An Integrated Fuzzy Evaluation System for Assessing Teaching Skills Based on Digitalization and Information Intelligence

Xingchen Hang
School of Nanjing University of Information Science and Technology, Nanjing210000, China
1327819298@qq.com

Abstract. The digital transformation of education has made information intelligence penetrate various aspects of contemporary teaching. Consequently, the evaluation of classroom teaching quality now requires a comprehensive consideration of various levels and elements, including the impact of digital factors. For higher education institutions, assessing the teaching skills of normal students, our future educators, is crucial. This study introduces a fuzzy comprehensive evaluation approach for a holistic assessment of student teachers' classroom teaching in tertiary institutions. It aims to encompass the diverse influences on teaching quality and provide substantiated evaluation outcomes. By establishing a robust and scientific assessment framework for teaching skills, this research seeks to enhance the training and selection of exemplary teaching professionals, foster the advancement of digital education, and improve the quality and effectiveness of educational delivery.

Keywords: Digitization, Fuzzy Comprehensive Evaluation, Teaching Skills.

1. Introduction

The report of the 20th National Congress of the Communist Party of China, presented by General Secretary Xi Jinping, emphasized the importance of propelling digital transformation in education to foster a learning society and establish a learning-oriented nation. Rapid technological advancements are significantly altering human cognition, production, lifestyles, and learning methods. Technologies such as big data and artificial intelligence continuously drive the digital transformation in education, encompassing the use of digital technologies and tools to enhance teaching, learning, and administration. This includes employing computers, the internet, and other digital devices for knowledge dissemination, instructional resource provision, online learning, and assessments. The primary goals of digital transformation in education are to improve the effectiveness and efficiency of educational processes, support personalized student learning experiences, and enrich the environment for teachers, students, and educational institutions.

As a key component of China's educational framework, school education and the training of student teachers as future educators are paramount. Teaching proficiency is a crucial skill set for student teachers in higher education. Typically, student teachers' teaching skills are assessed through the analysis of micro-teaching session recordings. However, this method has limitations, including retrospective evaluations that are subject to evaluator biases, leading to significant subjectivity. Moreover, the vague nature of assessment criteria presents challenges in maintaining objectivity and precision in evaluations.

In the context of ongoing educational digital transformation, the deep integration of information technology into classroom instruction is a critical aspect of modern teaching reform. This integration brings new professional development requirements for student teachers in higher education. Therefore, the evaluation of student teachers' teaching skills in universities should align with educational digitalization advancements, utilizing more scientific, objective, and precise methodologies. Incorporating virtual simulation technology, online teaching platforms, and data analytics could enable a more comprehensive evaluation of student teachers' instructional capabilities and performance. This approach could provide a deeper understanding of teaching competencies, offer targeted training and development, and thereby enhance teaching quality.

In conclusion, existing evaluation methods are increasingly insufficient for modern classroom teaching practices. There is an urgent need for a scientifically robust and digitally adaptive assessment framework for student teachers' teaching skills. This system should thoroughly examine the range of skills and competencies, including technological applications and transformations in digital education. It should include evaluative metrics for teaching design, classroom management, multimedia instruction, and online teaching competencies, ensuring a comprehensive and accurate assessment. Furthermore, the framework should utilize objective and systematic evaluation approaches, integrating teaching cases, demonstrations, and design assignments with real-world contexts to produce authentic and precise outcomes.

2. Literature Review

The trajectory of classroom teaching quality evaluation in international research has been complex, transitioning from a focus on student performance and pedagogical methods to more holistic assessments. Baird, J., & Mitchell, I. J. (1986) underscored the importance of evaluation in enhancing educational quality, particularly highlighting the teaching process and student engagement. Black, P., & Wiliam, D. (1998) criticized the excessive emphasis on summative evaluation in classroom teaching assessments, ignoring the vital role of formative evaluation in providing timely and targeted feedback. Hattie, J., & Timperley, H. (2007) emphasized the significant impact of feedback on improving teaching quality, viewing it as essential for the continuous development of both students and educators. Thus, evaluation is positioned not just as a summative tool, but as a catalyst for ongoing pedagogical refinement.

These international studies emphasize the evolving nature of classroom teaching quality evaluation, focusing on the teaching process, student engagement, the constraints of an overemphasis on summative evaluations, and the critical role of feedback in enhancing teaching quality. Their insights are invaluable in constructing a robust and scientifically grounded evaluation system for classroom teaching quality. In the context of educational digitization, experiences from these studies can inform the development of more scientific, objective, and accurate evaluation methodologies, thereby improving educational quality and the holistic advancement of teaching practices.

In China, the approach to classroom teaching quality evaluation has similarly evolved. The application of information technology in education has shifted from a peripheral role in showcasing teachers' content to a central element in driving comprehensive reforms and innovations in teaching and learning [3]. Traditional evaluation methods for student teachers' teaching skills, such as observation, reflective teaching, evaluative observation, student feedback, and self-assessment by student teachers, offer insights into their pedagogical competencies but have limitations. With the integration of artificial intelligence into primary and secondary education curricula [4], and the widespread adoption of microteaching technology—highly regarded in the global teacher education sector [5]—student teachers' instructional videos are predominantly stored as recorded micro-lessons. Currently, microteaching skills are assessed through verbal and written feedback from mentor teachers, peers, and the evaluated individuals themselves. However, notable gaps exist in current domestic research and practice in teaching skill evaluation. The assessment of teaching skills among college student teachers is complex and challenging to quantify accurately, yet when quantified scores are required, they tend to offer more credibility and persuasiveness. Moreover, research into the impact of student and teacher self-assessments is limited, indicating a lack of a professional, broadly applicable teaching skill evaluation framework [6].

The implementation of fuzzy comprehensive evaluation methods in assessing student teachers' teaching skills is increasingly gaining attention. By applying fuzzy logic to fuzzify evaluation criteria and for reasoning and computation, this method handles the diversity, uncertainty, and ambiguity inherent in the evaluation process better.

Overall, contemporary research on normal students' teaching skill evaluation is progressively focusing on the fuzzy comprehensive evaluation approach, achieving notable scholarly contributions.

Future studies could further refine these evaluation models and methods, enhancing the objectivity and practicality of the outcomes. This advancement is instrumental in strengthening student teachers' instructional capabilities and improving the quality of teacher training.

3. Research Process

3.1. Research Methodology

(1) Development of Comprehensive Evaluation Indicators

The fuzzy comprehensive evaluation method, based on the theory of fuzzy set membership degrees, effectively converts qualitative assessments into quantitative ones. This approach addresses the challenge of quantifying fuzzy evaluations, making it suitable for assessing various uncertainties [8].

Table 1. Comprehensive evaluation system for classroom teaching skills

<table>
<tr><td rowspan="14">Comprehensive evaluation system for classroom teaching skills</td><td>primary indicator</td><td>secondary indicator</td></tr>
<tr><td rowspan="4">Guidance and mastery
U1</td><td>Setting up pre-learning contexts and focusing on physical engagement
u11</td></tr>
<tr><td>Setting clear and scientific teaching objectives
u12</td></tr>
<tr><td>Designing pre-learning content based on teaching objectives
u13</td></tr>
<tr><td>Organise pre-learning feedback to get an overall grasp of the learning situation
u14</td></tr>
<tr><td rowspan="3">Teaching optimization and restructuring
U2</td><td>Use multimedia software to create teaching materials
u21</td></tr>
<tr><td>Fit for Purpose, Diverse and Digital
u22</td></tr>
<tr><td>Using information technology to design classroom teaching activities
u23</td></tr>
<tr><td rowspan="3">Teaching optimization and restructuring
U3</td><td>Control the pace of the classroom and create a classroom atmosphere
u31</td></tr>
<tr><td>Unifying classroom questions and refining core questions
u32</td></tr>
<tr><td>Clarify the goals of the inquiry and focus on key outcomes
u33</td></tr>
<tr><td rowspan="3">Academic development and demonstration
U4</td><td>Focus on timely evaluation to enable internalisation of knowledge
u41</td></tr>
<tr><td>Consolidation of learning and transfer to practice
u42</td></tr>
<tr><td>Designing learning scaffolds and practising with embodied activities
u43</td></tr>
</table>

Comprehensive evaluation involves a holistic judgment of a subject considering multiple influencing factors. The teaching skills of normal students are influenced multifactorially. At the same time, digitalization of education provides abundant learning resources, such as electronic textbooks, online tutorials, learning videos, and open education resources. This research develops a two-tiered comprehensive evaluation model. It incorporates perspectives from literature on teaching quality assessment [11-13] to analyze student teachers' teaching skills. Considering basic teacher qualifications and new professional development requirements in digital education, we raise an evaluation model which consists of four primary indicators and corresponding secondary indicators, including guidance and mastery, teaching optimization and restructuring, problem-driven and effective outcomes, academic development and demonstration. Each primary indicator is further divided into related secondary indicators, creating a multi-tiered system with assigned weights as presented in Table 1.

(2) Construction of a Decision Set

The decision set defines the levels for evaluating the identified indicators, categorized into four levels: V={V1, V2, V3, V4}={Excellent, Good, Average, Pass}.

(3) Weight Allocation Among Evaluation Factors

Table 2. Weighting of factors

	primary indicator	secondary indicator
Comprehensive evaluation system for classroom teaching skills	Guidance and mastery U1 (0.3)	Setting up pre-learning contexts and focusing on physical engagement u11 (0.2)
		Setting clear and scientific teaching objectives u12 (0.4)
		Designing pre-learning content based on teaching objectives u13 (0.2)
		Organise pre-learning feedback to get an overall grasp of the learning situation u14 (0.2)
	Teaching optimization and restructuring U2 (0.1)	Use multimedia software to create teaching materials u21 (0.4)
		Using information technology to design classroom teaching activities u23 (0.6)
	Teaching optimization and restructuring U3 (0.4)	Control the pace of the classroom and create a classroom atmosphere u31 (0.4)
		Unifying classroom questions and refining core questions u32 (0.3)
		Clarify the goals of the inquiry and focus on key outcomes u33 (0.3)
	Academic development and demonstration U4 (0.2)	Focus on timely evaluation to enable internalisation of knowledge u41 (0.3)
		Consolidation of learning and transfer to practice u42 (0.4)
		Designing learning scaffolds and practising with embodied activities u43 (0.3)

After determining the indicators, the next step is to establish the weight relationships among evaluation factors. Proper weight distribution, reflecting reality, is essential for the accuracy of final evaluations. This study primarily uses the Analytic Hierarchy Process (AHP) for weight allocation. The assumed weights obtained through AHP are detailed in Table 2.

(4) Membership Degree Calculation of Factor Sets at Each Level

Membership degrees, ranging from 0 to 1, indicate the extent of belonging to a set. The larger its value, the more it belongs to this set. An experimental method, similar to calculating the probability of random events, is used for determining membership degrees. In classical probability statistics, if n experiments are conducted on the occurrence or non occurrence of event A, the frequency of event A occurrence is calculated as (the number of times A occurs/the number of experiments n). In this article, the calculation of membership degree also adopts the probability calculation method. The larger the total number of surveys, the closer the obtained value is to the membership degree. For example, 50 experts participated in the evaluation and scoring. For a certain indicator, 20 out of 50 experts rated it as "excellent"; 15 people rated "good"; 10 people rated as "average"; Five people are rated as passing. So the membership degree of the u11 indicator on the "excellent" level is "20/50=0.4"; The membership degree on the "good" level is "15/50=0.3"; The membership degree at the "medium" level is "10/50=0.2"; The membership degree on the "pass" level is "5/50=0.1". And the fuzzy subset of u11 index on V is called R11=[0.4, 0.3, 0.2, 0.1]. According to this principle, the membership degrees of all evaluation indicators in this article are shown in Table 3.

Table 3. Membership Degree of evaluation indicators

primary indicator	secondary indicator	Excellent	Good,	Average	Pass
U1	U11	0.4	0.3	0.2	0.1
	U12	0.6	0.3	0.1	0.0
	U13	0.6	0.2	0.2	0.0
	U14	0.5	0.3	0.2	0.0
U2	U21	0.5	0.3	0.1	0.1
	U22	0.6	0.3	0.1	0.0
U3	U31	0.6	0.4	0.0	0.0
	U32	0.7	0.3	0.0	0.0
	U33	0.6	0.3	0.1	0.0
U4	U41	0.7	0.2	0.1	0.0
	U42	0.9	0.1	0.0	0.0
	U43	0.4	0.3	0.2	0.1

(5) Formulation of Fuzzy Judgment Matrix

Using Table 3, a fuzzy judgment matrix is created to correlate evaluation factors with their respective levels:

$$R1=\begin{bmatrix}0.4 & 0.3 & 0.2 & 0.1\\ 0.6 & 0.3 & 0.1 & 0.0\\ 0.6 & 0.2 & 0.2 & 0.0\\ 0.5 & 0.3 & 0.2 & 0.0\end{bmatrix} \qquad R2=\begin{bmatrix}0.5 & 0.3 & 0.1 & 0.1\\ 0.6 & 0.3 & 0.1 & 0.0\end{bmatrix}$$

$$R3=\begin{bmatrix}0.6 & 0.4 & 0.0 & 0.0\\ 0.7 & 0.3 & 0.0 & 0.0\\ 0.6 & 0.3 & 0.1 & 0.0\end{bmatrix} \qquad R4=\begin{bmatrix}0.7 & 0.2 & 0.1 & 0.0\\ 0.9 & 0.1 & 0.0 & 0.0\\ 0.4 & 0.3 & 0.2 & 0.1\end{bmatrix}$$

(6) Multi-tiered Comprehensive Evaluation

The factor set U is divided into groups: U={U1, U2, U3, U4}, with each Ui representing elements of the primary factor set. We refer to U as the second level factor set, where element Ui is the primary level factor set.

Step 1: The evaluation includes single-factor judgments on each factor in Ui={ui1, ui2, ui3,...} to establish fuzzy mappings and obtain judgment matrices Ri. Weights assigned to each factor in Ui lead to comprehensive judgments Bi=Ai○Ri (i=1, 2, 3...).

$$U_1=A_1\circ R_1=[0.2\ 0.4\ 0.2\ 0.2]\circ\begin{bmatrix}0.4 & 0.3 & 0.2 & 0.1\\ 0.6 & 0.3 & 0.1 & 0.0\\ 0.6 & 0.2 & 0.2 & 0.0\\ 0.5 & 0.3 & 0.2 & 0.0\end{bmatrix}=[0.54\ 0.28\ 0.16\ 0.02]$$

$$U2=A_2\circ R_2=[0.4\ 0.6]\circ\begin{bmatrix}0.5 & 0.3 & 0.1 & 0.1\\ 0.6 & 0.3 & 0.1 & 0.0\end{bmatrix}=[0.56\ 0.30\ 0.10\ 0.04]$$

$$U3=A_3\circ R_3=[0.4\ 0.3\ 0.3]\circ\begin{bmatrix}0.6 & 0.4 & 0.0 & 0.0\\ 0.7 & 0.3 & 0.0 & 0.0\\ 0.6 & 0.3 & 0.1 & 0.0\end{bmatrix}=[0.63\ 0.34\ 0.03\ 0.00]$$

$$U4=A_4\circ R_4=[0.3\ 0.4\ 0.3]\circ\begin{bmatrix}0.7 & 0.2 & 0.1 & 0.0\\ 0.9 & 0.1 & 0.0 & 0.0\\ 0.4 & 0.3 & 0.2 & 0.1\end{bmatrix}=[0.69\ 0.19\ 0.09\ 0.03]$$

Step 2: For the second level factor set U={U1, U2, …}, a comprehensive judgment U=A○R is derived.

$$R=\begin{bmatrix}0.54 & 0.28 & 0.16 & 0.02\\ 0.56 & 0.30 & 0.10 & 0.04\\ 0.63 & 0.34 & 0.03 & 0.00\\ 0.69 & 0.19 & 0.09 & 0.03\end{bmatrix}\quad A=[0.3\ 0.4\ 0.1\ 0.2]$$

$$U=A\circ R=[0.3\ 0.4\ 0.1\ 0.2]\circ\begin{bmatrix}0.54 & 0.28 & 0.16 & 0.02\\ 0.56 & 0.30 & 0.10 & 0.04\\ 0.63 & 0.34 & 0.03 & 0.00\\ 0.69 & 0.19 & 0.09 & 0.03\end{bmatrix}=[0.587\quad 0.276\quad 0.109\quad 0.028]=0.587$$

Following the principle of maximum membership in fuzzy mathematics, the highest membership degree identified is 0.587, classified under the "Excellent" category. Therefore, the final fuzzy comprehensive evaluation for the student teacher is considered "Excellent".

4. Conclusion

This study introduces the fuzzy comprehensive evaluation method for assessing normal students' teaching skills in the context of digital education transformation. Utilizing micro-teaching videos, this method translates experts' qualitative analyses into quantifiable data through fuzzy mathematical operations, thereby enhancing the scientific rigor of the evaluation. In the digital education landscape, improving classroom teaching quality necessitates structural reforms, including enhancing teachers' digital literacy, creating immersive learning environments, and advocating for innovative educational materials. Further refinements to the evaluation model are essential, with its development dependent on the collaborative efforts of educational authorities, universities, and related institutions. These stakeholders must engage in comprehensive research and discussions to develop and continuously refine evaluation standards and methods, ensuring alignment with the evolving demands and trends in digital education.

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