-indicators of the N th layer to which each indicator $Y_1,Y_2,\cdots,Y_m$ of the $N-1$ th layer belongs, obtaining the individual numerical literacy cognitive characteristic structure $w^{*}(j)=(\omega_1^{*}(j),\omega_2^{*}(j),\cdots,\omega_m^{*}(j))^{\tau}$ of observer j at the bottom-level indicators. Similarly, when this process is applied to all observers, the corresponding bottom-level cognitive structural features $w^{*}(1),w^{*}(2),\cdots,w^{*}(n)$ are obtained respectively.

(2) Recognition and determination of individual cognitive structure at the $N-1$ th layer. For observer j, bringing back their individual cognitive characteristics belonging to the bottom-level indicator Y_i of the $N-1$ th layer into Equation (3), the vector of their indicator values on Y_i can be obtained, denoted as $y_i^{*}(j)=\sqrt{\sum_{k=1}^{p_i}\omega_{ik}^{*}(j)^{2}(r_{ik}(j)-r_{ik}^{*})^{2}}$. Since $\omega_i^{*}(j)$ is the optimal solution of Model (3), it is evident that $y_i^{*}(j)$ achieves optimal values under this weight structure. At this point, $y_i^{*}(j)$ represents the weighted distance between the bottom-level sub-indicators belonging to Y_i and the ideal values, with the ideal distance value being 0. Similarly, to recognize the cognitive structural characteristics of observer j at the $N-1$ th layer of indicators, a goal programming model can be constructed based on Model (3).

$$\min s_{\mu(j)}=\sqrt{\sum_{i=1}^{m}\mu_i(j)^{2}(y_i^{*}(j))^{2}} \quad (5)$$
$$s.t.\begin{cases}\sum_{i=1}^{m}\mu_i(j)=1\\ \mu_k(j)\geq 0,\ \ i=1,2,\cdots,m\end{cases}$$

Referring to the solution method for individual cognitive structure at the bottom level, let $\mu^{*}(j)=(\mu_1^{*}(j),\mu_2^{*}(j),\cdots,\mu_m^{*}(j))^{\tau}$ be the optimal solution of Model (5), then ① when there are no variable coefficients equal to 0 in the objective function, i.e., $y_i^{*}(j)\neq 0$,

$$\mu_i^{*}(j)=\frac{1}{(y_i^{*}(j))^{2}\sum_{i=1}^{m}\frac{1}{(y_i^{*}(j))^{2}}} \quad (6)$$
$$i=1,2,\cdots,m;\ j=1,2,\cdots,n$$

② When there are variable coefficients equal to 0 in the objective function, the sum of the variables corresponding to the coefficients equal to 0 is set to 1, while the variables corresponding to the other coefficients are set to 0.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202408_7(8).0017

When the above process is applied to all observers, their cognitive structural characteristics at the $N-1$ th layer of indicators can be obtained respectively. Similarly, the cognitive characteristics of each observer at other layers of indicators can also be determined layer by layer from bottom to top according to the recognition process mentioned above, until reaching the top layer.

4.3. Group Identification Method for Public Cognitive Structure

Similar to the story of the blind men and the elephant, by exploring and gathering all observers' genuine insights into the individual cognitive structure of digital literacy for university teachers, the public cognitive characteristics structure for digital literacy of university teachers can be obtained, thereby acquiring the weights of all digital literacy assessment indicators. This is referred to as *group identification of public cognitive structure*.

By solving models (3) and (5), the individual cognitive structures $w_j=\{\omega_i^*(j)|i=1,2,\cdots,m;j=1,2,\cdots,n\}$ and $\mu_j=\{\mu_i^*(j)|i=1,2,\cdots,m;j=1,2,\cdots,n\}$ of observer j at each level of indicators can be obtained. By collecting these individual cognitive characteristic structures of all observers, the cognitive characteristic sets $\{w_j|j=1,2,\cdots,n\}$ and $\{\mu_j|j=1,2,\cdots,n\}$ of the population at each level of indicators can be obtained. According to certain rules, such as linear correlation strength or distance proximity, clustering analysis can be performed on the respective sets of weights at each level, resulting in several typical cognitive structural patterns for the population at corresponding indicator levels. Taking the bottom-level indicator as an example, assuming that pattern analysis yields cognitive patterns, let the h $(h=1,2,\cdots,s)$ th cognitive pattern contain l observers, and t represents the t $(t=1,2,\cdots,l)$ th member belonging to the h th public cognitive structure. If according to the principle of equality and democracy, the value parameter (i.e., weight) corresponding to the h th public cognitive structure is:

$$w_h^*=(\omega_{h1}^*,\omega_{h2}^*,\cdots,\omega_{hm}^*)^\tau=(\frac{1}{l}\sum_{t=1}^{l}\omega_{t1}^*,\frac{1}{l}\sum_{t=1}^{l}\omega_{t2}^*,\cdots,\frac{1}{l}\sum_{t=1}^{l}\omega_{tm}^*)^\tau \tag{7}$$

Similarly, the public cognitive patterns at other levels can also be calculated using formula (7). It is important to note that the public cognitive patterns obtained through cluster analysis may have multiple categories. Ultimately, the weight values for each level of indicators can be determined by either using the weights represented by the most prevalent public cognitive pattern at that level, or by using a combined weighting method to synthesize a set of weights from the various public cognitive patterns at that level. This approach can be flexibly adapted according to the specific requirements of the problem.

5. Conclusion

In response to the lack of comprehensive and unified evaluation tools for digital literacy among university teachers, this study adheres to the principles of comprehensiveness, hierarchy, and development. Through comparative analysis of various classic frameworks for evaluating teachers' digital literacy, as well as considering the work context and professional mission of university teachers, a set of evaluation indicators for digital literacy among university teachers was constructed. This system includes 6 primary indicators and 21 secondary indicators, covering technological proficiency, teaching ability, professional development, digital security and ethical awareness, adaptability to digital environments, and digital thinking and innovation.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202408_7(8).0017

Additionally, taking into account different disciplines, positions, and developmental stages, a group identification method based on individual cognitive structures for determining indicator weights is proposed. When used in conjunction with the evaluation indicator system, this method can facilitate the identification and evaluation of digital literacy among diverse groups of university teachers. This research addresses the shortcomings of the evaluation system for digital literacy among university teachers, enriches the assessment tools for their digital literacy, and lays the foundation for guiding the professional development of university teachers and enhancing the level of digitalized education in higher education.

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