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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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A B S T R A C T

As smart classroom learning environments enable teaching and learning processes, scholars have examined how classroom process quality affects student engagement in secondary education. Smart classroom learning environments provide a prominent signpost for how teaching and learning will be transformed to accommodate new technologies. However, a holistic model for smart classroom learning environments seems warranted. This study fills this knowledge gap by emphasizing both instructional quality and the use of technology as critical indicators of classroom process quality. A total of 1825 secondary school students and their 38 teachers participated in the study. By using teacher and student questionnaires, the relationship among teacher beliefs, classroom process quality, and student engagement in smart classroom learning environments 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 students' shared perceptions of connectedness and the use of technology were linked to student engagement. Unexpectedly, it was teacher education level rather than teacher beliefs that were associated with classroom process quality. Classroom process quality could also be influenced by teacher gender and teaching grade. Students' individual perceptions of three domains of classroom process quality were related to their engagement and boys reported significantly higher engagement than girls. Multilevel mediation analysis results showed that the relationships between teacher education level and student engagement were influenced by students' shared perceptions of connectedness and the use of technology. These findings contribute to a better understanding of how to best develop engaging smart classroom learning environments, and suggestions for future research are provided.

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1. Introduction

1.1. General 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; 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, challenging goals and authentic tasks (Shernoff et al., 2016). Recently, many emerging technologies (e.g., Internet of Things, Big Data Analytics, Augmented Reality, Virtual Reality) have been proposed for transforming traditional classrooms into interactive smart classrooms that can be effective, efficient, and engaging when it comes to supporting instructors and stimulating student learning (Memos, Minopoulos, Stergiou, Psannis, & Ishibashi, 2020). However, the reality is that these cutting-edge technologies are unavailable in most learning environments. Therefore, in the present study, smart classroom learning environments (SCLEs) refer to interactive face-to-face learning environments that adopt the active learning process and integrate advanced digital technologies to enhance students' learning experience (MacLeod, Yang, Zhu, & Li, 2018). Compared with the traditional lecturing approach, a meta-analysis of technology-enabled learning environments showed that smart classroom-based instruction significantly affects students' learning outcomes and will be more effective with a larger class (Shi, Yang, Zhang, Pu, & Yang, 2020). SCLEs have been implemented in government programs in many countries, such as in Poland (Digital School), Australia (The Smart Classrooms), and Thailand (One Tablet per Child project), to enable students to benefit from the advantages of the digital era. Overall, the effects of these projects provide preliminary evidence to support the idea that technology-based environments do have a positive influence on student engagement (Schindler, Burkholder, Morad, & Marsh, 2017). The accessibility of digital devices and digital resources has been the starting point of these ICT initiatives aimed at encouraging technology-based teaching and learning. In China, for example, smart classrooms are characterized by students' use of educational tablets, which increased from 5.47 million units in 2011 to 17.52 million units in 2017 (Intel Company®, 2019). While many regions have experimented with digital resources of tablets and other forms of intelligent terminals in primary and secondary schools, coastal regions (e.g., Shanghai, Guangzhou) have been at the forefront of smart classroom development, with approximately one-fifth of classrooms being smart classrooms. (iResearch, 2019). In rural areas, from our observations, smart classrooms were found in two of the 25 visited schools in Western China (Wang, Tigelaar, & Admiraal, 2022). It is therefore important to understand how the classroom process quality is developed in SCLEs and examine how different domains of classroom process quality influence student engagement during their learning, which will help us to understand interactional patterns between teachers and students in class and shorten digital gaps between schools in the long term.

Maintaining student engagement, especially in technology-based learning environments, seems challenging, however, due to in-class distractions and disengagement that lead to poor academic performance (Bergdahl et al., 2020). Moreover, mobile technologies might trigger situations in which students face more challenges. Students in secondary education especially reported using mobile devices to escape from boring classes more frequently when they were in lower grades (Bergdahl et al., 2020). Understanding lower levels of secondary school students' engagement is especially important and failure to do so may lead to ineffective teaching and learning with technologies. With regard to positively affecting student engagement, investigating classroom process quality can be considered important because several variables of classroom process quality have been found to influence students' learning outcomes (e.g., Olivier, Galand, Morin, & Hospel, 2021). The core mechanism behind classroom process quality is instructional quality, which involves three global dimensions: cognitive activation, supportive climate, and classroom management (Klieme, Pauli, & Reusser, 2009). Based on these dimensions, we define classroom process quality as the interactional patterns between teachers and students in class. Undoubtedly, a teacher's contribution to creating a supportive climate in smart classrooms is essential, but whether teachers are really engaged with creating such a climate and how they attempt to do so is known to be dependent on their beliefs (Chand, Deshmukh, & Shukla, 2020).

1.2. Problem statement

Classroom process quality has become much more important for secondary school students to be engaged in learning, but its measurement has been problematic. The majority of studies up to now have either focused on instructional quality or on technology usage as crucial indicators when evaluating technology integration in diverse contexts. However, this falls short of covering all aspects of teaching, learning, and technology in combination (Knezek & Christensen, 2016). Additionally, although one might argue that teacher beliefs toward SCLEs may influence their instructional practices and technology use and thus facilitate student learning (Eisenhart, Shrum, Harding, & Cuthbert, 1988), the varying focus on specific samples and technologies has caused inconsistent findings, and their efficacy remains unclear. Overall, this lack of a holistic view and considering a particular context are major concerns for understanding and supporting students who learn with technologies. In order to better understand the complex and multifaceted phenomena of teaching and learning with technology, additional research is needed into how technological factors interact with instructional factors that together may influence student engagement in secondary education. This is particularly the case for SCLEs as they go beyond the simple use of technology and educational strategies must be adapted to suit this specific context (Kinshuk, Chen, Cheng, & Chew, 2016). The transition from traditional classroom learning environments to smart classroom learning environments presents significant implementation challenges. The primary problem that this study attempts to unravel is SCLEs, including which factors support student engagement best. Both the global factors of instructional quality and specific teaching practices (i.e., the use of technology) could affect student engagement. Teachers' and/or students' background variables could result in variances in classroom process quality and student engagement. Thus, the purpose of this study was to examine 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. To analyze teachers' and students' roles in SCLEs, we developed and tested a model based on factors related to the specific learning environment features. We chose to use typical smart classrooms as the basis for the empirical study because these are widespread implemented in China (MOE, 2018) where teachers and students have access to mobile devices and digital resources to engage students in class. A typical smart classroom is equipped with technologies such as wireless Internet, interactive whiteboards and projectors for whole class instruction, mobile devices for the teacher and individual students to use, cameras to record and store lectures, sensors and acoustics to control the physical environment, and educational management and assessment tools (Saini & Goel, 2019). We also proposed a holistic model that includes variables both at the student and classroom level with regards to teaching, learning, and technology in combination (Knezek & Christensen, 2016), which includes relevant variables for examining possible influences on student engagement in typical smart classrooms.

2. Theoretical background

2.1. Classroom process quality in the smart classroom learning environment

Research has identified key aspects of good teaching practices that emphasize classroom process quality. One of the most cited international theoretical models is the basic (deep structure) dimensions of instructional quality model (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 are hypothesized to influence students' learning outcomes. According to Klieme et al. (2009), *cognitive activation* refers to promoting students' conceptual understanding through appropriate instructional strategies like providing students with 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 about coping with disruptive behavior, it also requires teachers to stay focused and provide clear and consistent rules and procedures in terms of content and social norms. 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 supporting co-learning through enhanced technology, have recently attracted attention in academia (see e.g., Jou & Wang, 2019). In smart classrooms, students use technologies for active learning in the first place, rather than merely reacting to learning tasks that are provided. The extent to which and how technologies are integrated into learning activities needs 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 classroom process quality, the present study, adopted the use of technology together with the three global dimensions that represent classroom process quality.

2.2. Connections between teacher beliefs and classroom process quality in the smart classroom learning environment

Teacher beliefs are the sum of teachers' judgments and evaluations about school-, teaching-, learning- and student-related matters, as well as about what matters beyond their profession (Pajares, 1992). Although researchers have argued that teacher beliefs are likely to be compatible with their teaching behavior (Bandura, 1986; Eisenhart et al., 1988), research has shown that relations between different teacher beliefs (e.g., teaching-specific or general beliefs) and their instructional practices are ambiguous. For example, Burić and Kim (2020) showed that secondary school teachers' self-reported beliefs in their teaching capabilities are linked with student-reported classroom management, cognitive activation, and supportive climate. 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 dependent on the teachers, 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). In a study in Spain, Gil-Flores, Rodríguez-Santero, and Torres-Gordillo (2017) found secondary school teachers with constructivist and learner-centered beliefs were more likely to use technology. Yet in another study, Han, Byun, and Shin (2018) found that South Korean teachers were unable to transform their beliefs into technology-enhanced teaching practices. In yet another study, Mills, Jass Ketelhut, and Gong (2019) reported that the beliefs of a science teacher changed after a three-year inquiry-based technology program; however, his classroom practice remained teacher-centered. Since classroom context matters, in the present study, teacher beliefs were narrowed down to focus more specifically on technology use and defined as teachers' overall attitudes toward smart classroom learning environments. A better understanding of the relations between teacher beliefs and classroom process quality is necessary to understand student engagement in SCLEs.

2.3. Classroom process quality and student engagement in the smart classroom learning environment

Engagement typically includes behavioral, emotional, and cognitive dimensions (Archambault & Dupéré, 2017). Researchers generally emphasize the directional flow that the quality of the learning environment has on students' engagement during learning activities (Xu, Chen, & Chen, 2020). For instance, Decristan et al. (2015) found that students' cognitive engagement (i.e., conceptual understanding) was 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, boredom, and anxiety), (see e.g., Fauth, Decristan, Rieser, Klieme, & Büttner, 2014). Finally, emotionally-supportive teacher behavior has been linked with students' behavioral engagement. (Ruzek et al., 2016).

Student engagement in SCLEs manifests itself differently, however, from engagement in regular classrooms. Schindler et al.'s (2017) review does provide preliminary evidence 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 inquiry-based learning with multiple experimental representations (MERs) can reduce cognitive load and increase conceptual understanding and thus can improve performance (Becker, Klein, Gößling, & Kuhn, 2020). Hammer, Göllner, Scheiter, Fauth, and Stürmer (2021) argue that using tablets is more appealing to students than instruction without technology, making learning activities more interesting and meaningful. Yang, Yu, Gong, and Chen (2017) conducted experimental research to compare primary students' perceptions about both the regular and smart classroom learning environment and found that compared with a regular multimedia classroom, students' perceptions of both instructional quality and the use of technology scored significantly higher in SCLEs. In addition, students appeared to be more engaged with individual learning and collaborative learning in the SCLEs. However, a recent study by Thomas, Parsons, and Whitcombe (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 remains unclear, especially in the context of SCLEs in secondary education.

2.4. Classroom process quality as a mediator

Despite the commonly accepted direct relationships between professors' views of effective teaching and their students' engagement in technology-rich classrooms (Gebre, Saroyan, & Bracewell, 2014), studies analyzing the responses of both teachers and students and recognizing the multilevel nature of such data have not found a stable relationship (see e.g., Burić & Kim, 2020). In particular, the effect of teacher beliefs on secondary school student engagement disappeared when interpersonal teacher behavior was included (van Uden, Ritzen, & Pieters, 2014). According to the model of teaching quality of Fauth et al. (2020), the 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 mediation, scientific evidence is minimal. To the best of our knowledge, only Fauth et al. (2019) have reported that the three basic dimensions of instructional quality mediate the relations between teacher beliefs (i.e.,

Table 1
Demographic information of the students and teachers.

Variables	Category	Frequency	Percent
Student information			
Age	12	516	28.3
	13	820	44.9
	14	421	23.1
	15	65	3.6
	16	3	0.2
Gender	Female	935	51.2
	Male	890	48.8
Teacher information			
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
Gender	Female	23	60.5
	Male	15	39.5
Education level	Secondary Vocational School Education	0	0
	Three -year college Education	2	5.3
	Bachelor	35	92.1
	Master	1	2.6
Teaching years in smart classroom learning environments	<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 smart classroom learning environments	7	15	39.5
	8	16	42.1
	9	7	18.4

teaching enthusiasm and pedagogical content knowledge) and student interest. Furthermore, the lack of research into the mediation role of technology makes it difficult to determine whether groups of students see differences in benefits derived from instructional quality and benefits derived from the use of technology. Thus, further elucidation of the role of classroom process quality (i.e., cognitive activation, supportive climate, classroom management, and the use of technology) mediating between teacher beliefs and student engagement in SCLEs is warranted.

3. Research framework and research questions

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. Although research has shown that even the ratings reported by primary school students can be regarded as a reliable, valid, and stable indicator of classroom process quality (Fauth et al., 2014, 2020), additional examination of the perspectives 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 what teachers think of SCLEs and how students perceive their learning processes in SCLEs could further clarify what may impact their engagement, which in turn could help researchers and practitioners to maximize the effectiveness of SCLEs.

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, differences within and between classrooms can bring valuable insights into how learners view their learning environments (Göllner, Wagner, Eccles, & Trautwein, 2018). There has been scant research until now that simultaneously investigates the effects of classroom process quality at both the student and classroom level in the context of SCLEs.

Upon reviewing relevant literature, this study aimed to fill the gaps in earlier studies by examining the relationships among teacher beliefs, classroom process quality, and student engagement in smart classrooms in lower levels of secondary school. Investigating student engagement in lower secondary schools is particularly important as disengagement tends to increase from that age (Bergdahl et al., 2020). Furthermore, given the potential role of teacher and student background characteristics on student engagement (Olivier et al., 2021; Winkler, Söllner, & Leimeister, 2021, p. 104148; Xu et al., 2020), we included several relevant characteristics (e.g., teachers' age, gender, and education level) as covariates (see Table 1 for subcategories of each demographic variable).

Fig. 1 shows that individual student-level (Level 1) constructs are based on responses by individual students and classroom-level (Level 2) constructs are based on aggregates of responses by students within the class or true Level 2 measures. This multilevel model evaluates whether classroom (or teacher) (Level 2, classroom-level) characteristics contribute to the prediction of students' (Level 1, student-level) outcomes beyond what can be explained by other individual characteristics of students (Marsh et al., 2012). We attempted to address the following research questions specifically (see Fig. 1):

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

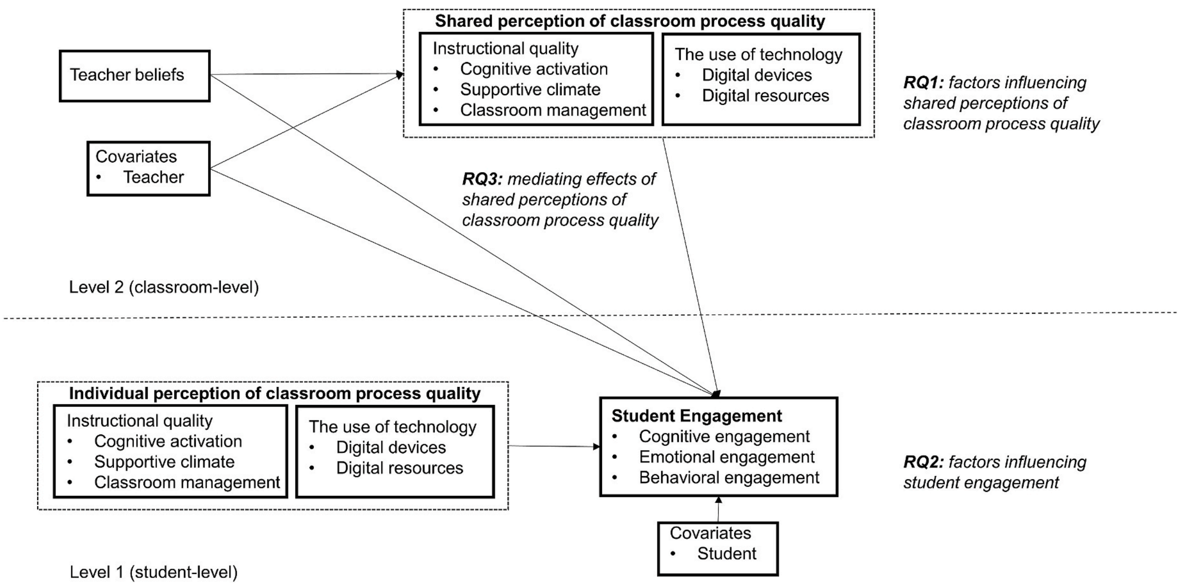

Fig. 1. The proposed research model.

RQ2. Which variables at the classroom level (i.e., teacher beliefs, teacher background variables, students' shared perceptions of classroom process quality) and student level (i.e., students' individual perceptions of classroom process quality, student demographic 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?

4. Methods

4.1. Research context

The Chinese central government has called on teachers to move beyond traditional teaching and embrace innovative pedagogical approaches using 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, apart from 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 these circumstances, if students hope to study in smart classrooms, their parents need to buy them mobile devices.

Three areas (i.e., Chongqing, Suining, and Guangyuan) in China were selected for this study where efforts by 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 owned a mobile device (this means tablets with multiple functions; mobile phones are not allowed in most Chinese secondary schools), and the internet speed was sufficient for effective teaching and learning. All teachers and students participating in the study had had at least some experience with smart classrooms. Although we intended 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).

4.2. 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. The teacher questionnaire was revised from an existing questionnaire covering eight constructs to measure teachers' overall views toward SCLEs (see section 4.3.1 for details). We then created a new student questionnaire by combining existing measures covering all aspects of classroom process quality and student engagement, as no such questionnaire had been developed previously. Teachers and students shared measures of the four constructs (i.e., Student Negotiation, Inquiry Learning, Reflective Thinking, and Connectedness). We also collected background information on the teachers and students through the respective questionnaires.

To collect as much valid data from students as possible, we sent hyperlinks via WeChat to teachers from first author's network and participating teachers were then instructed how to introduce the student questionnaire to their students. To ensure the student questionnaire was related to their teacher questionnaire, we sent a teacher questionnaire link and a student questionnaire link to each teacher, which meant that students in each classroom shared a specific questionnaire. Participation was voluntary, and all participants completed the questionnaire anonymously. Ethics approval was registered as *IREC_ICLON 2019-08* and was approved on July 8th, 2019. 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 about SCLE and students' perceptions of the actual learning processes in SCLEs, students were requested to complete the questionnaire after class; teachers completed their questionnaire in their free time. The final sample included 1825 students and their 38 teachers. The number of participating students in each class varied between 16 and 85 ($M = 48.026$, $SD = 16.511$) and only three classes had fewer 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 could be sufficient for estimating the regression coefficient (Kreft, 1996). The data collection period was from October 12th to December 17th, 2020. Table 1 shows the demographic information of the students and teachers.

4.3. Measures

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

4.3.1. Teacher beliefs

Teachers' context-specific beliefs toward SCLEs were evaluated by adapting the Chinese version of the Preference Instrument of Smart Classroom Learning Environments (PI-SCLE) (MacLeod et al., 2018). The scale includes eight measures: 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); and 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).

4.3.2. 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 Negotiation (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).

4.3.3. Classroom process quality: the use of technology

We also investigated the use of technology in SCLEs for assessing classroom process quality. This scale consists of two dimensions: use of digital devices (DD) and use of digital resources (DR). The instrument assesses the frequency of 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).

4.3.4. 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 rated with a 5-point scale, scoring from 1 (strongly disagree) to 5 (strongly agree).

4.3.5. Covariates

The teacher questionnaire included the teachers' background information, i.e., age, gender, education level, years of teaching in smart classrooms, and their current teaching grade in the smart classroom but not their beliefs about SCLEs. 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).

4.4. Data analyses

We performed five steps for data analysis. The first two steps, exploratory factor analyses (EFA) and Confirmatory factor analysis (CFA), were meant to decide which variables to include in the final analyses. The third step was multilevel confirmatory factor analysis (MCFA) which provided initial construct validity evidence for these classroom-level variables. The fourth and fifth steps were designed to examine the proposed model with nested data based on the variables selected.

First, to examine the underlying structure of instructional quality, the use of technology, and student engagement, EFA were performed using SPSS 25. Principal Component Analysis (PCA) was employed to create a reduced set of variables. After PCA with Oblimin rotation on 24 items of SN, IL and RT, CN, and CM, three variables were extracted: cognitive activation, connectedness, and classroom management. Similarly, 9 items of the use of digital devices and digital resources were entered into an EFA, yielding one variable: the use of technology; 10 items of CE, EE, and BE were entered into an EFA, yielding one factor: engagement.

Second, a series of single-level CFA were conducted for cognitive activation, connectedness, classroom management, the use of technology, and engagement to test the underlying structure. However, the results of discriminant validity did not support the four-factor structure of classroom process quality because of a high correlation between cognitive activation and classroom management. Therefore, we decided to delete classroom management from the model. 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 were aggregated to create a classroom-level score for cognitive activation, connectedness, and the use of technology. A multilevel confirmatory factor analysis (MCFA) was performed to validate each measure. Table 2 presents the fit indices, which are considered acceptable (see Hu & Bentler, 1999). We also examined aggregation for variables at the classroom level by using the

Table 2
Fit indices and inter-class correlation coefficients (ICCs).

	Acceptable values	Model values			
		Cognitive activation	Connectedness	The use of technology	Engagement
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

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 cognitive activation, connectedness and the use of technology, 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 (see LeBreton & Senter, 2008).

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 was 0.065, which is larger than the suggested value of 0.059 (Cohen, 1988), and it means that multilevel modeling was 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, education level, 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 cognitive activation, connectedness, and the use of technology, and classroom-level variables contained teacher ratings of teacher beliefs and the average of students' perceptions of cognitive activation, connectedness, and the use of technology. 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 to look for significant *p*-values indicating a model that fit the data better.

Finally, to answer RQ3, we performed the multilevel mediation analysis. As shown in Fig. 1, the two-level regression model was performed for a 2-2-1 mediation design. Here we regarded teacher beliefs and teacher background variables as the independent variables, students' shared perceptions of classroom process quality (i.e., cognitive activation, connectedness, the use of technology) as mediators, and 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.

5. Results

5.1. 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 3 and 4. The values of Cronbach's α are given on the diagonal in bold. The student results in Table 3 show that the lowest level for students' individual perceptions of classroom process quality was with regard to the use of technology (M = 3.80, SD = 0.816). Students reported experiencing more connectedness (M = 4.674, SD = 0.589) than cognitive activation (M = 4.430, SD = 0.711). The class results in Table 4 show that teachers most often tended to moderately agree with the statements about SCLEs (M = 3.994, SD = 0.578). connectedness had the highest agree rating from the class (M = 4.644, SD = 0.184) and the use of technology 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 5. Regarding RQ1, teacher beliefs was not significantly related to all domains of students' shared perceptions of classroom process quality (cognitive activation: B = −0.018, $\beta = -0.048$, $p = 0.782$; connectedness: B = −0.002, $\beta = -0.007$, $p = 0.969$; and the use of technology: B = −0.032, $\beta = -0.063$, $p = 0.697$). In terms of covariates, male teachers showed significantly lower cognitive activation (B = −0.156, $\beta = -0.344$, $p = 0.017$), and teachers with higher education levels was associated with significantly higher cognitive activation (B = 0.321, $\beta = 0.405$, $p < 0.001$), connectedness (B = 0.160, $\beta = 0.244$, $p = 0.001$) and the use of technology (B = 0.393, $\beta = 0.379$, $p < 0.001$). This means that classes taught by male teachers were perceived to have a lower level of cognitive activation, whereas classes taught by teachers with higher education levels were perceived to have a higher level of cognitive activation, connectedness, and technology use. Teachers teaching in higher grades performed higher the use of technology (B = 0.123, $\beta = 0.311$, $p = 0.017$) than teachers teaching lower grades. This indicates that teachers in higher grades contributed more to increased technology usage in smart classrooms.

Table 3
Means, standard deviations, and correlations of variables at student level.

Variable	M	SD	1	2	3	4	5
1. Cognitive activation	4.430	0.711	**0.903**				
2. Connectedness	4.674	0.589	0.683***	**0.892**			
3. The use of technology	3.830	0.816	0.519***	0.359***	**0.840**		
4. Engagement	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) *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; (b) student gender was coded as 1 = female, 2 = male.

Table 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. Cognitive activation	4.390	0.221	−0.161							
3. Connectedness	4.644	0.184	−0.166	0.857***						
4. The use of technology	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 education level	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) *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; (b) teacher gender was coded as 1 = female, 2 = male.

Table 5
Multilevel analysis: Relations among teacher beliefs, classroom process quality, and student engagement.

	Mediators: Students' shared perceptions of classroom process quality			Outcome: ENGAGE		
	Cognitive activation	Connectedness	The use of technology	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)
Cognitive activation						0.313***(0.028)
Connectedness						0.362***(0.037)
The use of technology						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)
Cognitive activation						−0.003(0.101)
Connectedness						0.693***(0.086)
The use of technology						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 education level	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

5.2. *Predicting student engagement in SCLEs*

Regarding RQ2, we tested whether teachers' beliefs, students' shared and individual perceptions of classroom process quality and covariates at both levels were related to student engagement. The results in Table 5 show 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 significantly higher engagement than girls (B = 0.057, $\beta = 0.051$, $p = 0.033$). This indicates that boys were more engaged than girls in smart classrooms. At the classroom level, male teachers were negatively associated with student engagement (B = −0.124, $\beta = -0.417$, $p = 0.015$) and teachers with higher education levels were positively associated with student engagement (B = 0.264, $\beta = 0.508$, $p < 0.001$). This means that the classes taught by teachers with higher education levels were perceived to stimulate engagement.

For the full model (Table 5, Model 2, ICC = 0.080), significant covariates associated with engagement were students' gender, teachers' education level and teaching years in SCLEs. In comparison to model 1, this indicates that after incorporating students' shared and individual perceptions of classroom process quality into model 2, the relationships between student gender and engagement, as well as between teacher education level and engagement, weakened, but remained significant. Additionally, results indicated that when other variables in model 2 were controlled for, teacher gender had no significant effect on student engagement, but teaching year did. Moreover, cognitive activation (B = 0.313, $\beta = 0.384$, $p < 0.001$), connectedness (B = 0.362, $\beta = 0.370$, $p < 0.001$) and the use of technology (B = 0.047, $\beta = 0.065$, $p = 0.001$) were all significantly and positively related to student engagement, after all covariates at both levels had been controlled for. This suggests that compared to an average student in a smart classroom, a student with a one-unit higher perception of cognitive activation, connectedness, and the use of technology has, on average, a 0.384, 0.370, and 0.065 higher rating of engagement, respectively. In terms of classroom level, students' shared perceptions of connectedness (B = 0.693, $\beta = 0.782$, $p < 0.001$) and the use of technology (B = 0.141, $\beta = 0.252$, $p = 0.040$) was significantly and positively related to student engagement, but teacher beliefs and cognitive activation were not. That is, a one-point change in class-perceived connectedness and the use of technology was associated with a 0.782-point and 0.252-point change in engagement respectively. Compared to Model 1, adding teacher beliefs, and students' shared and individual perceptions of cognitive activation, connectedness, and the use of technology 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 5, our results provide evidence that the full model fitted the data better.

5.3. Mediated relations

Table 6 shows the indirect effects. The results indicate that only the indirect effect of teacher education level on students' engagement through connectedness (B = 0.111, $p = 0.003$), and the indirect effect of teacher education level on students' engagement through the use of technology (B = 0.055, $p = 0.043$) were statistically significant. Teachers with higher education levels contributed to higher student engagement because they facilitated a higher level of connectedness and the use of technology. The results did not support the mediation relationships between teacher beliefs and engagement via students' shared perceptions of cognitive activation (B = 0.000, $p = 0.982$), connectedness (B = −0.001, $p = 0.969$), and the use of technology (B = −0.004, $p = 0.712$).

6. Discussion

The present study examined the relationships among teacher beliefs, classroom process quality, and student engagement across student and classroom levels in 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 an activating, supportive, and efficient learning environment, resulting in a high level of students' perceived engagement.

Unexpectedly, teacher beliefs did not influence classroom process quality, but teacher education level exhibited significant positive impacts on all three dimensions (i.e., cognitive activation, connectedness, and the use of technology). Additionally, both teacher (i.e., education level and teaching year) and student (i.e., gender) characteristics were related to student engagement. Another unexpected result was that boys reported significantly higher engagement than girls. 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

Table 6
Indirect effect results.

Mediation path (IV → MV→ DV)	*B*	*SE*	95% CI for indirect effect: Lower limit	Upper limit
Teacher beliefs →Cognitive activation →Engagement	0.000	0.002	−0.003	0.003
Teacher age →Cognitive activation →Engagement	0.000	0.004	−0.008	0.008
Teacher gender →Cognitive activation →Engagement	0.000	0.015	−0.028	0.029
Teacher education level →Cognitive activation →Engagement	−0.000	0.030	−0.060	0.059
Teaching year →Cognitive activation →Engagement	0.000	0.000	0.000	0.000
Teaching grade →Cognitive activation →Engagement	0.000	0.002	−0.004	0.005
Teacher beliefs →Connectedness →Engagement	−0.001	0.037	−0.074	0.071
Teacher age →Connectedness →Engagement	0.000	0.015	−0.029	0.030
Teacher gender →Connectedness →Engagement	−0.065	0.041	−0.145	0.015
Teacher education level →Connectedness →Engagement	0.111**	0.037	0.038	0.184
Teaching year →Connectedness →Engagement	−0.027	0.034	−0.092	0.039
Teaching grade →Connectedness →Engagement	−0.022	0.029	−0.080	0.035
Teacher beliefs →The use of technology →Engagement	−0.004	0.012	−0.028	0.019
Teacher age →The use of technology →Engagement	0.006	0.006	−0.006	0.018
Teacher gender →The use of technology →Engagement	−0.023	0.015	−0.052	0.006
Teacher education level →The use of technology →Engagement	0.055*	0.027	0.002	0.109
Teaching year →The use of technology →Engagement	0.009	0.009	−0.007	0.026
Teaching grade →The use of technology →Engagement	0.017	0.011	−0.004	0.038

Note. B indicates the strength of the indirect effect.

by teachers. One possible explanation for this finding may be that boys might have perceived more social support from teachers and peers (as shown by Lietaert, Roorda, Laevers, Verschueren, & De Fraine, 2015), giving them more opportunities to be (especially behaviorally and emotionally) engaged in technology-supported learning activities.

To better clarify the relationships proposed by this study, the main findings are discussed below. First, with regard to RQ1, we found that teacher beliefs were not related to cognitive activation, connectedness, or the use of technology in the specific context of SCLEs in secondary education. This result concurs with 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 of technology does not predict the integration of technology use in classrooms (Cheng, Lu, Xie, & Vongkulluksn, 2020). It has been suggested that teachers' pedagogical beliefs have to be aligned with their competences to integrate ICT into education more effectively (Aslan & Zhu, 2017). Teacher education level was found to be positively related to three aspects of classroom process quality in this study. We argue that the critical role of teacher education level, which may reflect a teacher's teaching quality, has been underestimated for a long time. Having a higher education level may imply that teachers have more opportunities to specialize in a subject area and gain more knowledge regarding teaching. Thus, teachers with a higher education level could engage more readily in innovations involving teaching with technologies in smart classrooms and take more time for reflection rather than focusing on preparation, planning, and classroom management skills. This finding extends previous research showing that improving teacher quality (e.g., Pedagogical content knowledge (PCK) and teacher self-efficacy) can improve teaching quality (Fauth et al., 2019). Taken together, these findings indicate that it is characteristics related to teacher education level, such as their actual knowledge and teaching experience, and technology, that contribute to a higher level of instructional quality and better use of technology in smart classrooms.

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. The finding that connectedness was the most important predictor among the factors influencing student engagement is consistent with previous research findings that aggregated ratings of supportive climate combined with embedded formative assessment had the most positive influence on students' science learning (Decristan et al., 2015). One explanation for this finding might be the adaptive instruction and feedback enabled by SCLEs that consider the students' learning needs and performance during the class. Given the significant role of connectedness, it is essential to foster positive social interactions, and teachers need to show caring behavior and provide timely constructive feedback to maximize the potential of SCLEs. Our results also confirmed that some of the teachers' and students' individual characteristics were associated with student engagement, although all the relations were weak. What is, however, unexpected is that teacher beliefs were not related to student engagement. An explanation for this may be found in an earlier study, in which students considered interpersonal teacher behavior when engaging students more important as it is part of students' experiences during a specific class (van Uden et al., 2014).

In terms of the use of technology, our findings show that using technology such as mobile devices, multimedia materials, and learning software increased student engagement, although the influences were small. This result is in line with findings from meta-analysis studies on mobile learning (see e.g., Sung, Chang, & Liu, 2016) showing that using mobile technology can improve student cognitive and affective learning outcomes. However, our 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. This explanation holds true for the present study, although the value in our study suggested good reliability.

Finally, regarding RQ3, the mediation results reveal that teachers with higher education levels contributed to higher student engagement because they facilitated a higher level of connectedness and use of technology. Fauth et al. (2020) argued that teaching quality (including classroom management, emotional support, and clarity of instruction) is theoretically assumed to connect teacher and student characteristics to student outcomes. However, this assumption was only supported for the important role of connectedness in the relations between teacher education level and student engagement in the context of SCLEs. A previous study proved that teachers with more positive beliefs promoted student performance because they showed a higher level of teaching quality (but not including the use of technology) (Fauth et al., 2019). Yet, we did not find such relations as this study found low correlations between teacher beliefs and all factors of classroom process quality. Additionally, we found that the use of technology in smart classrooms was a significant variable because it explained the relations between teacher education level and student engagement. This finding is unique and valuable because previous studies have largely ignored the role of technology as a mediator, making it impossible to determine which aspects of classroom process quality play a more significant role in terms of instructional and technological factors. However, one could argue that it is not the use of technology in itself but how technology is used that matters. Moreover, the mediation results have significant theoretical implications that the potential of teacher education level or relevant variables representing teachers' specialist knowledge need to be considered when examining the mediating role of teaching quality in other contexts.

7. Limitations and future directions

The first limitation is that though the sample of this study met the basic requirement for multilevel analysis, it could be that our findings only emerged due to the special characteristics of the classes that volunteered to participate. 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 they are not the only means to understand student engagement (Henrie, Halverson, &

Graham, 2015). In particular, classroom management was examined in the present study based on student perceptions. Because classroom management was found to be highly related to cognitive activation, the influences from classroom management on student engagement could not be examined in the present study. However, a recent study (Larson, Pas, Bottiani, Kush, & Bradshaw, 2021), has shown that teachers' use of positive behavioral management practices were positively related to secondary school students' engagement in class. In future research, additional data on classroom management could be obtained either through interviews with teachers or observations in smart classrooms. In this way, further insights could be obtained into teachers' reasoning and behavior in the classroom and into how technologies are used, thereby gaining 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.

Third, although a few demographic variables of the sample were investigated in this study, consideration of other student and teacher characteristics could 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. Especially, additional research into learning differences among subgroups such as ethnic minorities, migrant communities, and other community groups (see e.g., Rizvi, Rienties, Rogaten, & Kizilcec, 2022) is needed. 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.

Fourth, students' self-reported data give a limited view of their engagement with learning (Kirschner & van Merriënboer, 2013) and perceptions of teacher or peers as well as class observations could provide additional insights. Future research should use other measures, such as objectively measured abilities or skills that could better predict how students learn most effectively.

Fifth, while our results are not meant to be generalizable but to reflect the key factors associated with a typical smart classroom, our findings shed light on the importance of a typical smart classroom learning environment in supporting learners in developing an engaging learning experience based on the research model. However, since SCLEs consist of a combination of various elements, and the specific technologies and strategies may vary, depending on the implementation phase and context, we cannot be completely sure if the findings from this study are specific for SCLEs. Further research could be focused on exploring which specific variables in the model are applicable to other settings as well, for example, cutting-edge technologies in the Revolutionary Interactive Smart Classroom (cf. Memos et al., 2020).

8. Conclusions

Despite the popularity of technology-enhanced learning environments in education, understanding how they can promote student engagement is still evolving. 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. We 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 (i.e., gender, education level, teaching grade) had significant influence on at least one aspect of classroom process quality. Second, in addition to the critical role of student and teacher characteristics (i.e., student gender, teacher education level, teaching year), students' perceptions of connectedness and the use of technology at both the individual and classroom levels positively influenced their engagement while only individual perceptions of cognitive activation explained differences in student engagement. Third, the higher the teachers' education level, the more engaged students were, but this was only true for teachers using more technology and exhibiting higher levels of connectedness.

Several theoretical implications can be drawn from the findings. First, our findings extend the instructional teaching framework (Klieme et al., 2009) by showing differential relations between instructional quality factors (i.e., cognitive activation, classroom management, and supportive classroom climate) and student engagement. Moreover, this was the first study to investigate relationships between classroom process quality (integrating both instructional quality factors and technological factors) and student engagement at both the student and classroom level within the setting of SCLEs in secondary education. Our findings provide clear evidence that connectedness was among the instructional and technological factors that influenced student engagement most at both student and classroom levels.

This research offers several practical implications for establishing conditions that foster an engaging smart classroom learning environment. The role of teachers and their teaching is highlighted in this study, which implies that significant investments and support are necessary in future teacher practices in smart classrooms. First, for policymakers to effectively promote the development of SCLEs, it is necessary to emphasize the important role of teachers' specialist knowledge and to provide practical guidance regarding how to best develop an engaging smart classroom learning environment in the policy plans before investing substantial financial, technical and human resources. Second, as we found several teacher background variables were important for classroom process quality, these specific characteristics (i.e., education level, gender, teaching year, teaching grade) offer valuable starting points for school leaders to select the right group of teachers to participate in the smart classrooms in the early phase of implementation. Third, teacher education programs often focus on a single subject, but courses specifically aimed at integrating technology into specific subjects could be more helpful for developing teachers' specialist knowledge that they could then apply in practice. In addition, more experienced teachers could be provided with opportunities to apply their knowledge, skills, and ideas in their own teaching practice and to receive feedback from expert teachers during training programs. Finally, teachers need to know that learning environments that include high levels of cognitive activation, connectedness and use of technology support student engagement best. The influence of connectedness and the use of technology at the classroom level found in this study, suggest that establishing supportive relationships and equipping technologies for the whole class are important factors for teachers to consider in smart classrooms. To improve student engagement, teachers should use technology to provide integrated learning experiences, and create incentives for students, such as real-time feedback systems, reward systems, or game-based systems, to engage them in active and adaptive learning.

Credit author statement

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Declarations of interest

None.

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Appendices

Items marked with an asterisk indicate items included in the multilevel analysis.

Appendix A. Teacher questionnaire: Teacher beliefs and their constituent items

*SN1: In the smart classroom, students can get the chance to talk to each other.
*SN2: In the smart classroom, students can ask each other to explain their ideas.
SN3: In the smart classroom, students can ask each other to explain their ideas.
*SN4: In the smart classroom, students can discuss with each other how to conduct investigations.
*SN5: In the smart classroom, students can discuss their ideas with each other.
*IL1: In the smart classroom, students can find answers to questions by investigation.
*IL2: In the smart classroom, students can carry out investigations to test their own ideas.
*IL3: In the smart classroom, students can conduct follow-up investigations to answer their new questions.
*IL4: In the smart classroom, students can design their own ways of investigating problems.
*IL5: In the smart classroom, students can approach the problem from more than one perspective.
*RT1: In the smart classroom, students can think deeply about how they learn.
*RT2: In the smart classroom, students can think deeply about their own ideas.
*RT3: In the smart classroom, students can think deeply about new ideas.
*RT4: In the smart classroom, students can think deeply about how to become better learners.
*RT5: In the smart classroom, students can think deeply about their own understanding.
*FD1: In the smart classroom, students can have enough workspaces to use digital devices and learning resources.
*FD2: In the smart classroom, students are in a comfortable atmosphere.
*FD3: In the smart classroom, students can have flexible furniture arrangements for multiple learning purposes.
*FD4: In the smart classroom, students can have visual displays that support teacher and student interactions.
*FD5: In the smart classroom, students can have enough space for multiple small group discussions.
*CN1: In the smart classroom, the students and I care about each other.
*CN2: In the smart classroom, I feel connected to the students in the class.
*CN3: In the smart classroom, I feel a spirit of community.
*CN4: In the smart classroom, I feel that this class is like a family.
*CN5: In the smart classroom, I feel a sense of trust toward others.
*EU1: The smart classroom can provide strong and reliable wireless connectivity.
*EU2: The smart classroom can provide user-friendly learning devices and software.
*EU3: The smart classroom can provide learning devices and software that take only a short time to learn how to use.
*EU4: The smart classroom can provide learning devices and software which are fun to use.
*EU5: The smart classroom can provide technology which is easy to navigate.
*PU1: The smart classroom can benefit my teaching experience.

(*continued on next page*)

(*continued*)

*SN1: In the smart classroom, students can get the chance to talk to each other.
*PU2: The smart classroom can present information in meaningful ways.
*PU3: The smart classroom can improve students' abilities to communicate with others.
*PU4: The smart classroom enables opportunities for engagement and interaction.
*PU5: The smart classroom enables technology that is useful in a wide range of ways.
*MS1: The smart classroom enables discussion on a learning topic from teacher and student perspectives.
*MS2: The smart classroom enables presentation of a learning topic by personal research, group discussion, and lecture.
*MS3: The smart classroom enables exploration of various information sources during learning.
*MS4: The smart classroom allows content from me and my students to be shared through digital devices.
*MS5: The smart classroom can provide a combination of face-to-face and digital instruction.

Appendix B. Student questionnaire: Instructional quality and their constituent items

SN1: In the smart classroom, students got the chance to talk to each other.
SN2: In the smart classroom, students asked each other to explain their ideas.
*SN3: In the smart classroom, students discussed with each other how to conduct investigations.
SN4: In the smart classroom, students discussed their ideas with each other.
IL1: In the smart classroom, students found answers to questions by investigation.
*IL2: In the smart classroom, students carried out investigations to test their own ideas.
*IL3: In the smart classroom, students conducted follow-up investigations to answer their new questions.
IL4: In the smart classroom, students designed their own ways of investigating problems.
IL5: In the smart classroom, students approached the problem from more than one perspective.
RT1: In the smart classroom, students thought deeply about how they learn.
RT2: In the smart classroom, students thought deeply about their own ideas.
*RT3: In the smart classroom, students thought deeply about new ideas.
RT4: In the smart classroom, students thought deeply about how to become better learners.
RT5: In the smart classroom, students thought deeply about their own understanding.
*CN1: In the smart classroom, the students and teacher cared about each other.
CN2: In the smart classroom, I felt connected to the teacher and students in the class.
*CN3: In the smart classroom, I felt a spirit of community.
*CN4: In the smart classroom, I felt that this class is like a family.
CN5: In the smart classroom, I felt a sense of trust toward others.
CM1: In the smart classroom, none of the students disturbed the lesson.
CM2: In the smart classroom, students were quiet when the teacher spoke.
CM3: In the smart classroom, everybody listened and students were quiet.
CM4: In the smart classroom, nobody interrupted other people talking.
CM5: In the smart classroom, everybody followed the teacher.

Appendix C. Student questionnaire: The use of technology and their constituent items

Instruction: Please indicate how often the following digital devices and digital resources were used when you studied in the smart classroom for this lesson.

DD1: Digital devices for the teacher and whole class (e.g., projection screen, interactive whiteboard, and touch screen television).
*DD2: Mobile devices for the teacher and individual student (e.g., laptop, tablet, and smart phone).
DR1: Multimedia courseware
*DR2: Multimedia material (text, pictures, animation, video, audio, etc.)
*DR3: Question bank/test papers
*DR4: Subject software and tools (geometry, virtual lab, etc.)
DR5: Thematic page/website
DR6: E-textbook/periodicals
*DR7: Course management software

Appendix D. Student questionnaire: Student engagement and their constituent items

*BE1: In the smart classroom, I listened carefully in class.
*BE2: In the smart classroom, I paid attention in class.
*BE3: In the smart classroom, the first time my teacher talked about a new topic, I listened very carefully.
*BE4: In the smart classroom, I asked questions.
CE1: In the smart classroom, when doing the assignment, I tried to relate what I was learning to what I already know.
CE2: In the smart classroom, while studying, I tried to connect what I was learning with my own experiences.
CE3: In the smart classroom, I tried to make all the different ideas fit together and make sense.
*EE1: I felt curious about what we were learning.
EE2: I felt interested in what we were learning.
EE3: I enjoyed the class.

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