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Enhancement or Impediment? How University Teachers' Use of Smart Classrooms Might Impact Interaction Quality

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Abstract: Technology's involvement in teaching and learning is identified as an opportunity to bolster sustainable development in education. However, how it influences teaching quality and classroom interaction is a hotly debated subject, and the variations in interactions, by different technologies, between students and teachers in Smart Classrooms, particularly the ways in which interactions are impacted, are rarely discussed in existing research. The present study examines the effects of various degrees of technology on the quality of interactions in university-based Smart Classrooms based on an analysis of 38 courses, which were recorded and analysed over a three-year period. Also, an instrument to analyse interaction quality in a university Smart Classroom (USCIQAS) was developed. The results showed that advanced technological applications increase the quality of classroom interactions, particularly those involving student–teacher (ST) interactions, although it has a lower effect on the social–emotional outcomes of student–student (SS) interactions. Based on these findings, in order to maximize the potential of Smart Classrooms to improve classroom interactions, both teachers and students should be encouraged and trained to use technology. Teachers may also need to improve their pedagogy and technology use in tandem to avoid the risk of lower social–emotional outcomes of SS interaction.

Keywords: smart classroom; e-learning; technology usage; ICT; classroom interaction; teacher education

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1. Introduction

It has been identified that education is a key element in promoting the sustainable development of many aspects of society. However, faced with the current complexities of society and the natural environment, as well as the uncertainty of the future, there is an urgent need to shape a peaceful, just, and sustainable future, which requires that education itself be transformed [1] and that young generations acquire 21st century competencies [2]. On the other hand, in the information age, recent studies have shown that technology has an influence on education reform in many ways, and it can provide support for education reform and improve teaching quality [3,4] (pp. 27–32). First, the development of technology affects our educational aims and objectives. Second, the use of technology improves educational ecologies and contexts of learning. Third, technology promotes the innovation of teaching modes. Fourth, technology-enabled teaching, experimentation, and management have improved teaching management [5]. Fifth, the use of technology can improve students' learning efficiency, in that technology expands students' learning resources and broadens their learning space, which enables students to learn more and faster. Sixth, the use of technology promotes teacher development by improving teachers' learning efficiency, enriching their learning resources, and promoting the innovation of teachers' teaching concepts and methods [6].

It is worth mentioning that, during the COVID-19 pandemic, we have witnessed the rapid development of online education, e-learning, and critical digital pedagogies.

Some found that it made a positive contribution to teaching and students' learning [7,8]; however, others argued that technologically distant learning increased the gaps and deficits of student populations and dramatically exacerbated the digital inequalities that already existed before the pandemic [9,10] (pp. 90–97). Moreover, technology use and e-learning have become widespread and have received increasing attention in recent years, and the impact of technologies on education continues.

The way students interact with digital technology has changed considerably over the last two decades, and the classroom, which was formerly a technology-deficient setting, has been altered by technological connection [11]. In universities in particular, the incorporation of technology into the classroom has altered the foundations of education [12]. In this context, teachers must also become knowledgeable in the information resources of today and be skilled in the use of these tools to promote life-long learning and sustainable development, social harmony, and global understanding [13]. To achieve this, teachers need opportunities to apply technologies, training, and just-in-time support [14] (p. 1). So, the integration of information literacy and technologies throughout teacher preparation and development programs becomes an important element in preparing teachers to meet the global challenges of the 21st century and sustainable development in education [13,15].

The question is, can and to what extent can the use of information technology promote teaching? Studies have shown that the level of technology used by teachers has been identified as having a larger influence on the overall education process [12] and in promoting the quality of teaching by facilitating classroom interaction [16–18]. However, Hunt (1997) [13] and Kay (2011) [19] hold opposite views that the quality of technology-enhanced instruction is determined not by the technology itself but also by the teacher's use of it and good teaching. Shah (2013) [20] also claimed that smart technologies are sometimes used incorrectly and may make the learning process more complex, hindering student understanding. For instance, the majority of technology use engages and inspires kids, which does not necessarily foster cognitive progress related to academic objectives [21]. And, conversation, one of the most essential forms of classroom engagement, may be severely negatively impacted by new technologies [22]. The necessary questions thus become "Is there a difference in teaching quality based on teachers' mastery of the necessary technology skills?", "What factors directly influence the quality of classroom interaction?", and "Exactly what kind of interaction is being affected?".

2. Research Background and Questions

2.1. Smart Classroom

The embedding of the idea of "Smart" in the term Smart Classroom is itself intriguing and most likely arises from joint usage of smart technology. The "Smart Classroom," as a technology capable of affecting classroom interaction, usually refers to a physical classroom that integrates advanced forms of educational technology to increase the instructors' ability to facilitate students' learning and their ability to participate in learning experiences beyond the possibilities of traditional classrooms [17,23,24]. The educational technology includes flexible hardware devices (such as computers, mobile terminals, electronic whiteboards, presentation equipment, and activity desks and chairs) and more interactive software with artificial intelligence (such as online interactive platforms, learning management systems, face recognition, and emotional recognition) [25].

From a theoretical perspective, the Smart Classroom architecture and philosophies are based on constructivist learning theories [26], which emphasize students' self-development via social interactions [27] (pp. 1–14). As a result, the term "Smart" may thus refer to the ability to maintain a high degree of classroom involvement throughout the learning process, which emphasizes the exploration of interactions as an important point in studies of this phenomenon. According to Yau et al. (2003) [28], Yu et al. (2022) [29], and Yuan (2022) [30], Smart Classrooms are intended to improve teacher–student interactions to thus improve the teaching and learning experience. Based on constructivism, Garrison (2007) [31] proposed a Community of Inquiry (CoI) model to understand and guide online learning experiences.

He believes that community cooperative learning and interaction, including social, cognitive, and teaching, are of great significance for students' advanced learning. Therefore, technology can promote teaching and student learning in these aspects based on the CoI model. Huang et al. (2012) [32] also proposed a "SMART" concept model with the five dimensions of "Showing", "Managing", "Accessing", "Real-time feedback", and "Testing", as a framework for the impact of technology on teaching and learning. Researchers further think that Smart Classrooms may improve the presentation of educational information, make it easier for students to acquire learning resources, encourage engagement in classes [17], help teachers assess student learning [32] and take charge of in-classroom teaching [33], and provide better interactions and better physical environments [34].

2.2. The Influence of Technology on Classroom Interaction Quality

The term classroom interaction is generally understood to mean the communication between teacher and students and between students themselves [35] (pp. 3–12). It is believed that quality interaction can enhance the classroom atmosphere, as well as promote students' learning behaviours and engagement, and thus improve the quality of classroom teaching [29,36]. Researches have identified the influence of both a single technology and Smart Classroom on classroom interaction quality.

Some previous research has focused on the influence of interactive whiteboards (IWBs), with evidence from studies by Smith et al. (2006) [37], Manny-Ikan et al. (2011) [38], and Hall and Higgins (2005) [39] indicating that the versatility and multimedia functions of IWBs and the "theatrical tension" that they bring to the classroom help to attract students and increase their interest and engagement. Technology can be used to improve the interactions between the instructor and the students, or in-group collaboration among the students [28]. Some studies, however, also indicated that such student participation was short-lived and that the advantages of IWBs were lost, where the class lacked higher-order thinking skills [38]. Knowledge and understanding of technology were also seen to affect teachers' use of IWBs and, consequently, their confidence in teaching [40], suggesting that the quality of the resulting interactions may also be affected. Raman et al. (2014) [41] pointed out that IWB acceptance among teachers or students further affects the quality of teaching, while Glover, Miller, and Averis (2007) [42] noted that the interactive function of IWBs was maximized to differing extents based on teachers' personal technical and pedagogic fluency.

Other research has focused on personal response systems (PRS) and group response systems (GRS), such as clickers, with the findings suggesting that these help to break up traditional lecture models by promoting learner-centred active learning and to increase student participation and student–teacher interaction by removing students' fear of public mistakes or embarrassment [43–46]. And, it was found that, with the use of tablet PCs, response systems can improve individual students' participation and interaction in various group sizes [47]. As a result, it is becoming accepted that technological interventions can have an influence on classroom engagement, though the effect is often associated with the degree of involvement.

It is critical to understand that it is inappropriate to examine the impact on interaction in new Smart Classrooms by separately examining the impact of some single technology, as He and Li (2009) [48] (p. 103) argue that the development of educational technology is cumulative, with previous generations of technology coexisting with new generations. A Smart Classroom is a comprehensive technical system where the function of the whole can exceed that of the sum of its parts. In this sense, Smart Classrooms must be seen as multilevel technology systems containing co-existing generations of technology: these commonly include the simple multimedia environment represented by projection, the interactive multimedia environment represented by the IWB, and the interactive teaching system represented by intelligent terminal technology [49].

Some researchers have suggested that the use of full Smart Classrooms can promote interaction in primary and secondary schools. Wang et al. (2016) [50] analysed 54 English classes in Beijing, Shanghai, and Shenzhen using an interactive analysis scale, finding that Smart Classrooms supported classroom interactions, improving its frequency and enriching its content. The use of Smart Classrooms also enhances the dynamic, effective, and harmonious interaction between teachers and students, thus enabling technology to reinforce the impact of students' involvement in learning and intelligence with regard to academic performance [16,18,51]. Some scholars also consider that smart technologies may help to improve interactions, with which teachers will be able to choose more suitable ways of teaching (i.e., online, face-to-face, or blended) to meet different types of needs [17], and to extend the limitations of time and space for learning [52]. In a Smart Classroom, students have more opportunities to explore, create, display, and evaluate with the support of smart technology. Teachers can also use technology to present content, detect students' learning statuses, diagnose the teaching process, and adjust their teaching method in a timely manner [53].

The impact of Smart Classrooms on interaction may, however, differ at different stages of education. The use of Smart Classrooms has led to a significant increase in teacher–student interactions at the K12 level, helping to improve the quality and efficiency of teacher–student interactions [54]. At the primary school level, Jo and Lim (2015) [55] compared the interaction within two lessons in South Korean and found that lessons in Smart Classrooms involved more indirect teaching, a higher question ratio, and less lecture-style teaching. However, it is questionable whether interactions at the university level are positively influenced by Smart Classroom use, as in comparison with research carried out at primary and secondary schools, there are much fewer studies on the influence of Smart Classrooms on interaction at the university level. Chen, Chang, and Chien (2015) [56] used the "Speech-Driven PowerPoint" (SDPPT) system to enhance interactions at a Taiwanese university, determining that student enjoyment and motivation increased with such use, and Jiang et al. (2018) [57] showed that the amount of classroom interaction in Smart Classrooms in mainland China generally increased, although the levels of technology used by teachers were quite different.

However, there is some controversy. Li, Liang, and Xue (2018) [58] suggested that Smart Classrooms did not significantly improve class interaction and that such technology was mainly used to support teacher-centred teaching. Furthermore, although the existing literature provides some overview of the interactions facilitated through the use of technology, the specific relationship between Smart Classrooms and interaction quality in university classrooms remains unknown, and any discussion of the impact of layered technology systems on interaction is thus lacking.

2.3. Instrument to Analyse Classroom Interaction Quality

It may be difficult to quantify the classroom interaction quality, and the only way is through some kind of standardized observation method [59]. Hence, the development of classroom observation instruments, such as an observation framework and scale, may be required to measure the quality of interactions.

A great deal of research has gone into developing instruments to analyse classroom interactions based on different criteria for "quality interactions". There are mainly two kinds of interactions in educational relationships, defined as student–teacher (ST) and student–student (SS). An analysis of ST interactions tends to focus on evaluating the quality of teachers' influence on and support of students. Flanders (1963) [60] assumed that teachers typically exerted their influence on students by means of verbal statements and thus proposed the "Flanders System of Interaction Analysis" (FSIA) to analyse both teacher talk and student talk. Pianta, Hamre, and Allen (2012) [61] instead divided teacher support into the domains of emotional support, classroom organization, and instrument support, thus developing the "Classroom Assessment Scoring System" (CLASS), which includes 11 dimensions based on the various domains to evaluate the effectiveness of interactions between teachers and children. As Johnson (1981) [62] noted, however, in addition to ST interactions, SS interactions are also necessary for students' achievement, socialization, and healthy development. Kumpulainen and Wray (2001) [63] thus proposed the "Analytical Framework of Peer-group Interaction" (AFPI) to analyse SS interactions from sociocultural and sociocognitive perspectives. Hillman, Willis, and Gunawardena's (1994) [64] research incorporated the learner–interface interaction into the instrument used to analyse interaction, while Gu and Wang (2004) [65] adapted FSIA by adding items to increase the focus on students' behaviour and student–technology interactions, thus proposing the "Information Technology-based Interaction Analysis System" (ITIAS) to analyse interactions in the classroom in a manner integrated with information and communications technology (ICT) use. Mu and Zuo (2015) [66] similarly took ICT into consideration when proposing the "Teaching Behavior Analysis System" (TBAS), which was used to observe teacher and student behaviours, ST interactions, and the use of media in class. Wang et al. (2016) [50] similarly developed the "Smart Classroom-based Interaction Analysis System" (SCIAS) for primary and secondary schools, which includes an analysis of basic information, classroom facilities, and interactive processes.

Other research has focused on constructing an analysis instrument to consider interactions from the perspective of the learning process. Henri (1992) [67] proposed an analytical model that emphasized five dimensions of the learning process in a computer-mediated communications (CMC) environment: these were participation, interaction, social, cognitive, and metacognitive. After examining this model and other studies, Sing and Khine (2006) [68] then concluded that the most commonly used interaction dimensions were participation, cognitive processing, and social interaction.

Due to the variety of different contexts in which these instruments were developed, they cannot be used to analyse the quality of interactions in university Smart Classrooms without alteration, however. FSIA and CLASS do not include sufficient indicators of SS interaction, as they are mainly aimed at evaluating ST interactions, while CLASS is most appropriate for early childhood education. Similarly, the instruments proposed by Henri, and Sing and Khine are predominantly used to evaluate interactions in distance education, rather than prioritizing face-to-face interactions, while ITIAS, TBAS, and SCIAS are largely used in primary and secondary schools and also do not focus on the quality of interactions. As a result, based on the research above, a novel framework adapted to university classroom interaction assessment needs to be developed.

2.4. Research Questions

All in all, although previous studies have outlined the role of Smart Classrooms in promoting classroom interactions, it is unclear whether the use of hierarchical technology has a significant impact on classroom interaction, and less attention has been paid to university Smart Classrooms and student–student interactions. To address these questions, this study aimed to reveal the impact of Smart Classrooms on the quality of classroom interactions by investigating the relationship between the levels of technology used by teachers and the interaction quality. The findings may address the existing research gap, in a way, and encourage teachers and Smart Classroom designers to evaluate and understand the effectiveness of smart technologies in the teaching and learning process in order to improve Smart Classroom design, to provide appropriate support to teaching and learning, to provide clear guidance for future teacher training, and to promote the sustainable development of education. The current study adopted a video analysis method and developed an interactive quality analysis and scoring system for university Smart Classrooms; this system in turn allowed for the measurement and comparison of the quality of ST and SS interactions as influenced by different technology levels from various engagement, social, and cognitive dimensions.

The study in this article focuses on universities for several reasons, including the relative lack of research focusing on the influence of Smart Classrooms on interactions at the university level. The situation in university classrooms is quite different from that in primary and secondary schools, especially in China, and since China initiated the New Curriculum Reform, which is oriented towards developing self-regulated, collaborative, and inquiry learning, in 2001, primary and secondary teachers' knowledge of classroom interaction has greatly improved. These reforms have not been instituted in Chinese higher education, however. University teaching is also now more student-led, with teacher-supported teaching models [69]. But, the main teaching model in universities still remains traditional lectures, with the proportion of teacher "talking" in class remaining as high as 84% [70]. In some classrooms, lectures thus still constitute the sole teaching approach [56]. The current state of classroom teaching means that the interactive nature of university classrooms may make it more likely that technology will more significantly influence the quality of the interaction. As research by Jiang et al. (2018) [57] shows, different teachers use different levels of technology in Smart Classrooms. Due to teachers' dominance in these interactions, it is possible to use colleges as a case study in order to gain a better understanding of how various instructors' technological proficiency influences classroom interaction.

In summary, our research questions are as follows:

(1) How can we develop an instrument to analyse interaction quality in university Smart Classrooms?
(2) Does the level of technology use affect the overall interaction quality in university Smart Classrooms?
(3) Does the level of technology use affect the ST interaction quality in university Smart Classrooms?
(4) Does the level of technology use affect the SS interaction quality in university Smart Classrooms?

3. Methods

3.1. Developing an Instrument to Analyse Interaction Quality in University Smart Classrooms

3.1.1. USCIQAS Framework

To observe and evaluate the quality of classroom interactions, the current study developed the "University Smart Classroom-based Interaction Quality Analysis System (USCIQAS)" based on a comprehensive analysis of the existing literature. To begin, this study split interactions into ST and SS interactions from the standpoint of educational partnerships. Second, based on Sing and Khine (2006)'s [68] work, this study built categories and descriptions of "USCIQAS" for the assessment of both ST and SS interactions, including three first-level indicators—Engagement, Social, and Cognitive, as well as nine second-level indicators (Table 1).

Table 1. University Smart Classroom-based Interaction Quality Analysis System (USCIQAS).

Dimensions	Analytical Category	Description of ST and SS Interactions
Engagement	Involvement breadth	The proportion of students involved in the learning activity
	Involvement intensity	The extent to which students engaged themselves in the learning activity
	Emotional involvement	The extent to which students experience positive emotion during the action
Social	Interactive sensitivity	The class or group atmosphere that influences student feelings, whether positively or negatively
	Interactive climate	The extent to which students' cues and needs are noticed and responded to by the teacher or other students within the classroom
	Interactive agency	The extent to which individual students have agency within ST and SS interactions
Cognitive	Concept development	The extent to which discussions and activities promote students' higher-order thinking skills rather than focus on rote and fact-based learning
	Cognitive strategy	The extent to which feedback focuses on expanding learning and understanding as opposed to correctness or the end product
	Quality of feedback	The extent to which interaction focuses on learning how to learn as opposed to mastering knowledge

The following is an illustration of our framework:

Dimension 1: Analysis of student engagement

According to Skinner and Belmont (1993) [71], individual participation often incorporates behavioural and emotional components. The term "Engagement" refers to the breadth and intensity of a student's participation in educational activities, as well as their emotional commitment.

- Involvement breadth may be defined as the percentage of students who participate in a learning activity.
- Involvement intensity refers to the extent to which a student engages in a learning activity, and deeply engaged students often demonstrate strong effort, focus, and an embrace of difficulty, among other characteristics.
- Emotional involvement refers to the extent to which students may feel positive emotions such as excitement, optimism, curiosity, and interest throughout a learning activity.

Dimension 2: Analysis of social interaction

Social interaction is a term that refers to communication behaviours that are unrelated to formal educational content but are beneficial for increasing student engagement, feeling of belonging, and group cohesiveness [67]. Pianta et al. (2012) [61] placed a premium on teachers' emotional and social support of students in the classroom while designing CLASS, suggesting three categories: emotional environment, teacher sensitivity, and consideration of student viewpoints. Both of these concepts, as well as others from FSIA [60], are used in our work to analyse ST and SS interactions. Interactive climate, interactive sensitivity, and interactive agency are our three categories:

- Interactive climate refers to the classroom or group setting that has an effect on both positive and negative student sentiments. The former setting fosters the formation of warm caring connections and the pleasure of classroom time, while the latter entails screaming, embarrassment, and frustration, among other things.
- Interactive sensitivity relates to the extent to which individual student cues and needs are noticed and responded to. Individuals' sentiments are quickly recognized and reacted to in a nonthreatening way by the teacher or other pupils in high-quality interactions.
- Interactive agency is the extent to which individual students have agency within ST and SS interactions. While high-quality ST interactions are often designed around students' interests and goals, high-quality SS interactions enable participants to voice their ideas and to take ownership of group activities.

Dimension 3: Analysis of cognitive interaction

Cognitive engagement is a term that relates to classroom activities that are centred around students' knowledge creation. Based on the research in this area, this study categorizes cognitive interaction into the following categories: idea formation (Pianta et al., 2012) [61], feedback quality [60,61], and strategy [67].

- Concept development refers to the amount to which dialogues and activities foster students' higher-order thinking abilities, as opposed to an emphasis on rote and fact-based learning [61]. The sequence of thought may be summarized as follows: recall, comprehend, apply, analyse, evaluate, and create [72].
- Quality of feedback refers to the extent to which feedback focuses on expanding learning and understanding as opposed to correctness or the end product [61].
- Cognitive strategy refers to the extent to which an interaction focuses on learning how to learn as opposed to mastering knowledge.

3.1.2. Scale Based on USCIQAS

An interactive quality scoring scale based on the USCIQAS framework was created for the observation of classroom interaction and video coding. The "USCIQAS" scale comprised two distinct sets of observable indicators and scoring systems for ST and SS interactions. Each set of indicators has nine question items, and each question has five options (A–E), corresponding to 1–5 points: the higher the score, the better the interaction quality (Table 2).

Table 2. "USCIQAS" scale.

Primary Indicators	Secondary Indicators	Teacher–Student Interaction	Student–Student Interaction
A1: Engagement	B1: Involvement breadth	The number of individuals interacting with the teacher per lesson. A. $\leq$3; B. 4–5; C. 6–7; D. 8–9; E. $\geq$10	Proportion of students participating in student–student interactions per class. A. $\leq$40%; B. 41–50%; C. 51–60%; D. 61–70%; E. $\geq$70%
	B2: Involvement intensity	The level of students' responses A. Students respond in unison B. Students answer by roll call C. Students answer actively D. Students ask questions E. Students bring up a new topic	The level of student responses to each other A. Tangible without substance B. Talking in different ways C. Group summaries D. A little debate E. A violent collision
	B3: Emotional involvement	A. Resistant; B. Uninterested; C. Indifferent; D. Happy; E. Excited	A. Resistant; B. Uninterested; C. Indifferent; D. Happy; E. Excited
A2: Social	B4: Interactive sensitivity	A. Blame; B. Disregard; C. Give chance; D. Encouragement; E. Praise	A. Blame; B. Disregard; C. Give chance; D. Encouragement; E. Praise
	B5: Interactive climate	A. Hostile; B. Nervous; C. Neutral; D. Relaxed; E. Pleasure	A. Hostile; B. Nervous; C. Neutral; D. Relaxed; E. Pleasure
	B6: Interactive agency	A. Taunts; B. Serious denial; C. Neutral; D. Encourage speaking; E. Recognize points of view	A. Taunts; B. Serious denial; C. Neutral; D. Encourage speaking; E. Recognize points of view
A3: Cognitive	B7: Concept development	A. Memorize and state facts B. Express understanding C. Discuss the application D. Evaluate and analyse E. Create new knowledge	A. Memorize and state facts B. Express understanding C. Discuss the application D. Evaluate and analyse E. Create new knowledge
	B8: Cognitive strategy	A. Limited to knowledge B. Inform about the solution C. Enlighten with the solution D. Teach learning methods E. Reflect on learning methods	A. Limited to knowledge B. Use existing methods to solve problems C. Explore problem-solving methods D. Discuss learning methods E. Reflect on learning methods
	B9: Quality of feedback	A. Teachers provide facts B. Teachers express their opinions C. Teachers pay attention to students' views D. Teachers clarify students' views E. Teachers extend students' views	A. Repeat facts B. Make one's point C. Expand upon the group members' views D. Develop new ideas E. Introduce new topics

3.1.3. Reliability and Validity Test

A correlation analysis and a *t*-test were performed to analyse the items of our proposed USCIQAS framework and scale in terms of differentiation, reliability, and validity. The correlation coefficients between each item and the overall score ranged between 0.415 and 0.854, and there was a statistically significant difference in the total score between the high and low groups (p = 0.0280.05). Cronbach's internal consistency coefficient of 0.901 suggested that the scale had a high degree of reliability. The factor analysis revealed that KMO = 0.727 > 0.5, the Bartlett significance threshold was 0.00 0.05, the cumulative contribution rate of the two extracted common components was 76.53% > 60%, and the factor loading coefficient was larger than 0.35, suggesting that the scale has structural validity.

3.2. Sample

The university in Central China where this study was conducted, referred to as University A, is one of the pilot universities recognized by China's Ministry of Education to integrate ICT into undergraduate education and was rated "outstanding" in the 2018 evaluation. University A promoted the shift from teaching-centred to learning-centred teaching approaches via the deployment of Smart Classrooms. Between 2020 and 2023, the university implemented 88 Smart Classrooms, which were utilized by teachers in practically every course. As a consequence, University A makes an excellent research case study.

As previously mentioned, the use of technology by teachers needs to be separated into several levels. This research used Wang et al. (2016)'s [50] stratification in order to create a technological hierarchy based on the state of multimedia technology development and the current state of University A. The hierarchy is composed of three tiers (Table 3). At the first level, teachers utilize Smart Classrooms as straightforward multimedia environments, relying only on media to provide material. At the second level, teachers use Smart Classrooms as interactive multimedia spaces, maximizing the screen's interactive capability. At the third and highest level, teachers fully use the interactive teaching system's capabilities in the Smart Classroom. Students utilize the smart terminal as a cognitive tool, while the teaching system assesses and provides feedback in real time. Because several levels coexist, teachers may choose their favourite level and include many levels of technology into a single lesson (See Figure 1).

Table 3. Technology levels in the Smart Classroom.

Level	Teacher Terminals	Student Terminals	Software Resource
1 (low)	Ordinary whiteboard	No terminals	Presenting media
2 (middle)	Interactive whiteboard	No terminals	Screen interaction
3 (high)	Interactive teaching system	Tablet, mobile phone, or computer	Interactive system, cognitive APP, real-time assessment, etc.

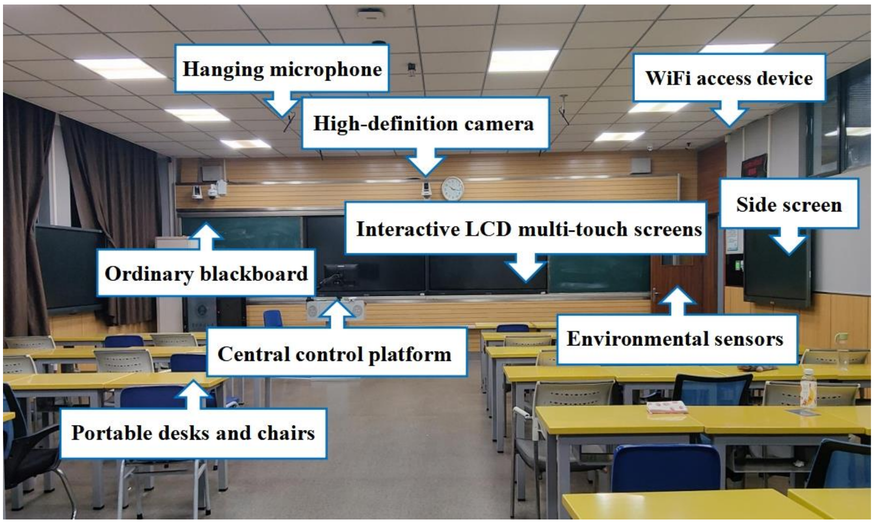

Figure 1. Smart Class in University A. (Some classrooms are equipped with computers for students, which is not shown on the picture).

To create the sample, this study randomly picked 50 courses from the 95 that were recorded in University A's Smart Classrooms between 2020 and 2023 and randomly selected one videoed lecture from each of these 50 courses. This study narrowed the sample down to 38 lessons by excluding those in which the main technology level employed by teachers was unclear. Finally, we categorized the samples into categories based on their technological sophistication. Table 4 summarizes the sample distribution.

Table 4. Distribution of lessons in University A's Smart Classrooms.

Technology Levels (Groups)	Lesson Samples
1 (low level)	18
2 (middle level)	12
3 (high level)	8

Given that the samples are from a Chinese university, our results will be influenced by the specific cultural and educational context.

3.3. Data Collection

To gather the data, this study used the "USCIQAS" scale to observe and code 38 videoed lectures. The first step was independent coding. The observational approach is extremely conscientious about the researcher's analytical independence, as the researcher interprets the data fully on their own [73]. Hence, in order to ensure the authenticity of our data, each videotaped lecture was seen by two individuals who assessed it based on the scale and directed any disagreements to the authors. The second step was expert rating and discussion. The 38 classes were then rated according to the quality of ST and SS interactions by the authors and a third pedagogical expert, and a comparison was performed between authors' scale-based ranking and the expert-based ranking. Once a discrepancy was discovered, the observers and specialists collaborated to determine the source and to resolve the issue.

3.4. Data Analysis

In this part, SPSS was used to generate aggregate and group statistics describing the interaction quality of the 38 lectures and to see if classroom interaction quality can be improved by increasing the use of technology.

The first step was to describe the mean value of the overall interaction quality across the engagement, social, and cognitive aspects within three groups to see if the overall interaction quality changes as the use of the technology increases.

The second step was to conduct ANOVAs (analyses of variance) and post hoc comparisons to see if the change in overall interaction quality is significant and in which dimensions.

The third step was to identify the reasons for significance or non-significance by describing the mean value of the overall interaction quality on each item.

In the last step, the above steps were used again to analyse the changes in ST and SS interaction quality in order to identify whether the interaction quality of ST and SS will be significantly affected by various degrees of technology.

4. Results

4.1. The Influence of Technology Use Levels on Overall Interaction Quality

The term "overall interaction quality" refers to the total score for the quality of ST and SS interactions. We classified interactions into three dimensions and then nine categories using the USCIQAS framework and then analysed their overall quality. The total score for the ST and SS interaction quality for each dimension and category is therefore the overall interaction quality for that dimension and category.

The data on total interaction quality (Table 5) indicate that the third group's interaction is superior to the second group's, while the second group's interaction is superior to that of the first (3.645 > 3.485 > 3.2000). This shows that when teachers employ more technology, the general quality of interaction improves as well. However, when considering the quality of interaction across all three dimensions, this trend is only seen at the cognitive level. Within the social and engagement aspects, the second group had worse interaction quality than the first.

Table 5. Descriptive statistics of overall interaction quality.

Dimension	Group	Number of Cases (N)	Mean	Standard Deviation	Minimum	Maximum
Engagement	1	18	3.472	0.434	2.75	4.08
	2	12	3.408	0.876	1.67	4.33
	3	8	3.760	0.343	3.17	4.25
Social	1	18	3.816	0.592	3.00	4.50
	2	12	3.815	0.640	2.67	4.50
	3	8	3.979	0.668	3.00	4.83
Cognitive	1	18	2.629	0.785	1.67	3.83
	2	12	3.000	0.750	1.33	3.67
	3	8	3.563	0.641	2.67	4.33
Whole	1	18	3.200	0.320	2.86	3.81
	2	12	3.485	0.399	3.03	4.14
	3	8	3.645	0.383	3.00	4.08

Although greater levels of technology do correlate with better overall interaction quality (Table 6), the difference is not statistically significant (F = 3.202, $p = 0.059$). In terms of interaction within different dimensions, there is a significant difference in overall interaction quality in the dimension of cognitive interaction, of which the quality of interaction is much greater in the third group than in the first. However, there is no discernible variation in the other two dimensions.

Table 6. ANOVAs and post hoc comparison of overall interaction quality.

Dimension		Sum of Square	Degrees of Freedom	Mean Square	F	Significance (%)	Least Significance Difference
Engagement	Between groups	0.602	2	0.301	0.782	0.469	
	Within groups	9.235	35	0.385			
Social	Between groups	0.150	2	0.075	0.188	0.830	
	Within groups	9.610	35	0.400			
Cognitive	Between groups	3.721	2	1.860	3.473	0.047 *	3 > 1
	Within groups	12.857	35	0.536			
Whole	Between groups	0.875	2	0.437	3.202	0.059	3 > 1
	Within groups	3.278	35	0.137			

* $p < 0.05$.

To find the reason why the difference between the groups of overall interaction was not statistically significant, we examined the different categories of interaction. The data on overall interaction quality in several categories (Table 7) revealed that, throughout the cognitive dimension, the fundamental tendency is for more technological applications to be related to better overall interaction quality. Within the other dimensions, classrooms with the most technology scored best in terms of involvement breadth, interactive sensitivity, and interactive agency. However, the situation is different when it comes to the overall quality of interaction in the involvement intensity, emotional involvement, and interactive climate categories, of which the first group has the greatest interaction quality and is superior to the third group.

Overall, classrooms in group 3 had the highest interaction quality in the categories of involvement breadth, interactive sensitivity, interactive agency, concept development, cognitive strategy, and quality of feedback, whereas classrooms in group 1 had the highest interaction quality in the categories of involvement intensity and emotion, and interactive climate.

Table 7. The overall interaction quality for different categories of interaction.

Dimension	Group	Number of Cases (N)	Mean	Standard Deviation	Minimum	Maximum
Involvement breadth	1	18	3.500	1.369	1.00	5.00
	2	12	3.150	1.001	1.00	4.00
	3	8	4.500	0.463	4.00	5.00
Involvement intensity	1	18	3.250	0.484	2.25	3.75
	2	12	3.325	1.028	1.00	4.50
	3	8	3.219	0.411	2.50	3.75
Emotional involvement	1	18	3.667	0.612	2.50	4.50
	2	12	3.750	0.858	2.50	5.00
	3	8	3.563	0.563	3.00	4.50
Interactive sensitivity	1	18	3.500	0.707	3.00	5.00
	2	12	3.800	0.856	2.00	4.50
	3	8	3.938	0.678	3.00	5.00
Interactive climate	1	18	3.944	0.768	3.00	5.00
	2	12	3.800	0.675	2.50	4.50
	3	8	3.875	0.694	3.00	5.00
Interactive agency	1	18	4.000	0.707	3.00	5.00
	2	12	3.850	0.626	3.00	4.50
	3	8	4.125	0.744	3.00	5.00
Concept development	1	18	2.611	0.928	1.50	4.00
	2	12	3.150	0.818	2.00	4.50
	3	8	3.375	0.694	2.00	4.00
Cognitive strategy	1	18	2.167	1.061	1.00	3.50
	2	12	2.800	0.789	1.00	3.50
	3	8	3.625	0.694	2.50	4.50
Quality of feedback	1	18	3.111	0.601	2.50	4.50
	2	12	3.050	0.926	1.00	4.00
	3	8	3.688	0.799	2.50	4.50

4.2. The Influence of Technology Use Levels on ST Interaction Quality

The data indicating the quality of ST interactions (Table 8) reveal that, on average, interaction quality is greater in the third group than in the second and that it is higher in the second group than in the first (3.811 > 3.468 > 3.043). The engagement and cognitive elements of ST interaction both have a propensity to improve in quality as technology level rises, but not the social dimension.

Table 8. Descriptive statistics of ST interaction quality.

Dimension		Group	Number of Cases (N)	Mean	Standard Deviation	Minimum	Maximum
ST interaction	Engagement	1	18	2.982	0.556	2.00	3.83
		2	12	3.096	0.722	1.67	4.17
		3	8	3.688	0.509	3.00	4.17
	Social	1	18	3.500	0.618	2.33	4.33
		2	12	4.113	0.642	3.00	5.00
		3	8	4.084	0.611	3.00	5.00
	Cognitive	1	18	2.648	0.780	1.33	4.00
		2	12	3.194	0.916	1.33	4.33
		3	8	3.666	0.666	2.67	4.67
	Whole	1	18	3.043	0.445	2.22	3.83
		2	12	3.468	0.691	2.00	4.28
		3	8	3.811	0.537	3.00	4.50

The ANOVAs and post hoc comparisons of ST interaction quality (Table 9) indicate that there is a substantial difference in the quality of ST interactions across technology levels in the aspects of engagement, social, and cognitive interaction. Both the third and second groups score considerably better in terms of interaction quality than the first, according to the post hoc comparison. There are significant changes in the quality of interaction across technology levels in the areas of engagement, interactive sensitivity, idea formation, and cognitive strategy. However, no discernible distinctions exist across the other groups.

Table 9. ANOVAs and post hoc comparison of ST interaction quality.

Dimension		Sum of Square	Degrees of Freedom	Mean Square	F	Significance (%)	Least Significance Difference
Engagement	Between groups	2.844	2	1.422	3.885	0.030 *	3 > 1, 3 > 2
	Within groups	12.810	35	0.366			
Social	Between groups	3.432	2	1.716	4.407	0.020 *	2 > 1, 3 > 1
	Within groups	13.629	35	0.389			
Cognitive	Between groups	6.203	2	3.102	4.785	0.015 *	3 > 1
	Within groups	22.688	35	0.648			
Whole	Between groups	3.562	2	1.781	5.862	0.006 **	2 > 1, 3 > 1
	Within groups	10.633	35	0.304			

* $p < 0.05$, ** $p < 0.01$.

4.3. The Influence of Technology Use Levels on SS Interaction Quality

The descriptive statistics on the quality of SS interaction (Table 10) indicate that the quality of interaction is generally greater in the third group than in the first and that the quality of interaction is generally higher in the first group than in the second (3.720 > 3.379 > 3.421). Thus, except in the cognitive component, the trend for interaction quality to improve with increasing technological level is not evident here. In the dimension of social contact, classrooms with lower technology levels achieve a greater quality of SS interaction, whereas the first group also achieves a higher quality of SS interaction in the dimension of engagement interaction.

Table 10. Descriptive statistics of SS interaction quality.

Dimension		Group	Number of Cases (N)	Mean	Standard Deviation	Minimum	Maximum
SS interaction	Engagement	1	18	3.814	0.473	3.00	4.33
		2	12	3.734	1.142	1.67	5.00
		3	8	3.833	0.398	3.33	4.33
	Social	1	18	3.928	0.813	2.67	4.67
		2	12	3.532	0.878	2.33	5.00
		3	8	3.876	0.795	2.67	5.00
	Cognitive	1	18	2.520	0.746	1.67	3.67
		2	12	2.865	0.690	1.33	3.67
		3	8	3.458	0.666	2.33	4.33
	Whole	1	18	3.421	0.586	2.67	4.22
		2	12	3.379	0.857	1.78	4.56

The ANOVAs and post hoc comparisons (Table 11) indicate that, while there is no significant difference in the overall quality of SS interaction between technology levels (F = 0.042, p = 0.959), there is when the cognitive dimension is considered separately (F = 3.832, p = 0.036), with the third group performing significantly better than the first. The only other area in which a substantial difference occurs is cognitive strategy.

Table 11. ANOVAs and post hoc comparison of SS interaction quality.

Dimension		Sum of Square	Degrees of Freedom	Mean Square	F	Significance (%)	Least Significance Difference
Engagement	Between groups	0.051	2	0.026	0.042	0.959	
	Within groups	14.629	35	0.610			
Social	Between groups	0.877	2	0.439	0.632	0.540	
	Within groups	16.652	35	0.694			
Cognitive	Between groups	3.781	2	1.890	3.832	0.036 *	3 > 1
	Within groups	11.839	35	0.493			
Whole	Between groups	0.589	2	0.294	0.623	0.545	
	Within groups	11.333	35	0.472			

* $p < 0.05$.

5. Discussion

5.1. Overall and ST Interaction Quality in Smart Classroom

The present research suggests that overall interaction quality will rise as the technology level rises. Specifically, an increase in technology level makes a very significant difference to the quality of ST interaction, while improvements in the quality of an ST interaction are known have a strong impact on the development of students [54,74]. So, working to improve the technology level used by teachers makes sense.

In addition, as Kozma (1991) [75] notes, in these newly emergent high-interaction education environments, technology and teaching method are intertwined. Technology will enable teaching method, while teaching method can maximize the potential of technology, and good design will thus integrate them both. From this perspective, while it is true that teachers using first-level technology may do better than those using third-level technology, integrating third-level technology into their classrooms may allow these successful teachers to further improve the quality of their classroom interactions. Two teachers from group 1, for example, won first prize in University A's teaching competition, evidencing their inherent high interaction quality. This phenomenon is consistent with the view of Clark and Mayer (2016) [76] (pp. 29–49) that a teacher who has access to effective teaching methods will support learning better than those who fail to use effective teaching methods, no matter what technology is used.

5.2. SS Interaction Quality in Smart Classroom

The findings from the current study also suggest that there is a very significant difference in ST interaction quality between technology levels, while no significant difference is evident in SS interaction quality. This may be related to the fact that interactive technology in Smart Classrooms is mainly used by teachers to promote ST interactions, and the finding is consistent with the research conclusions of Smith et al. (2006) [37] with regard to the influence of IWB technology. They found that, compared with non-IWB lessons, IWB lessons offered more whole-class interaction and less group work, potentially because most interaction technologies in Smart Classrooms are designed to support ST rather than SS interactions, including SMART response systems, random calling, anonymous grading, learning outcome screening, and real-time testing and responses. In addition, although support from technology is sometimes important in SS interactions (e.g., when using mobile devices to collect individuals' work in a group), most SS interactions in classrooms involve face-to-face discussions, which may be negatively impacted by technologies (Przybylski and Weinstein, 2013) [22]. Finally, and importantly, teachers tend to neglect the use of ICT by students in individual learning activities. While the current findings show that teachers who use higher technology levels tend to organize more SS interactions in Smart Classrooms, even in these lessons, few students used the available technology to its fullest extent. This suggests that few teachers are sufficiently aware of the use of technology as a means to improve SS interactions, instead tending to organize student activities as done within a traditional classroom. Wartella (2015) [21] and Cobb (1997) [77] argue, however, that technology should be seen as a tool for students' cognitive engagement, not only as a means for teachers to deliver content, while Hall and Higgins (2005) [39] warn that, although ICT is engaging for students, if educators cannot help students to access the necessary technology, any potential advantages offered by ICT will not be realized.

The results further show that while there is no significant difference in the quality of SS interactions overall between technology use levels, the difference in the quality of cognitive SS interactions is substantial, with the quality of interactions found to rise with the level of technology. However, within the categories related to social and emotional interactions, the reverse was true, which could indicate that technology is only used by teachers to improve students' cognitive interaction and knowledge acquisition. This may be linked to Chinese teaching culture and current teaching reform, as while ancient Chinese education drew on a Confucian ideology centred on learners' social–emotional development, China's modern teaching culture has been cognition-oriented for a long time [78]. As such, regardless of the level of technology used by teachers, they will believe their purpose is to promote students' acquisition of knowledge. The fact that social and emotional interactions did not increase in quality as the technology level increased may alternatively mean that technology may inherently only lead to improvements in the quality of interactions related to knowledge acquisition, at times even lowering the quality of social–emotional interactions. One reason for this could be that teachers tend to neglect social–emotional outcomes when concentrating on promoting learning via new technology. It could also be that when certain technologies, such as response systems, replace immediate human–human interaction, features unique to human communication are lost. There has been much debate on the relationship between technology and social–emotional interaction [79–81], and some studies suggest that technology-mediated communication is likely to be less friendly, emotional, or personal and more serious or task-oriented than interpersonal communication [44,82].

5.3. Implication for Teacher Education

Studies have shown that Smart Classrooms can enhance the effective interaction between teachers and students, make the relationship between teachers and students more equal and harmonious, and support teachers in better carrying out various teaching activities [34]. This has important implications for classroom teaching and teacher education. First, both teachers and students should be encouraged to use technology. Relevant departments of the school should regularly organize basic operation training to familiarize teachers and students with the equipment and their basic use in a Smart Classroom. Second, we should pay attention to the improvement in teachers' information literacy to promote their development. Third, as Smith (1997) [83] claimed, the primary way to ensure students developing their information literacy is to ensure that faculty understand how to develop information literacy and value its development. Teacher training should not only pay attention to teachers' technology use but also train teachers how to teach students to use technology. Fourth, teacher training should focus on how to promote SS interactions through technology, and teachers should also pay attention to the social and emotional interactions between students in Smart Classroom, including improving upon their teaching methods and integrating information technology into student activities. The above two implications clearly reflect a student-centred position. Finally, attention should be paid to the joint promotion of information technology and effective teaching methods, since the quality of technology-enhanced instruction is determined by those two elements.

5.4. Innovations and Limitations

The innovations of this study include the following: First, this study discussed the specific relationship between Smart Classrooms and interaction quality and the impact of layered technology systems on interaction in university classrooms. Second, while most previous studies focused on ST interaction, this study also paid attention to SS interactions for the reason that technology should be regarded as a tool for students' cognitive engagement rather than just a means for teachers to deliver content. Third, this study found that technology performs poorly in facilitating students' social–emotional interactions; therefore, some implications are proposed for teachers to use technology to promote students' social–emotional interactions. Finally, a new classroom interaction analysis framework (USCIQAS) was developed, which is not only suitable for analysing classroom interactions in university Smart Classrooms but also important for teacher and educator evaluation and inspection and can further improve classroom interactions and teaching quality.

However, there are some limitations to this study. First, we only chose one university as the research sample. Second, the deductive construction of the interactive analysis framework is highly subjective, which may be influenced by the researchers' concerns, interests, and experience to some extent. Third, although several researchers conducted multiple rounds of coding and scoring on the interactive quality and reached a consensus with the authors, it is still difficult to avoid a certain degree of subjectivity. Fourth, this study used only classroom observations and video analytics to assess the quality of interactions; however, it may be useful to ask students and teachers their views on the impact of social relationships and Smart Classrooms, since the answers to these questions are highly individualized.

6. Conclusions

Technology used in education is identified as an opportunity to bolster sustainable development in education. With the increasing involvement of technology in teaching and learning, there is a pressing need to consider the changes in the interactive processes of teaching and learning in universities in the modern day. A comprehensive discussion of Smart Classrooms is particularly necessary due to their potential to have a profound impact on the future quality of classroom teaching at universities. The Smart Classroom, as defined in this article, is not a singular technology, but instead a multilevel technology system that provides teachers with access to different levels of technology. Thus, only by investigating the influence of these different levels of technology on interaction quality can a full understanding of how Smart Classrooms can be used to improve teaching be developed.

The results from this study illustrate that teachers can improve the quality of interactions in their classrooms, particularly ST interactions, by using higher levels of technology; however, this higher usage must be matched by improvements to teachers' pedagogy. Currently, the quality of an SS interaction does not rise significantly as the technology level rises, which may suggest that teachers should not seek to use technology merely as a means to deliver content, but instead discover ways to use it to improve SS interactions and to help students to access content themselves. Finally, the finding that an increase in the level of technology may correspond to a decrease in social–emotional interaction quality suggests that teachers must stay alert to the risk of impaired social–emotional outcomes due to the intervention of technology in immediate human interactions. These results, taken together, thus have the potential to support teacher educators in the formulation of guidelines to help teachers improve their teaching in technology-rich environments.

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