Author: Wang, J.
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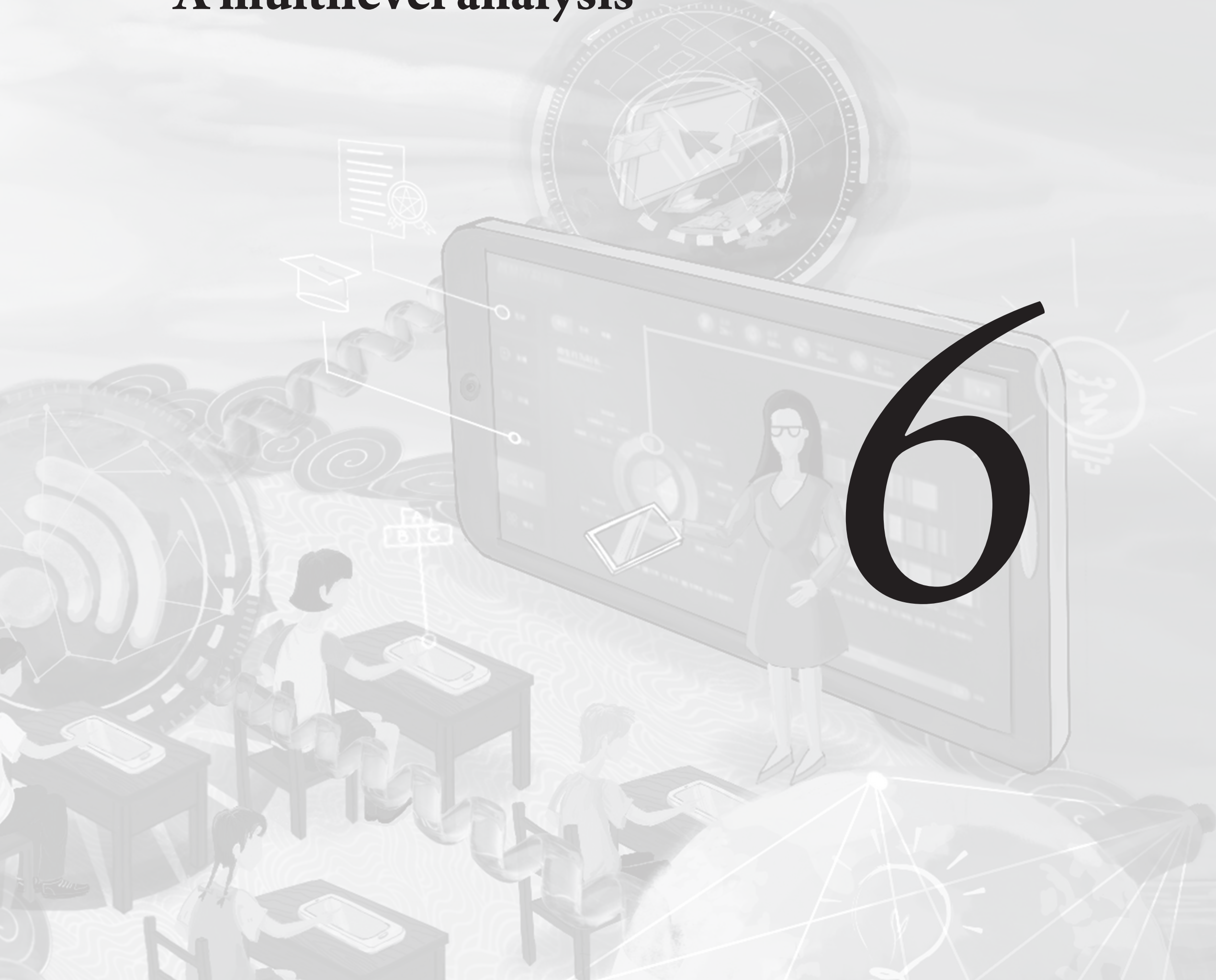
Teacher beliefs, classroom process quality, and student engagement in the smart classroom learning environment: A multilevel analysis



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Abstract

A smart classroom learning environment enables learners to learn better and faster. Although the number of studies focusing on the impact of learning environments on student engagement is increasing, still limited empirical knowledge is available about how secondary school students' engagement can be enhanced in a smart classroom learning environment. Also, more studies are needed that include both pedagogical and technological perspectives. In this study, by using teacher and student questionnaires, the relationship among teacher beliefs, classroom process quality, and student engagement in smart classrooms in secondary schools was investigated. Three components of classroom process quality were distinguished: cognitive activation, connectedness, and the use of technology. Results from a multilevel regression analysis revealed that at the classroom level, students' shared perceptions of connectedness and the use of technology, teachers' degree, and teaching year were linked to student engagement. At the student level, students' individual perceptions of all three domains of classroom process quality and students' gender were related to their engagement. Multilevel mediation analysis results showed that students' shared perceptions of connectedness and the use of technology mediated the relationships between teachers' degree level and student engagement. Remarkably, the relationships between teacher beliefs and students' shared perceptions of classroom process quality were nonsignificant. However, classroom process quality could be explained by teacher background characteristics, such as teacher degree, teacher gender, and teaching grade. Theoretical and practical implications are discussed, and suggestions for future research are given.

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Keywords

Improving classroom teaching; Pedagogical issues; Mobile learning; Media in education; Secondary education

6.1 Introduction

Engaging students is seen as crucial for student learning in various environmental settings, educational stages, and school subjects (e.g., Bergdahl, Nouri, Fors, & Knutsson, 2020; Lazarides & Buchholz, 2019; Raes et al., 2020). Student engagement, i.e., students' involvement in their own learning activities, can be regarded as a product of individual and class influences. Student engagement is known to be fostered in classroom learning environments with supportive teachers and peers, and challenging goals and authentic tasks (Fredricks, Blumenfeld, & Paris, 2004; Shernoff et al., 2016). Recently, emerging enhanced technologies, such as cloud computing, learning analytics, and wearable technology, have transformed traditional classroom learning environments to smart classroom learning environments (SCLEs) that are more effective, efficient, and engaging (Spector, 2014) when it comes to supporting instructors and to stimulating better and faster student learning (Koper, 2014). In many countries, governmental programs have been implemented for the development of SCLEs, such as in Turkey (FATİH project), Poland (Digital School), Australia (The Smart Classrooms), South Korea (SMART education), and Thailand (One Tablet per Child project). The accessibility of digital devices and educational resources has been the starting point of these ICT initiatives aimed at encouraging technology-based teaching and learning. Overall, the effects of these projects provide preliminary support that technology-based environments do have an influence on student engagement (Schindler, Burkholder, Morad, & Marsh, 2017). However, additional research is needed with regards to how technological factors interact with instructional factors that together may influence student engagement (Chang et al., 2015; MacLeod, Yang, Zhu, & Li, 2018) and the setting of the current SCLEs as the SCLEs goes beyond the simple use of technology (Kinshuk, Chen, Cheng, & Chew, 2016). While technology has changed how students can be supported in the learning environment, the principles of effective instruction have not changed (Price, 2015). Therefore, determining how to best develop an engaging smart classroom learning environment is an essential issue for research on educational technology, pedagogical instruction, and student learning today.

Maintaining students engaged especially in technology-based learning environments, however, seems challenging due to in-class distractions that occur routinely and disengagement leads to poor academic performance and spending more time for non-school related activities (Bergdahl et al., 2020). Moreover, mobile technologies increase the complexity of the student learning experiences, and there are situations in which students face more challenges. For example, issues of low engagement often arise within secondary schools (Krauss, Kornbluh, & Zeldin, 2017) since the students face self-regulatory challenges (Brooks & Weaver, 2019), which threats the preparation for university education (Van Rooij, Jansen, & Van de Grift, 2017). Furthermore, Asian systems are usually hierarchical in nature, which means that teachers tend to be strict, and teaching practices tend to be teacher-centered (Chand, Deshmukh, & Shukla, 2020). Due to a lack of student autonomy and a tendency to discourage independence of thought, students in Asian countries have been found to suffer from a low-level of engagement (Tan, 2017). Increasing interactivity and engagement among students is vital, given that smart classrooms are prevalent in secondary schools and new conditions for engagement emerge (Bergdahl et al., 2020). Hence, for secondary students' learning, especially for those in an Asian hierarchical system, the quality of smart classroom learning environments is highly significant for student engagement.

With regards to positively affecting student engagement, investigating classroom process quality, and in particular, the interactional patterns between teachers and students (Fauth, Atlay, Dumont, & Decristan, 2021), is considered important because these patterns have been found to influence students' learning outcomes (e.g., Lazarides & Buchholz, 2019; Olivier, Galand, Morin, & Hospel, 2021; Shernoff et al., 2016). The core mechanism behind classroom process quality that is widely acknowledged is instructional quality, which is involving three global dimensions (i.e., cognitive activation, supportive climate, and classroom management; Klieme, Pauli, & Reusser, 2009). Undoubtedly, a teacher's contribution to creating a supportive climate in smart classrooms is essential, but whether teachers really are engaged with creating such a climate and how they attempt to do so is known to be dependent on their beliefs (Chand et al., 2020). Recent evidence supports the idea that teacher beliefs (e.g., about their self-efficacy) are related to students' perceptions of the three dimensions of instructional quality (Burić & Kim, 2020), which in turn influence student engagement and learning. Although both pedagogical and technological factors are crucial contributing to student engagement, research findings on the relationship between the use of technology and student learning in the specific context of SCLEs have been inconsistent (see e.g., Becker, Klein, Gößling, & Kuhn, 2020; Thomas, Parsons, & Whitcombe, 2019). Furthermore, despite evidence showing that teacher beliefs are expected to be more indirectly related to student engagement in the classroom in general (Burić & Kim, 2020), it can be assumed that classroom process quality can function as a connection between teacher beliefs to student engagement in SCLEs remains to be studied.

By now, empirical studies investigating whether teacher beliefs on SCLEs, instructional quality, and the use of technology in SCLEs contribute to student engagement in the SCLEs is rare. Moreover, research has not identified which aspects of classroom process quality matter the most, especially not in situations where Asian secondary students experience more potential challenges when learning in the SCLEs than their peers. Therefore, the current study is aimed at empirically examining the underlying relationships between teacher beliefs toward SCLEs, classroom process quality (i.e., instructional quality and the use of technology), and engagement of students nested in smart classrooms by incorporating secondary school teachers' and students' viewpoints. The findings can add to the existing knowledge of underlying mechanisms of learning that can be facilitated by teachers' instructional quality combined with the use of technology, and provide valuable evidence for the design and implementation of smart classrooms.

6.2 Background

6.2.1 Classroom process quality in the smart classroom learning environment

Research has identified key aspects of good teaching practices that emphasize on the classroom process quality. One of the most cited international theoretical models is the model of basic (deep structure) dimensions of instructional quality (Klieme et al., 2009). Three global dimensions (i.e., cognitive activation, supportive climate, and classroom management) have been identified in secondary education studies (e.g., Atlay, Tieben, Hillmert, & Fauth, 2019). These three deep structure level dimensions were hypothesized to influence students' learning outcomes. According to Klieme et al. (2019), cognitive activation refers to promoting students' conceptual understanding through appropriate instructional strategies like providing students challenging tasks or opportunities to discuss ideas with classmates within the learning environment. A supportive classroom climate requires positive social interactions in classrooms characterized by caring teacher behavior and constructive feedback. Classroom management is not only coping with disruptive behavior, but also requires teachers to stay focused and provide clear and consistent rules and procedures in terms of content and social norms. Previous research has mainly focused on broad dimensions of teaching quality in secondary education; however, student learning is known to be improved more by integrating particular educational strategies (e.g., the use of technology in the classroom) with global factors of instructional quality (Decristan et al., 2015). Therefore, Lazarides and Buchholz (2019) suggest identifying specific educational strategies related to creating supportive, well-structured, and activating learning environments.

Smart classrooms, as one of the student-centered learning environments permitting the co-learning procedure through enhanced technology, have recently attracted attention in academia (Jou & Wang, 2019). A typical smart classroom is equipped with technologies such as, wireless Internet, interactive whiteboard and projectors for the whole class, and mobile devices for the teacher and individual student use, cameras to record and store lectures, sensors and acoustics to control the physical environment, and educational management and assessment tools (Saini & Goel, 2019). MacLeod et al. (2018) have summarized and validated the most relevant features of SCLEs: Student Negotiation, Inquiry Learning, Reflective Thinking, Ease of Use, Perceived Usefulness, Multiple Sources, Connectedness, and Functional Design. In smart classrooms, students use technologies for active learning in the first place, rather than merely reacting to learning activities as a given. The extent to which and how technologies are integrated in learning activities need further investigation, although it is already known that students learn more when digital technologies are used in combination with other teaching methods rather than as substitutes (Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020). Since the use of technology is important for understanding the classroom process quality, in the present study, we adopt the use of technology together with the three global dimensions that represent the classroom process quality.

6.2.2 Connections between teacher beliefs of and classroom process quality in the smart classroom learning environment

Teacher beliefs are the sum of their judgments and evaluations about school-, teaching-, learning- and students-related matters, as well as about matters beyond their profession (Pajares, 1992). Although researchers have argued that teacher beliefs are likely to compatible with their teaching behavior (Bandura, 1986; Eisenhart, Shrum, Harding, & Cuthbert, 1988), the available research has shown that relations between different teacher beliefs (e.g., teaching-specific or general beliefs) and their instructional practices are mixed. For example, secondary school teachers' self-reported beliefs in their teaching capabilities are linked with student-reported classroom management, cognitive activation, and supportive climate (Burić & Kim, 2020). In contrast, Fauth et al. (2019) found nonsignificant relations between teachers' constructivist beliefs and their teaching quality in science education. In another study, constructivist beliefs of secondary school teachers were negatively associated with classroom management (Kunter et al., 2013).

Besides the fact that the success of innovations in teaching with technology are heavily depended on the teachers who perceive and interpret classroom events, researchers have underlined that empirical evidence on the relationship between teachers' technology adoption and their constructivist beliefs about teaching with technologies is ambiguous (Chand et al., 2020). For instance, in the Spanish context, secondary school teachers with constructivist and learner-centered beliefs were more likely to use technology (Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017). In another study, Han, Byun, and Shin

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(2018) found that although South Korean teachers having similar constructivist beliefs with teachers in the United States, they were unable to transform their beliefs into technology-enhanced teaching practices. Mills, Jass Ketelhut, and Gong (2019) reported that the belief of a science teacher was changed after a three-year inquiry-based technology program; however, his classroom practice remained didactic and teacher-centered. Therefore, a better understanding of the relations between teacher beliefs and classroom process quality is necessary to ensure the SCLEs is not hindered.

6.2.3 Classroom process quality and student engagement in smart classroom learning environment

Engagement typically includes behavioral, emotional, and cognitive dimensions (Archambault & Dupéré, 2017). Student engagement represents a central issue for teachers and students because it encompasses many different aspects of the teaching and learning process. Researchers generally emphasize the directional flow that the quality of environmental challenges and support has on students' subsequent engagement during learning activities (Shernoff et al., 2016; Xu, Chen, & Chen, 2020). For instance, despite the influence of individual student perceptions of SCLEs on learning, Decristan et al. (2015) found that students' cognitive engagement outcome (i.e., conceptual understanding) were also affected by the aggregated student ratings of cognitive activation, supportive climate, and classroom management. Concerning emotional engagement, research has shown that cognitive activation, teacher support, and classroom management can have an impact on various types of student emotions (e.g., interest, enjoyment, bored, and anxiety), but these effects vary at the student or classroom level (see e.g., Fauth, Decristan, Rieser, Klieme, & Büttner, 2014; Lazarides & Buchholz, 2019). Besides, teacher emotionally-supportive has been linked with students' behavioral engagement. (Ruzek et al., 2016).

However, student engagement in SCLEs manifests differently than engagement in traditional classrooms, and in previous research on teaching quality it has been ignored how technologies shape engagement. Still, Schindler et al.'s (2017) review does provide preliminary support that technology-based environments have an influence on student engagement. Recent research on secondary school students' classroom learning processes and learning outcomes has shown that using mobile devices can support a reduction of cognitive load and increase conceptual understanding and thus can improve performance more than teacher behavior (Becker et al., 2020). Hammer, Göllner, Scheiter, Fauth, and Stürmer (2021) therefore argue that using tablets is more appealing to students than instruction without technology, making learning activities more interesting and meaningful with integrated tablets. Yang, Yu, Gong, and Chen (2017) conducted experimental research to compare primary students' perceptions about both the traditional and smart classroom learning environment and found that compared with traditional multimedia classroom students perceptions of both instructional quality and the use of technology scored significantly higher, and also, students were more engaged with individual learning and collaborative learning in the SCLEs. However, a recent study (Thomas et al., 2019) investigating university students' perceived learning in SCLEs indicated that social support significantly affected learning, but the use of technology did not. Thus, which aspect of classroom process quality matters most has remained unclear, especially in the context of SCLEs in secondary education.

6.2.4 Classroom process quality as a mediator

Despite the commonly accepted direct relationships between teacher beliefs and student engagement in technology-rich classrooms (Gebre, Saroyan, & Bracewell, 2014), the relationship found is not stable based on studies analyzing the responses of both teachers and students and recognizing the multilevel nature of such data (see e.g., Burić & Kim, 2020). Especially, the effect of teacher beliefs faded out when interpersonal teacher behavior was included (Van Uden, Ritzen, & Pieters, 2014). According to the model of teaching quality (Fauth et al., 2020), three dimensions of instructional quality can function as a bridge between teacher characteristics (e.g., teacher beliefs) and student outcomes (e.g., student engagement). In terms of this suggested cross-level meditation, scientific evidence is minimal. To our knowledge, Fauth et al. (2019) alone have reported that the three basic dimensions of instructional quality mediate the relations between teacher beliefs (i.e., teaching enthusiasm and pedagogical content knowledge) and student interest. Furthermore, the lack of research on the mediation role of technology makes it difficult to determine whether students see differences in benefits derived from instructional quality and the use of technology. Thus, further elucidation of the mediation role of classroom process quality (i.e., cognitive activation, supportive climate, classroom management, and the use of technology) between teacher beliefs and student engagement in SCLEs is warranted.

6.2.5 The present study

Given that teachers' self-reports of their teaching practices are subject to various biases, including social desirability (Retelsdorf, Butler, Streblow, & Schiefele, 2010), Fraser (1998) suggests that students' perceptions of their classroom learning environment matter for learning. Although research has shown that even the ratings reported by primary school students can be regarded a reliable, valid, and stable indicator of classroom process quality (Fauth et al., 2014; Fauth et al., 2020), additional examination of the perspective of teachers may yield a more comprehensive view of the predictors and the outcomes of classroom process quality (Burić & Kim, 2020; Decristan et al., 2015). Given this importance, studying how teachers think of SCLEs and how students perceive their learning processes in SCLEs can further clarify what may impact their engagement, which in turn can help researchers and practitioners to maximize the effectiveness of SCLEs by identifying critical aspects that students in specific settings most prefer (e.g., Chang et al., 2015).

Theoretically speaking, classroom process quality refers to classroom-level variables. This means that aggregating student ratings can indicate the general classroom process quality at the classroom level. Nevertheless, both differences within and between classrooms can bring valuable insights into how learners view their learning environments (Göllner, Wagner, Eccles, & Trautwein, 2018). Moreover, the preferences of the analysis level depend on the research questions investigated (Marsh et al., 2012). Previous results provide strong empirical support that student ratings of instructional quality can be seen as construct-specific responses consisting of shared perceptions at the classroom level and individual perceptions at the student level (Fauth et al., 2014; Wagner, Göllner, Helmke, Trautwein, & Luedtke, 2013). Until now, in the context of the SCLEs, research that simultaneously investigates the effects of classroom process quality at both the student and classroom level is scant.

Upon reviewing relevant literature, this study aims to fulfill the gaps in earlier studies by examining the relationships among teacher beliefs, classroom process quality, and student engagement in secondary school smart classrooms. Also, given the potential role of teacher and student background characteristics on student engagement (Olivier et al., 2021; Xu et al., 2020; Winkler, Söllner, & Leimeister, 2021), we included several relevant characteristics as covariates. We attempt to address the following research questions specifically (see Figure 6.1):

RQ1. At the classroom level, which variables (i.e., teacher beliefs, teacher background variables) explain differences between students' shared perceptions of classroom process quality in SCLEs?

RQ2. At the classroom level (i.e., teacher beliefs, teacher background variables) and student level (i.e., students' shared and individual perceptions

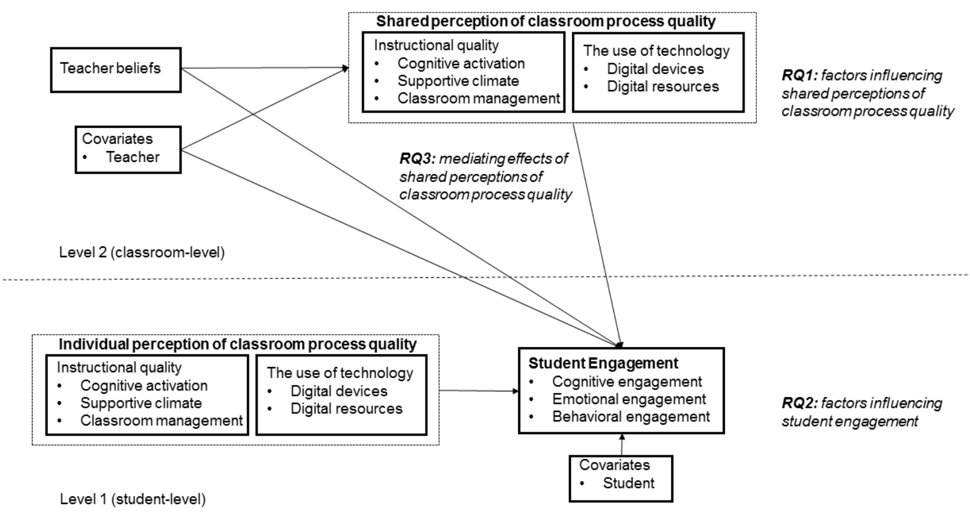

Figure 6.1. The proposed research model.

of classroom process quality, student demographic variables), which variables explain differences between student engagement in SCLEs?

RQ3. Is there an indirect effect of teacher beliefs, and teacher background variables on student engagement in SCLEs through students' shared perceptions of classroom process quality?

6.3 Methods

6.3.1 Research context

Given the potential impact of smart classrooms on the traditional teaching structure, China has made efforts to facilitate smart classrooms. The Chinese central government calls teachers to move beyond traditional teaching and embrace innovative pedagogical approaches with technologies (MOE, 2018). In order to respond to the national call and promote the smart classrooms, many local governments have issued their action plans. However, except some economically developed areas where schools have been provided with student personal tablet PCs and interactive desks (Li, Kong, & Chen, 2015), other local governments typically only provide the infrastructure and equipment for classrooms, and it is not possible to equip each student with a mobile device. Under this circumstance, when students hope to study in smart classrooms, their parents need to buy them mobile devices.

In the current study, three areas (i.e., Chongqing, Suining, and Guangyuan) in China were selected where efforts from the local governments, companies, schools, and parents have resulted in the implementation of smart classrooms. Smart classrooms in secondary schools were selected where each student owns a mobile device (here: tablets with multiple functions; mobile phones are not allowed in most Chinese secondary schools), and the internet speed is sufficient for effective teaching and learning. All teachers and students participating in the study have had at least some experience with smart classrooms. Although we intend to include all secondary education grades (i.e., grades 7 to 12), the teachers and students participating in this study were all from the lower level of secondary education (i.e., grades 7 to 9) due to the high pressure during the final three years for Gaokao (national exams).

6.3.2 Participants and procedures

The participants were teachers and their students in smart classrooms. We developed two digital questionnaires; the student questionnaire was developed to measure classroom process quality and student engagement, and the teacher questionnaire was developed to measure teacher beliefs. We also collected their background information through the respective questionnaire.

We collected data by sending a hyperlink via WeChat to teachers from first author's network and participation was voluntary. To be able to link the teacher questionnaire to the student questionnaire, we administered a teacher questionnaire and a student questionnaire in each class. Each set of links was sent directly to teachers and then indirectly through teachers to their students. As we were interested in teachers' general beliefs toward SCLE and students' perceptions of the actual learning processes in SCLEs, students were requested to complete the questionnaire after the class; teachers completed their questionnaire in their free time. The final sample included 1825 students and their 38 teachers. In each class, the number of participating students varied between 16 and 85 (M = 48.026, SD = 16.511) and only three classes had less than 30 participants. This sample size satisfies the 30/30 rule which means a sample of at least 30 groups with at least 30 individuals in each group, and this could be sufficient for the estimation of the regression coefficient (Kreft, 1996). The data collection period lasted from October 12th to December 17th, 2020. Table 6.1 shows the demographic information of the students and teachers.

6.3.3 Measures

Since most instruments are in English, the original items were first translated into Chinese by a Chinese researcher, and then were translated back to English by another bilingual researcher. All items for each measure have been included in the Appendix I.

6.3.3.1 Teacher beliefs

Teacher beliefs of smart classroom learning environment were evaluated with the adaption of the Chinese version of Preference Instrument of Smart

Table 6.1. Demographic information of the students and teachers.

Variables	Category	Frequency	Percent
Student information			
Student age	12	516	28.3
	13	820	44.9
	14	421	23.1
	15	65	3.6
	16	3	0.2
Student gender	Female	935	51.2
	Male	890	48.8
Teacher information			
Teacher age	<26	0	0
	26-30	0	0
	31-35	7	18.4
	36-40	13	34.2
	41-45	4	10.5
	46-50	13	34.2
	51-55	1	2.6
	>55	0	0
Teacher gender	Female	23	60.5
	Male	15	39.5
Teacher degree	Secondary Vocational School Education	0	0
	Three-year college Education	2	5.3
	Bachelor	35	92.1
	Master	1	2.6
Teaching years in SCLEs	<1	11	28.9
	1-2	14	36.8
	3-4	11	28.9
	4-5	2	5.3
	>5	0	0
Teaching grade in SCLEs	7	15	39.5
	8	16	42.1
	9	7	18.4

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Classroom Learning Environments (PI-SCLE) (MacLeod et al., 2018). The scale includes eight measures, i.e., Student Negotiation (SN, 5-items), Inquiry Learning (IL, 5-items), Reflective Thinking (RT, 5-items), Ease of Use (EU, 5-items), Perceived Usefulness (PU, 5-items), Multiple Sources (MS, 5-items), Connectedness (CN, 5-items), Functional Design (FD, 5-items). Because the original version of the PI-SCLE was evaluated from the students' perspective, the subject of some items was changed from "I" to "students". After this process, SN3 was deleted from the original questionnaire because SN3 was the same as SN2. Teachers responded to the 39 items scaled from 1 (strongly disagree) to 5 (strongly agree).

6.3.3.2 Classroom process quality: Instructional quality

Instructional quality was assessed using the measures of cognitive activation (CA) and connectedness (CN) from PI-SCLE (MacLeod et al., 2018), and classroom management (CM) from the Teaching Quality Scales (Fauth et al., 2014). CA consists of three dimensions: Student Negotation (SN), Inquiry Learning (IL), and Reflective Thinking (RT). All items were rated on a 5-point scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

6.3.3.3 Classroom process quality: The use of technology

In addition, we investigated the use of technology in SCLEs for assessing classroom process quality. This scale consists of two dimensions: the use of digital devices (DD) and the use of digital resources (DR). The instrument assesses the frequency that the use of technology during one lesson taught in the smart classroom. The two items of the use of digital devices were self-developed, while the seven items of the use of digital resources were adapted from Teachers' Use of Digital Educational Resources (Wang, Tigelaar, & Admiraal, 2019). These items were scored on a 5-point scale, ranging from 1 (never) to 5 (very much).

6.3.3.4 Student engagement

Student engagement was assessed by applying an adaptation of the scale of Student Engagement (Jang, Kim, & Reeve, 2012; Reeve & Tseng, 2011). This scale evaluates student behavioral engagement (BE), cognitive engagement (CE), and emotional engagement (EE). The 10 items were included with a 5-point scale, scoring from 1 (strongly disagree) to 5 (strongly agree).

6.3.3.5 Covariates

Except for the teacher beliefs toward SCLEs, the teacher questionnaire included the background information of the teachers, i.e., age, gender, degree, years of teaching in smart classrooms, and the current teaching grade in the smart classroom. Students also provided their demographic information (i.e., age and gender) in the student questionnaire. The gender of teachers and students was dummy coded (0 = female, 1 = male).

6.3.4 Data analyses

We performed five steps for data analyses. First, to examine the underlying structure of instructional quality, the use of technology, and student engagement, exploratory factor analyses (EFA) were performed using SPSS 25. After Principal Component Analysis with Oblimin rotation on 24 items of SN, IL and RT, CN, and CM, three variables were extracted: CA, CN, and CM. Similarly, 9 items of the use of digital devices and digital resources were entered into an EFA, yielding one variable: TECH; 10 items of CE, EE, and BE were entered into an EFA, yielding one factor: ENGAGE.

Second, a series of single-level Confirmatory factor analysis (CFA) were conducted for CA, CN, CM, TECH, and ENGAGE. However, the results of discriminant validity did not support the four-factor structure of classroom process quality and there is a high correlation between CA and CM. Therefore, we decided to delete CM from the model (Cohen, Cohen, West, & Aiken, 2003). The results showed acceptable convergent validity and internal reliability of all measurement models.

Third, because factors of classroom process quality observed by students were also conceptualized at the classroom level, student-level scores are aggregated to create a classroom-level score for CA, CN, and TECH. A multilevel confirmatory factor analysis (MCFA) was performed to validate each measure.

Table 6.2 presents the fit indices, which are considered acceptable (Hu & Bentler, 1999). We also examine aggregation for variables at the classroom level by using the intra-class correlation coefficients (ICCs). We computed ICC(1) to compare the variance between classes with the variance within classes using the individual responses and ICC(2) to assess the reliability of the classroom-level means as aggregated from the student level measures (Lüdtke, Marsh, Robitzsch, & Trautwein, 2011). For CA, CN, TECH, the ICC(1) was 0.078, 0.094, 0.113, and the ICC(2) was 0.802, 0.791, 0.859, respectively, suggesting sufficient between-class variation and good reliability of class-mean ratings (LeBreton & Senter, 2008).

Table 6.2. Fit indices and inter-class correlation coefficients (ICCs).

	Acceptable values	Model values			
		CA	CN	TECH	ENGAGE
Fit index					
χ^2		12.871	0.111	10.624	15.001
df		4	0	10	10
RMSEA	≤ 0.08	0.035	0.000	0.006	0.017
CFI	≤ 0.9	0.995	1.000	1.000	0.998
TLI	≤ 0.9	0.985	1.000	0.999	0.997
$SRMR_W$	≤ 0.08	0.008	0.000	0.008	0.008
$SRMR_B$	≤ 0.08	0.015	0.002	0.039	0.033
ICCs					
ICC(1)	≥ 0.05	0.078	0.094	0.113	0.070
ICC(2)	≥ 0.7	0.802	0.791	0.859	0.783

Fourth, to answer RQ1 and RQ2, we employed multilevel regression analysis to build a multilevel-level model. Given the sample's stratified nature, students were nested within class. All multilevel analyses were conducted using M*plus* 8 software (Muthén & Muthén, 1998-2017) using the robust maximum likelihood estimation. All of the student-level variables were centered around the group mean and the aggregated ratings of classroom process quality were centered at the grand mean. There were three different models for the data analysis. In the first stage, we conducted an unconditional, two-level regression analysis: students at Level 1, classroom at Level 2. The preliminary results show that between-class variance (ICC) for student engagement is 0.065, which is greater than the suggested value of 0.059 (Cohen, 1988), and it means that multilevel modeling is appropriate for examining the data. Next, a conditional model with covariates at both levels was conducted. Student-level covariates contained students' age and gender, and classroom-level covariates included teachers' gender, age, degree, teaching years, and grade in smart classrooms. Third, the full model with variables and covariates at both levels was conducted. Except for the covariates at both levels, student-level variables contained students' individual perceptions of CA_S, CN_S, TECH_S, and classroom-level variables contained teacher ratings of teacher beliefs and the average of students' perceptions of CA_C, CN_C, TECH_C. We compared different models using the Akaike Information Criterion (AIC), and Bayes Information Criterion (BIC), for which lower values indicate better model fit (Raftery, 1993). We also used the Wald χ^2 test used to look for significant *p*-values indicating a model fit the data better.

Finally, to answer RQ3, we performed the multilevel mediation analysis. As shown in Figure 6.1, the two-level regression model was performed for a 2-2-1 mediation design. Here we regarded teacher beliefs, teacher background variables as the independent variable, students' shared perceptions of classroom process quality (i.e., CA_C, CN_C, TECH_C) as mediators, student engagement as the dependent variable. We used the *model indirect* command implemented in M*plus* to test the indirect effects controlling for student covariates.

6.4 Results

6.4.1 Predicting students' shared perceptions of classroom process quality

The descriptive statistics and correlations of variables at the student and classroom levels are reported in Tables 6.3 and 6.4. The values of Cronbach's α are given on the diagonal in bold. The student results in Table 6.3 show that the lowest level for students' individual perceptions of classroom process quality with regard to TECH_S (M = 3.80, SD =0.816). Students reported experiencing more CN_S (M = 4.674, SD = 0.589) than CA_S (M = 4.430, SD = 0.711). The class results in Table 6.4 show that teachers most often tend to moderately agree with the statements about SCLEs (M = 3.994, SD = 0.578). CN_C had the highest agree rating from the class (M = 4.644, SD = 0.184) and TECH_C had the lowest agree rating from the class (M = 3.790, SD = 0.290). The three classroom process quality domains were not significantly associated with teacher beliefs.

A summary of the results from the multilevel mediation models is given in Table 6.5. Regarding RQ1, teacher beliefs was not significantly related to all domains of students' shared perceptions of classroom process quality (CA_C: B = -0.018, β = -0.048, p = 0.782; CN_C: B = -0.002, β = -0.007, p = 0.969; and TECH_C: B = -0.032, β = -0.063, p = 0.697). In terms of covariates, male teachers showed significantly lower CA_C (B = -0.156, β = -0.344, p = 0.017), and teachers with higher degrees was associated with significantly higher CA_C (B = 0.321, β = 0.405, $p < 0.001$), CN_C (B = 0.160, β = 0.244, p = 0.001) and TECH_C (B = 0.393, β = 0.379, $p < 0.001$). Teachers teaching in higher grades performed higher TECH_C (B = 0.123, β = 0.311, p = 0.017) than teachers teaching lower grades.

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6.4.2 Predicting student engagement in SCLEs

Regarding RQ2, we tested whether teacher beliefs, students' shared and individual perceptions of classroom process quality and covariates at both levels are related to student engagement. The results in Table 6.5 showed that Model 0 predicting students' engagement yielded an ICC of 0.065, indicating that the student-level variance accounted for 93.5% of the total variance in the outcome variable, whereas 6.5% of the total variance was at the classroom level. Compared to Model 0, the residual variance of Model 1 (ICC = 0.065) was reduced. The proportion of variance explained by covariates was 0.33% ((0.307-0.306)/0.307 = 0.0033) at the student level and 38.10% ((0.021-0.013)/0.021 = 0.3810) at the classroom level. At the student level, boys reported a significantly higher engagement than girls (B = 0.057, β = 0.051, p = 0.033). At the classroom level, male teachers were negatively associated with student engagement (B = -0.124, β = -0.417, p = 0.015) and teachers with higher degrees were positively associated with student engagement (B = 0.264, β = 0.508, $p < 0.001$).

Table 6.3. Means, standard deviations, and correlations of variables at student level.

Variable	M	SD	1	2	3	4	5
1. CA_S	4.430	0.711	**0.903**				
2. CN_S	4.674	0.589	0.683***	**0.892**			
3. TECH_S	3.830	0.816	0.519***	0.359***	**0.840**		
4. ENGAGE	4.580	0.567	0.686***	0.670***	0.415**	**0.877**	
5. Student age	2.024	0.819	-0.051	-0.072	0.119**	-0.023	
6. Student gender	0.488	0.500	0.021	0.000	0.073**	0.055*	0.038*

Note. (a) CA_S = students' individual perceptions of cognitive activation, CN_S = students' individual perceptions of connectedness, TECH_S = students' individual perceptions of the use of technology; (b) $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; (c) student gender was coded as 1 = female, 2 = male.

Table 6.4. Means, standard deviations, and correlations of variables at classroom level.

Variable	M	SD	1	2	3	4	5	6	7	8
1. Teacher beliefs	3.994	0.578	**0.973**							
2. CA_C	4.390	0.221	-0.161							
3. CN_C	4.644	0.184	-0.166	0.857***						
4. TECH_C	3.790	0.290	-0.071	0.653**	0.363*					
5. Teacher age	4.684	1.195	0.102	0.075	-0.055	-0.053				
6. Teacher gender	1.605	0.489	-0.171	0.251	0.197	0.277*	-0.259			
7. Teacher degree	2.974	0.279	-0.182	0.368*	0.281**	0.229	-0.182	-0.076		
8. Teaching year	2.105	0.882	0.344*	-0.098	-0.255	0.305**	-0.168	0.096	0.524***	
9. Teaching grade	1.789	0.731	0.067	-0.188**	-0.263*	0.313**	-0.167	0.136	-0.284	-0.095

Note. (a) CA_C = students' shared perceptions of cognitive activation, CN_C = students' shared perceptions of connectedness, TECH_C = students' shared perceptions of the use of technology; (b) $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; (c) teacher gender was coded as 1 = female, 2 = male.

Table 6.5. Multilevel analysis: Relations among teacher beliefs, classroom process quality, and student engagement.

	Mediators: Students' shared perceptions of classroom process quality			Outcome: ENGAGE		
	CA_C	CN_C	TECH_C	Model 0	Model 1	Model 2
Intercept	4.451***(0.039)	4.681***(0.033)	3.856***(0.051)	4.556***(0.273)	4.578***(0.035)	4.546***(0.013)
Level 1 (student-level) variables						
Student age					0.025(0.031)	0.031(0.022)
Student gender					0.057* (0.027)	0.043*(0.018)
CA_S						0.313***(0.028)
CN_S						0.362***(0.037)
TECH_S						0.047**(0.014)
Level 2 (classroom-level) variables						
Teacher beliefs	-0.018 (0.066)	-0.002(0.054)	-0.032(0.081)			0 (0.014)
CA_C						-0.003(0.101)
CN_C						0.693***(0.086)
TECH_C						0.141*(0.069)
Teacher age	0.043(0.027)	0.000(0.022)	0.044(0.034)		0.015(0.019)	0.012(0.008)
Teacher gender	-0.156*(0.065)	-0.094(0.058)	-0.166(0.089)		-0.124* (0.051)	-0.043(0.023)
Teacher degree	0.321***(0.091)	0.160**(0.050)	0.393***(0.080)		0.264***(0.037)	0.102***(0.024)
Teaching year	0.001(0.048)	-0.038(0.048)	0.067(0.051)		0.015(0.035)	0.033*(0.013)
Teaching grade	-0.024(0.046)	-0.032(0.042)	0.123*(0.052)		-0.024(0.035)	-0.018(0.021)
Random effects						
Level 1 residual				0.307***(0.103)	0.306***(0.023)	0.145***(0.011)
Level 2 residual	0.036***(0.007)	0.027***(0.007)	0.057***(0.013)	0.021**(0.006)	0.013**(0.004)	0(0.001)
R^2 level 1					0.003	0.522
R^2 level 2	0.275	0.200	0.319		0.397	0.997
Model fit (-2LL)				3076.967	3056.918	1652.968
Wald χ^2					135.383 ($p < 0.001$)	1102.143 ($p < 0.001$)
AIC				3082.967	3076.918	1686.969
BIC				3099.496	3131.651	1780.627
Reference					Model 0	Model 1

For the full model (Table 6.5, Model 2, ICC = 0.080), CA_S (B = 0.313, β = 0.384, p < 0.001), CN_S (B = 0.362, β = 0.370, p < 0.001) and TECH_S (B = 0. 047, β = 0. 065, p = 0.001) were all significantly and positively related to student engagement, after all covariates at both levels were controlled for. In terms of classroom level, students' shared perceptions of CN_C (B = 0.693, β = 0.782, p < 0.001) and TECH_C (B = 0.141, β = 0.250, p = 0.252) was significantly and positively related to student engagement, but teacher beliefs and CA_C were not. Compared to Model 1, adding teacher beliefs and students' shared perceptions of CA_C, CN_C, TECH_C, and students' individual perceptions of CA_S, CN_S, and TECH_S as predictors of student engagement reduced the between-class variance by 61.9%% ((0.013–0)/0.021 = 0.619).

We also assessed the improvement of each model over the preceding one (from the intercept-only model to the models with the predictor variables). As shown in Table 6.5, our results provide evidence that the full model fit the data better.

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6.4.3 Mediated relations

Table 6.6 shows the indirect effects. The results indicated that only the indirect effect of teachers' degree level on students' engagement through CN_C (B = 0.111, p = 0.003), and the indirect effect of degree level on students engagement through TECH_C (B= 0.055, p = 0.043) were statistically significant. The results did not support the mediation relationships between teacher beliefs and ENGAGE via students' shared perceptions of CA_C (B= 0.000, p = 0.982), CN_C (B = -0.001, p = 0.969), and TECH_C (B = -0.004, p = 0.712).

Table 6.6. Indirect effect results.

Mediation path	*B*	*SE*	95% CI for indirect effect	
(IV → MV→ DV)			Lower limit	Upper limit
Teacher beliefs → CA_C → ENGAGE	0.000	0.002	-0.003	0.003
Teacher age → CA_C → ENGAGE	0.000	0.004	-0.008	0.008
Teacher gender → CA_C → ENGAGE	0.000	0.015	-0.028	0.029
Teacher degree → CA_C → ENGAGE	-0.000	0.030	-0.060	0.059
Teaching year → CA_C → ENGAGE	0.000	0.000	0.000	0.000
Teaching grade → CA_C → ENGAGE	0.000	0.002	-0.004	0.005
Teacher beliefs → CN_C → ENGAGE	-0.001	0.037	-0.074	0.071
Teacher age → CN_C → ENGAGE	0.000	0.015	-0.029	0.030
Teacher gender → CN_C → ENGAGE	-0.065	0.041	-0.145	0.015
Teacher degree → CN_C → ENGAGE	0.111**	0.037	0.038	0.184
Teaching year → CN_C → ENGAGE	-0.027	0.034	-0.092	0.039
Teaching grade → CN_C → ENGAGE	-0.022	0.029	-0.080	0.035
Teacher beliefs → TECH_C → ENGAGE	-0.004	0.012	-0.028	0.019
Teacher age → TECH _C → ENGAGE	0.006	0.006	-0.006	0.018
Teacher gender → TECH _C → ENGAGE	-0.023	0.015	-0.052	0.006
Teacher degree → TECH _C → ENGAGE	0.055*	0.027	0.002	0.109
Teaching year → TECH _C → ENGAGE	0.009	0.009	-0.007	0.026
Teaching grade → TECH _C → ENGAGE	0.017	0.011	-0.004	0.038

Note. B indicates the strength of the indirect effect.

6.5 Discussion

In the present study, we examined the relationships among teacher beliefs, classroom process quality, and student engagement across the student and class levels in the smart classrooms in secondary education. This research offers a significant understanding of classroom process quality within SCLEs by arguing that both the global factors of instructional quality (i.e., cognitive activation and connectedness) and specific teaching practices (i.e., the use of technology) have the potential to create activating, supportive, and efficient learning environments, resulting in a high level of students' perceived engagement.

Unexpectedly, teacher beliefs had no effects on classroom process quality, but teacher degree exhibited significant positive effects on all three dimensions (i.e., cognitive activation, connectedness, and the use of technology). Moreover, the classes taught by male teachers scored lower on cognitive activation, and teachers teaching in higher grades contributed to the use of technology more often in smart classrooms. Additionally, both teacher (i.e., teacher degree and teaching year) and student (i.e., gender) characteristics were related to student engagement. Another unexpected result was that boys reported a significantly higher engagement than girls did in this Chinese secondary school context. This result differs from Archambault and Dupéré's (2017) finding that schoolboys were more likely to show more disruptive behavior and to be less engaged in the literacy domain as perceived by teachers. One possible explanation for this finding may be that boys perceived more social support from teachers and peers (Lietaert, Roorda, Laevers, Verschueren, & De Fraine, 2015), thus having more opportunities to be (especially behaviorally and emotionally) engaged in technology-supported learning activities.

To better clarify the relationships proposed by this study, below we discuss the main findings and their theoretical and practical implications in details. First, with regard to RQ1, we found that teacher beliefs were neither related to cognitive activation, connectedness, nor the use of technology in the specific context of SCLEs in secondary education. The result is in agreement with the recent findings showing that simply having certain beliefs about teaching and learning could not guarantee high instructional quality (Fauth et al., 2019), and perceived usefulness about the use of technology does not predict any technology integration practice in classrooms (Cheng, Lu, Xie, & Vongkulluksn, 2020; Mills et al., 2019). It is suggested that teachers' pedagogical beliefs have to be aligned with their competences to integrate ICT into education more effectively (Aslan & Zhu, 2017). Therefore, our findings extend previous research on the relationships between teacher beliefs and classroom process quality (see e.g., Backfisch, Lachner, Stürmer, & Scheiter, 2021). Furthermore, teacher degree was found to be positively related to three aspects of classroom process quality. Owning a higher academic degree may imply that teachers have more opportunities to specialize in a subject area and thus gain more knowledge regarding teaching. The finding extends previous research that improving teacher quality can increase teaching quality (Fauth et al., 2019).

Secondly, concerning RQ2, classroom process quality and covariates were found to be related to student engagement. We conclude that students' interactions with teachers, peers, and technologies can improve their learning experiences and engagement: both shared and individual perceptions of connectedness and the use of technology were related to student engagement with connectedness at both levels as the strongest predictor of student engagement. This finding is in line with the results of Manwaring, Larsen, Graham, Henrie, and Halverson (2017), who found that in blended learning environments in higher education classes student-perceived learning activities had a stronger influence on engagement than individual student characteristics. The climate effects of connectedness and the use of technology at the classroom level suggest that establishing supportive relationships and equipping technologies for the whole class are important for teachers to consider in the design of smart classrooms. However, secondary students' perceptions of cognitive activation at the classroom level were not related to their individual engagement. This result is consistent with Fauth et al. (2019), who showed that elementary school students' interest was not predicted by cognitive activation observed by external raters. Atlay et al. (2019) further stated that the non-association between cognitive activation at the classroom level and learning achievement could be explained by the low ICC(1) value of cognitive activation, which may lead to relatively low reliability of this measure, and this explanation holds true for the present study.

Finally, regarding RQ3, the mediation results reveal that teachers with higher degrees contributed to higher student engagement because they facilitated a higher level of connectedness and the use of technology. Fauth et al. (2020) have argued that teaching quality is theoretically assumed to connect teacher and student characteristics and student outcomes. A previous study proved the mediating role of teaching quality between teacher beliefs and student performance (Fauth et al., 2019). Yet, the current study did not find such effects due to low correlations between teacher beliefs and all factors of classroom process quality. The results have significant theoretical implications that the potential of teacher degree that representing teachers' specialist knowledge need to be considered when examining the mediating role of teaching quality.

6.6 Limitations and future directions

Several limitations need to be addressed. The first limitation relates to the possible biased sample of our study. Even though the sample of the current study meets the basic requirement for multilevel analysis, it could be the case that our findings only emerged as the voluntary classes with special characteristics were obtained. Therefore, it would be valuable to replicate our study with a more diverse sample size (especially larger class size), and within other specific social and cultural contexts. Second, surveys may be the most effective but not the only means for understanding student engagement (Henrie, Halverson, & Graham, 2015). In particular, in the present study classroom management was only examined based on students' perceptions. Classroom management could also be obtained through either interviews with teachers or observations in the smart classrooms. In doing so, further research could gain more insights into teachers' reasoning on how they behave in the classroom and how technologies are used, thereby obtaining a more comprehensive picture of the diverse conditions for improving classroom process quality and gaining more valid results for teaching quality at the classroom level. Lastly, although a few demographic variables of the sample have been investigated in this study, the consideration of other student and teacher characteristics would provide further insights about what should be considered at a pilot phase of developing smart classrooms to maximize the efficiency of unique smart classroom hardware and software. For example, it would be interesting to examine whether SCLEs differentially benefit certain types of students (e.g., from rural schools and urban schools), and whether and to what extent this new condition for learning closes the educational gap between student groups in terms of their engagement.

6.7 Conclusions

We have explored cross-level mediation relationships among teacher beliefs, classroom process quality, and student engagement. First, teacher beliefs were not related to cognitive activation, connectedness, and the use of technology, but other teacher characteristics had significant effects on at least one aspect of classroom process quality. Second, in addition to the critical role of student and teacher characteristics, students' perceptions of connectedness and the use of technology at both the individual and classroom levels positively influenced student engagement while only individual perceptions of cognitive activation explained differences in student engagement. Third, connectedness and the use of technology at the classroom level mediated the relationship between teacher degree and student engagement.

Findings have implications for advancing our knowledge of the design and implementation of smart classrooms. Despite the popularity of the smart classroom in secondary education, understanding how it can be used to promote student engagement is still evolving. Although much research exists on teaching quality in education in general, few studies have combined the specific teaching practice with global factors of classroom process quality in the context of SCLEs. This study provides empirical evidence regarding what pedagogical and technological factors are likely to affect student engagement and offers insights regarding which dimensions of classroom process quality deserve closer attention for enhancing student engagement. Drawn from the finding, we argue that researchers should consider student perspectives to examine classroom practices. In addition, it is essential to improve teachers' specialist knowledge before enacting the technology-integrated lessons in smart classrooms.

This research offers several practical implications to establish conditions that foster an engaging smart classroom learning environment. We argue that the critical role of teacher degrees, which may reflect teachers' quality, to improve all aspects of the classroom process quality has been underestimated for a long time. For policymakers, paying more attention to teacher competence seems to be an effective way to promote student learning (Fauth et al., 2019). As we found several teacher characteristics were important for classroom process quality, these specific characteristics offers valuable starting points for selecting the right group of teachers to participate in the smart classrooms in the early phase of implementing smart classrooms. Especially, given the critical role of teacher degree, teacher education and professional development seem to be good levers to bring change to scale. Additionally, the learning environments including high levels of cognitive activation, connectedness and the use of technology support student engagement best. To improve student engagement, teachers should use technology to provide integrated learning experiences, and create incentives, such as real-time feedback systems, reward systems, or game-based systems, for students to engage them in active learning.