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Effects of Teachers' Collaborative Reflection Supported by Smart Classroom System: A Perspective of Human-machine Collaboration

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Abstract: *Teachers' reflection has become increasingly important in prompting their professional development and enhancing the quality of classroom teaching. In recent years, more attention has been given to exploring this research field with the aim to improve the quality of teachers' reflection. The application of smart classroom system facilitates the generation of classroom teaching analysis reports, which not only broadens the content of teachers' reflection but also enriches the methods of their reflection. From a human-machine collaboration perspective, this study constructed a practical framework for teachers' reflection based on smart classroom system. This study employed a mixed method integrating quantitative and qualitative approaches to explore the effects of teachers' reflection practices. The results indicated that there was a significant improvement in the breadth, depth, and participation of teachers' reflection after six weeks of practice. Finally, this study also discussed the advantages and limitations of "machines" and "humans" intelligence in the context of teachers' reflection practices.*

Keywords: *Smart classroom system, Artificial intelligence technology, Teachers' reflection, Human-machine collaboration*

1. Introduction

At the beginning of the 21st century, countries worldwide have attached great importance to evidence-based evaluation of classroom teaching as a way to promote the improvement in teachers' professional development. In 2002, the United States issued the No Child Left Behind Act, which emphasized that "there must be reliable evidence to confirm that the instructional activities carried out in schools and the instructional behaviors of teachers are effective and make a positive impact on student learning" [1]. In 2015, the Making Every Student Success Act, released in the United States, set standards and incentives for educational evidence and encouraged the award of high standards of evidence for instructional programs and practices [2]. China has also introduced relevant policies to enhance teachers' digital literacy and their professional development. For example, in 2021, The National Center for Educational Technology (NCET) has launched a pilot application of an intelligent training platform, aimed at promoting innovation in teachers' training modes and changing the way teachers grow professionally. The Compulsory Education Curriculum Plan and Curriculum Standards (2022 edition) of china, provided strong support for the high-quality, balanced development of compulsory education, which advocating "evidence-based evaluation". However, the digital literacy of teachers is still insufficient [3], and the reflection ability of them also still needs to be improved. With the application of AI technology in education, the methods of classroom teaching analysis and teachers' reflection have undergone profound changes. Compared with traditional manual observation and recording methods, AI technology can provide rich data and quantitative analysis for classroom teaching analysis and teachers' reflection, and has advantages in providing continuous feedback and process evaluation [4]. Evaluation based on multidimensional data can optimize the analysis dimension of teacher and student behavior in classroom, and improve the convenience, efficiency and accuracy of teaching evaluation [5]. AI technology helps teachers make data-driven teaching decisions, which can have a positive impact on improving classroom teaching and reflection.

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2. Literature Review

In recent years, researchers have developed many frameworks for classroom teaching evaluation based on new information technology. The aim is to replace traditional classroom evaluation methods with the assistance of the technologies such as machine learning, big data analysis, and knowledge graphs. Meanwhile, some educational technology manufacturers have also introduced classroom teaching analysis and improvement systems based on AI technology. For example, iFLYTEK's Smart Classroom System can intelligently analyze multiple features of teachers' classroom teaching and generate teaching analysis reports. It has been shown that the intelligent technology can help teachers achieve more accurate and efficient teaching evaluation [6]. A classroom analysis report generated based on artificial intelligence technology can provide teachers with accurate data to aid in their teaching reflection. This helps teachers to delve deeper into classroom teaching, increase the depth and breadth of their teaching reflection [7], and promote the effectiveness of teaching reflection [8]. For example, Kang et al. developed an intelligent evaluation system for high school mathematics teachers' reflection by combining artificial intelligence technology, evaluation index system, evaluation model, and semantic similarity algorithm based on CNKI (the Chinese National Knowledge Infrastructure) [9]. After testing the system, it was found that the accuracy of the intelligent evaluation system reached more than 80%, which initially realized the application of the intelligent evaluation system for high school teachers. Jiang et al. adopted a sociocultural perspective to examine the obstacles a group of kindergarten teachers faced with collaborative reflection in collectivist cultural contexts [10]. They also explored three methods that successfully helped teachers overcome these collaborative reflection constraints. Qudsia et al. investigated the impact of collaborative reflection on pre-service teachers' environmental practices and found that the use of collaborative reflection can serve as a pedagogy for environmental education [11]. Klara et al. analyzed the transcripts of four Lesson Study groups at German primary schools, and their findings indicated that these groups differed significantly in the depth and trajectories of their reflection processes. They considered the implications for post-lesson discussions and critical reflection as a core skill of Lesson Study [12].

Despite the widespread application of technology in teachers' reflection practices, it is important to note that technology itself is not the key factor determining the improvement in teachers' reflection. Instead, how to apply technology rationally to enhance teachers' professional development levels needs to be specifically designed. For example, a study in Australia indicated that the mere use of laptops does not improve teachers' reflection abilities, and some specially designed technological application methods may achieve this goal [13]. It is recommended to strengthen collaboration and communication among teachers and share experiences of technology use. Therefore, further exploration is needed on how to integrate AI technology with teachers' reflection, fully harnessing the intelligence of "machines" and "humans."

3. Methodology

3.1. Research Design

Collaborative reflection refers to the process by which members of a community reflect through social interaction, as well as to the outcomes of this process. Teachers' collaborative reflection is an active, continuous, thorough, in-depth, and self-regulatory thinking process carried out among a group of teachers. Its purpose is to collectively reflect on past or current teaching activities and the theories and assumptions behind them, aiming to identify teaching problems and seek strategies for resolving these issues during the reflection activities. From a perspective of human-machine collaboration, this study has constructed a practical framework for teachers' collaborative reflection in smart classroom (as shown in Figure 1), with the aim of helping schools to improve the quality of classroom teaching evaluation and promote teachers' professional development.

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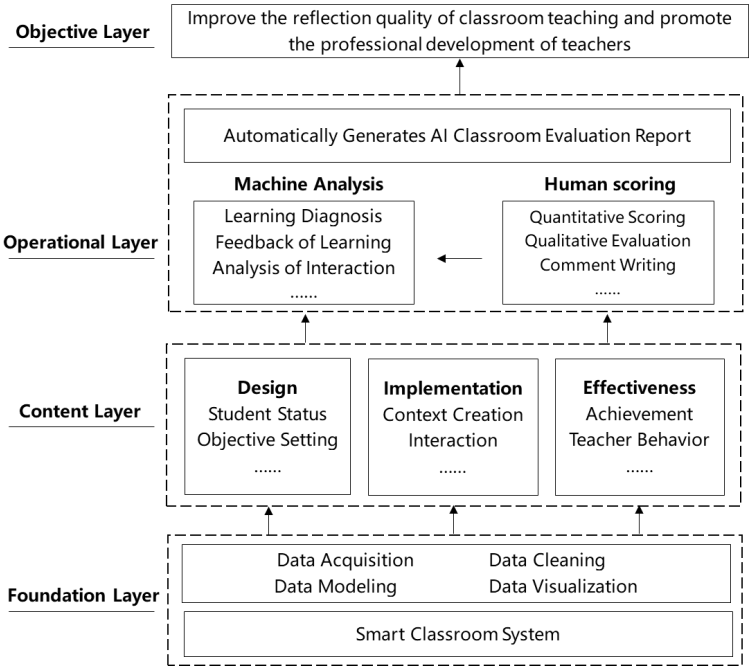

Figure 1: Framework of Teachers' Collaborative Reflection Practice Based on Smart Classroom System

The framework consists of four layers: ① Foundation layer. The framework is built on the foundation of the smart classroom system, which includes the smart processing center, smart tablet for teacher, smart tablet for student, smart microphone, and smart display and other parts. When teachers teach in smart classrooms, the system can provide intelligent support services, automatically collect teaching process data, and conduct statistical analysis. ② Content Layer. It primarily evaluates three aspects of teachers' teaching: instruction design, instruction implementation, and effectiveness of the lesson. The quality of teaching is assessed from three stages: before, during, and after the lesson. ③ Operational Layer. The smart classroom system automatically generates an AI classroom evaluation report to assist teachers in reflecting on their teaching. Classroom evaluation is neither purely expert-based nor solely machine-based. It is a collaborative human-machine evaluation, which includes two parts: human scoring and machine analysis. ④ Objective Layer. The goal of this framework is to help teachers improve the quality of reflection through intelligent technology, so as to promote teachers' development and improve teaching. Overall, this framework presents a complete process from data acquisition to final outcome assessment, highlighting the role and application of artificial intelligence in education.

3.2. Participants

Figure 2: Leaning in the Smart Classroom Environment of One-to-One tablet

In this study, nine primary school teachers in Bengbu City, Anhui Province were randomly selected as subjects. When one of the teachers was teaching a lesson in the smart classroom environment (as shown in Figure 2), the other teachers acted as evaluators and scored their classroom performance. After the lesson, the smart classroom system automatically integrates the evaluators' scores with the teachers' teaching behaviors captured in real time to generate an AI classroom evaluation report. Following the

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completion of the teaching session, the teacher and the evaluators engaged in reflection based on the AI classroom evaluation report, summarizing the strengths and weaknesses of the class and proposing future teaching improvement plans. Subsequently, the roles were exchanged, and evaluated each other. The study period lasted for 6 weeks, with pre- and post-questionnaire measurements administered to the teachers before and after the experiment.

3.3. Measuring Tools

3.3.1. Teachers' Reflection Questionnaire

In this study, a Teachers' Reflection Questionnaire (7-point Likert scale) was developed with reference to previously established teachers' reflection questionnaires[14-16], combined with the experience of teachers in teaching reflection practice. Teachers' reflection and improvement effects were measured from the dimensions of teachers' reflection breadth, depth, participation, and willingness. The Cronbach's alpha coefficient of the pre-test questionnaire was 0.811, and the Cronbach's alpha coefficient of the post-test questionnaire was 0.954, which were both greater than 0.7, indicating that the developed questionnaire had good reliability. Additionally, each item in the questionnaire has been validated by three rounds of experts, ensuring its validity.

3.3.2. AI Classroom Evaluation Report

After completing a lesson in the smart classroom environment, teachers can download and view their personal AI classroom evaluation report through the Web. Teachers can visually see the usage of digital resources, tools, and other aspects through the report. Meanwhile, they can view various charts of online interactions between teachers and students, students and students (as shown in Figure 3), as well as the graph of the teacher's speed of speech in lectures, etc., allowing them to gain insights into their teaching behavior performance.

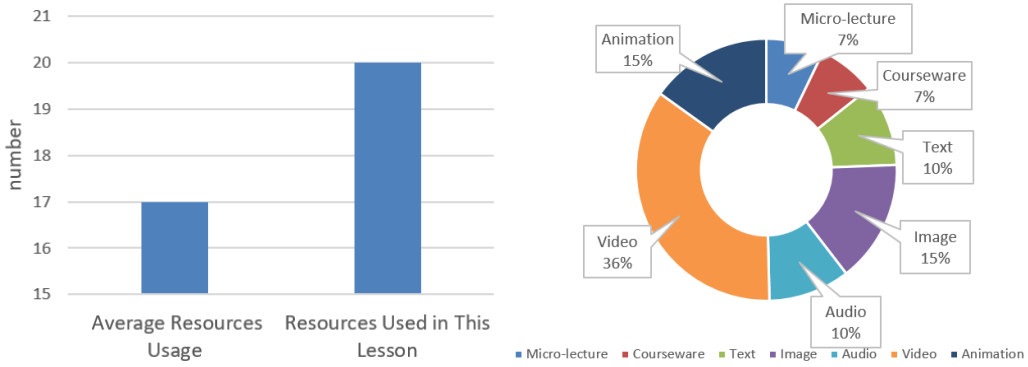

Figure 3: Part of Charts in the Report about Online Interactions

4. Results

4.1. Breadth of Teachers' Reflection

Before participating in the activity, the teachers took a pre-test for the breadth of reflection. When the activity ended, the teachers took a post-test for this dimension. After conducting a normality test on the pre- and post-test data of breadth, it was found that the data did not follow a normal distribution. Therefore, the Wilcoxon signed-rank test for paired samples was chosen to analyze the differences between the pre- and post-test data, as shown in Table 1. The median of the pre-test was 5.00, and the median of the post-test was 6.50, with $Z=2.117$ and $p<0.05$. It indicated a significant difference between the pre- and post-test data on the dimension of breadth. This result suggested that teachers can expand the scope of discussion topics and propose suggestions and opinions for teaching improvement during the collaborative reflection activity.

Table 1: Wilcoxon signed-rank test results of breadth before and after teachers' reflection activity

	Before		After		Wilcoxon signed-rank test
Breadth	Median	P25, P75	Median	P25, P75	Z=2.117 (p<0.05)
	5.00	3.75, 6.00	6.50	5.75, 6.75	

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4.2. Depth of Teachers' Reflection

Following the previous steps, a pre-test and post-test were conducted for depth of teachers' reflection. After conducting a normality test on the pre- and post-test data of depth, it was found that the data did not follow a normal distribution. Therefore, the Wilcoxon signed-rank test for paired samples was chosen to analyze the differences between the pre- and post-test data, as shown in Table 2. The median of the pre-test was 5.00, and the median of the post-test was 6.00, with $Z=2.255$ and $p<0.05$. It indicated a significant difference between the pre- and post-test data on the dimension of depth. From the results, it appeared that teachers were not only able to evaluate based on the specific facts of teaching activities, but also can combine these facts with value judgments and improvement suggestions to carry out a more comprehensive classroom teaching activity evaluation.

Table 2: Wilcoxon signed-rank test results of depth before and after teachers' reflection activity

	Before		After		Wilcoxon signed-rank test
Depth	Median	P25, P75	Median	P25, P75	Z=2.255 (p<0.05)
	5.00	5.00, 5.75	6.00	5.50, 6.33	

4.3. Participation of Teachers' Reflection

The same operational procedures were used to study the participation of teachers' reflection. After conducting a normality test on the pre- and post-test data of participation, it was found that the data did not follow a normal distribution. Therefore, the Wilcoxon signed-rank test for paired samples was chosen to analyze the differences between the pre- and post-test data, as shown in Table 3. The median of the pre-test was 4.33, and the median of the post-test was 6.00, with $Z=2.375$ and $p<0.05$. It indicated a significant difference between the pre- and post-test data on the dimension of participation. This results suggested that teachers were more engaged in teaching discussions and more inclined to offer their personal recommendations for enhancing teaching, with the assistance of the AI classroom evaluation report.

Table 3: Wilcoxon signed-rank test results of participation before and after teachers' reflection activity

	Before		After		Wilcoxon signed-rank test
Participation	Median	P25, P75	Median	P25, P75	Z=2.375 (p<0.05)
	4.33	3.67, 5.67	6.00	5.50, 6.33	

4.4. Willingness of Teachers' Reflection

After completing survey of willingness of teachers' reflection and conducting a normality test on the pre- and post-test data, it was found that the data did not follow a normal distribution. Therefore, the Wilcoxon signed-rank test for paired samples was chosen to analyze the differences between the pre- and post-test data, as shown in Table 4. The median of the pre-test was 6.00, and the median of the post-test was 6.00, with $Z=1.906$ and $p>0.05$. It was found that there was no remarkable difference between the pre- and post-test data on this dimension; that is, intelligent evaluation technology did not significantly increase teachers' willingness to engage in classroom teaching evaluation and reflection. Post-interviews indicated that this was partly because teachers were busy with their regular work. Although more data was provided with the assistance of intelligent technology, the organization of activities had become more cumbersome and complicated. Additionally, some data in the current AI classroom evaluation report were not accurate enough, and required teachers to modify it based on classroom observations.

Table 4: Wilcoxon signed-rank test results of willingness before and after teachers' reflection activity

	Before		After		Wilcoxon signed-rank test
Willingness	Median	P25, P75	Median	P25, P75	Z=1.906 (p>0.05)
	6.00	4.50, 6.00	6.00	5.67, 6.33	

5. Discussion

This study explored the practice of collaborative teacher reflection supported by the smart classroom system, and the results indicated a significant effect of teaching reflection practice under the collaboration

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of humans and machines. Firstly, teachers are able to expand the scope of classroom teaching reflection, promoting their professional development from multiple dimensions. Secondly, teachers can engage in deeper teaching reflection, beyond personal experience and surface observations. This approach is more conducive for teachers to implement teaching according to students' aptitudes based on the their different physiological, psychological, and social differences [17]. Thirdly, teachers can increase their participation in teaching reflection activities and continuously promote the collaborative reflection level during this process. The perspective of human-machine collaboration proposed in this study demonstrates the effectiveness of human-computer collaborative decision-making [18], highlights the roles of both the intelligence of "machines" and the intelligence of "humans". In terms of the intelligence of "machines", AI technology can provide more comprehensive, objective, and scientific teaching feedback data, and achieve more convenient visualization and presentation of data, which to overcome the subjectivity of traditional teachers' reflection. In terms of the intelligence of "human", teachers can provide personalized interpretation of the information in AI classroom evaluation reports, rather than relying solely on the data provided by technology.

However, this study also has some limitations, which provide directions for further research on teachers' collaborative reflection practices. For example, the measurement of teachers' reflection before and after in this study was conducted through self-report questionnaires, which inevitably introduced some subjectivity. Moreover, the sample size of this study was not large enough. Future research could collect more data on teachers' reflection using transferable task measurement methods. Additionally, future work could combine subjective experiential data with objective factual data to cross-validate and enhance the credibility and generalizability of research conclusions.

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