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ABSTRACT

During school closures forced by the COVID-19 pandemic, remote/online learning has been adopted to help students continue to learn. Student engagement, which is energized by motivation as explained by self-determination theory (SDT), is a prerequisite for learning. Therefore, this study investigated how the three perceived psychological needs in SDT affected student engagement in online learning using pre- and post-questionnaires completed by 1201 Grade 8 and 9 students within 6 weeks of partaking in online learning. The results suggested that digital support strategies better satisfied students' needs, that all of the needs were predictors of the level of engagement, and that relatedness support was very important.

Over one billion students—more than 98% of the world's student population—have been affected by school closures as a result of the COVID-19 pandemic (UNESCO, 2020). Consequently, school education has changed dramatically, with a significant rise in the use of technology for remote teaching and learning, which is referred to as "online learning and teaching" in this paper. The urgent transition to online learning and teaching has posed challenges to both school students and teachers. Many adolescents and young people experience high levels of stress and anxiety arising from online learning, resulting in various mental health issues. Not all adolescents have the capacity to benefit from these unfamiliar learning environments, while others are simply struggling to keep up with their education and to stay motivated and engaged (UNESCO, 2020). Indeed, adolescence is an especially precarious stage for motivation (Eccles et al., 1997).Without direct and immediate teacher help in online learning, students lack the ability to construct meaning through assuming agency in learning, to initiate and sustain meaningful multimodal communications, and to develop conceptual understanding through active engagement with digital resources (Hartnett, 2016). Moreover, most teachers, who have never had online teaching experience or received relevant training, are unlikely to deliver effective online learning (Chiu, 2017; Chiu & Churchill, 2016a; Ingvarson et al., 2005). They may not appropriately support student learning needs due to lack of familiarity with their students' home learning environments. Furthermore, the unique combination of the public health crisis, social isolation, and economic recession causes anxiety and stress, which worsen students' existing mental health problems (Singh et al., 2020). In this context, the critical roles of student self-regulation, motivation, and

positive learning disposition are accentuated (Chen & Jang, 2010; Chiu & Hew, 2018). These contemporary issues and challenges all originate from the pivotal question: How do we motivate students to engage in online learning? Although a number of studies have examined this issue in the field of educational technology, research into how to appropriately adapt pertinent motivational theories to design effective and sustainable online pedagogy and learning in complex, multifaceted, and even situational online learning environments is still relatively under-investigated, particularly in the K-12 context (Bedenlier et al., 2020; Chen & Jang, 2010; Chiu & Hew, 2018).

Self-determination theory (SDT), proposed by Deci and Ryan (1985), is a macro-level theory of human motivation that aims to explain the dynamics of human need, motivation, and well-being within a social context. The theory suggests that all individuals possess three universal and psychological needs—autonomy (feeling self-governed and self-endorsed), competence (feeling competent and effective), and relatedness (feeling connected, loved, interacted)—that move them to act or not to act. Individuals experience greater psychological well-being through the satisfaction of these three psychological needs, and conversely feel highly fragmented, isolated, and reactive when their needs are not met. When pedagogical design adequately addresses these psychological needs, students are actively motivated to engage in learning tasks (Hsu et al., 2019). Classrooms that support these three psychological needs are more likely to engage students in learning (Reeve, 2013). Accordingly, this theory can explain the effects of needs-based support on student motivation, engagement, and learning.

Student motivation and engagement are influenced by various contextual factors, such as teacher and peer support (Lietaert et al., 2015). Teacher support is one of the most important factors, as teachers play a crucial role in fostering student motivation in schools (Allen et al., 2013; Roorda et al., 2011; Wang & Eccles, 2012). The three teacher support dimensions distinguished in SDT for classroom practice are autonomy support, structure, and involvement (Lietaert et al., 2015; Roorda et al., 2011). Aiming to satisfy students' psychological needs through these dimensions, i.e. to promote positive learning, could be an effective teaching strategy given the challenges of the current pandemic.

Although SDT has been widely applied to optimize student learning in the face-to-face context (Ryan & Deci, 2017, 2020), it has been largely overlooked in online learning research in K-12 settings (Chen & Jang, 2010; Hsu et al., 2019). Ryan and Deci (2020) suggested that future SDT research should look more closely at how technologies in e-learning and remote classrooms motivate student engagement and learning. Online learning has been studied in higher education (Hsu et al., 2019); however, the impact of teacher support on school students is very different from that on university students. As a result, we understand very little about how K-12 school students engage in online learning from an SDT perspective. This study investigated the relationships between need satisfaction and student engagement in the K-12 online learning context through the lens of SDT during the pandemic. It contributes to SDT by presenting evidence on how teachers use technology to satisfy school students' need for better engagement, and to teaching practice by suggesting more strategies to engage young children in online learning.

The remainder of the paper is organized as follows. It first presents the theoretical framework of this study and discusses previous studies on the three needs in online learning. It then describes the purpose and methodology of the study. Next, it presents the results of our analyses, followed by a discussion of the results and our conclusions.

Literature review

Student engagement dimensions and SDT

Student engagement refers to students' active involvement in educationally effective practices and their commitment to educational goals and learning, and is an essential pathway to highly valued
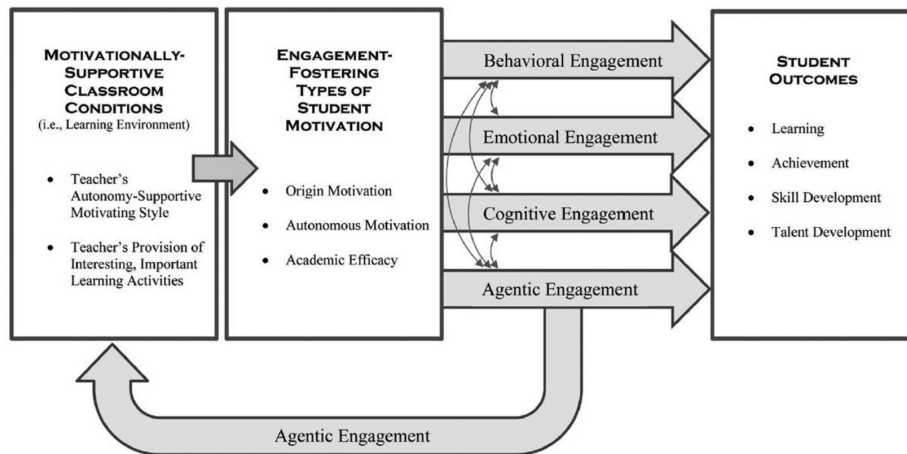
Figure 1. Four interrelated dimensions of student engagement, adapted from Reeve (2013).

educational outcomes such as academic achievement (Christenson et al., 2012). It is a multidimensional construct comprising four dimensions: behavioral, cognitive, emotional, and agentic. Behavioral engagement refers to how involved students are in learning activities in terms of attention, participation, effort, intensity, or persistence. Cognitive engagement refers to how much mental effort students spend in completing learning tasks in terms of using sophisticated rather than superficial learning strategies. Emotional engagement refers to the feelings students have toward teachers, peers, learning activities, and school experience, as well as their sense of belonging (Sinatra et al., 2015). Agentic engagement is defined as the act of taking initiatives that constructively contribute to learning and teaching (Reeve, 2013; Reeve & Tseng, 2011). These dimensions correspond to the learning processes of acting, thinking, feeling, and communicating, respectively (Reeve, 2013; Wang & Eccles, 2013).

Reeve (2013) further explained how the four dimensions of student engagement are interrelated (Figure 1). Despite being interrelated, these dimensions are operationalized and conceptualized as distinct (Christenson et al., 2012; Reeve, 2013; Sinatra et al., 2015) (Figure 1). Acts of agentic engagement are qualitatively distinct from the other three dimensions in that they are proactive, planned, and collaborative ways for teachers to engage in learning activities. If agentic engagement contributes to a more supportive learning environment (e.g., greater autonomy support, more valued activities), the learning environment will be beneficial to student motivation, which is conducive to energized, direct, and sustained student engagement.

Student engagement has been mostly seen as an outcome of motivational processes; fostering different types of motivation is an energy source that activates students to be engaged in learning activities (Reeve, 2013). Therefore, it lies within the domain of SDT (Losier et al., 2001; Ryan & Deci, 2017, 2020). SDT defines intrinsic and extrinsic sources of motivation, and its propositions focus on how social and cultural factors facilitate or impair individual well-being and quality of performance (Deci & Ryan, 1985; Ryan & Deci, 2017, 2020). This theory advocates four major subtypes of extrinsic motivation: external regulation and introjected regulation (which are outside of personal control and non-autonomous), and identified regulation and integrated regulation (which are autonomous). It suggests that students' motivational orientation to progress from amotivation to extrinsic motivation to intrinsic motivation is enabled by supporting the three universal needs introduced above: autonomy, competence, and relatedness. Autonomy is the need to feel in control of our own behaviors and goals; competence is the need to feel competent, effective, and challenged; and relatedness is the need to experience interaction, feel connected,

and care for others (Ryan & Deci, 2017, 2020). This theory also emphasizes the role of the social context in supporting or thwarting optimal motivation. In summary, more autonomous forms of motivation will lead to improved student engagement and learning.

Teacher practices and student engagement in online learning

Teacher practices play an important role in fostering student motivation in online/distance learning, and teachers can accomplish this by encouraging student autonomy, by ensuring learning, and by being involved interpersonally (Hartnett, 2015; Vonderwell et al., 2007; Xie et al., 2006; Xie & Ke, 2011). In line with SDT, teaching practices are grouped into the dimensions of autonomy support (autonomy), structure (competence), and involvement (relatedness) (Lietaert et al., 2015; Sierens et al., 2009; Vansteenkiste et al., 2009; Vollet et al., 2017).

Autonomy support involves encouraging and facilitating students to pursue their personal goals, and supporting student endorsement of learning behaviors (Assor et al., 2002). In online learning, autonomy-supportive teachers will consider student perspectives, allow for choices around learning, give a rationale when choice is constrained, avoid the use of controlling language, and reduce unnecessary stress and demands on students (Alamri et al., 2020; Lee et al., 2015; Trenshaw et al., 2016; Xie et al., 2006). For example, teachers should give students access to varied learning resources in several languages and navigation support to choose different learning materials (Bedenlier et al., 2020; Hartnett, 2015), and should provide personalized learning opportunities by respecting and accepting students' individual interests and allowing flexibility to customize learning activities (Alamri et al., 2020; Lee et al., 2015). Then, students can make their own choices and decisions with regard to their personal goals and self-efficacy, and use their own voices to seek help, and in return feel empowered in learning (Alamri et al., 2020; Lee et al., 2015; Trenshaw et al., 2016). Moreover, autonomy-supportive teaching fosters student engagement (Lee et al., 2015). Students with autonomy-supportive teachers have better concentration and time management (behavioral engagement, Vansteenkiste et al., 2005), enjoy their lessons more (emotional engagement) (Skinner et al., 2008), and communicate with their teachers on learning (agentic engagement) (Reeve, 2013). Autonomy gives students more latitude to choose their learning goals, which might result in more cognitive engagement; however, this has not been examined systematically (Bedenlier et al., 2020).

Structure involves communicating clear expectations with respect to student behavior (Sierens et al., 2009). In online learning, structuring teachers will design well-structured discussion forums (Vonderwell et al., 2007) and multiple user-friendly functions (Xie et al., 2006), organize peer moderation to allow students to share information with peers (Xie & Ke, 2011), provide strong guidance during online lessons, demarcate the boundaries of learning activities (Chiu & Mok, 2017), give competence-relevant feedback, express confidence in student abilities (Hartnett, 2015), and distribute effective learning materials to achieve desired outcomes (Chiu et al., 2020; Chiu & Lim, 2020; Chiu & Mok, 2017; Ng & Chiu, 2017). Structure has an established relationship with student engagement. A suitable learning structure helps students to feel competent, effective, and challenged in learning; hence, it is considered a critical motivating factor for student cognitive engagement (Skinner et al., 2008). When this need is met, students will develop a sense of mastery of the topic being studied and feel encouraged to actively participate in course activities, as well as feel positively about the course. This will lead to better behavioral and emotional engagement (Reeve, 2013). Some studies have investigated the relationship between structure and agentic engagement (Reeve, 2013), but not extensively.

Involvement pertains to the types of behavior shown by teachers, including warmth, affection, and enjoyment, which have been shown to encourage a close and caring teacher–student relationship (Skinner et al., 2008). In online learning, involved teachers will provide students with emotional and motivational support such as pedagogical caring, involvement closeness, acceptance,
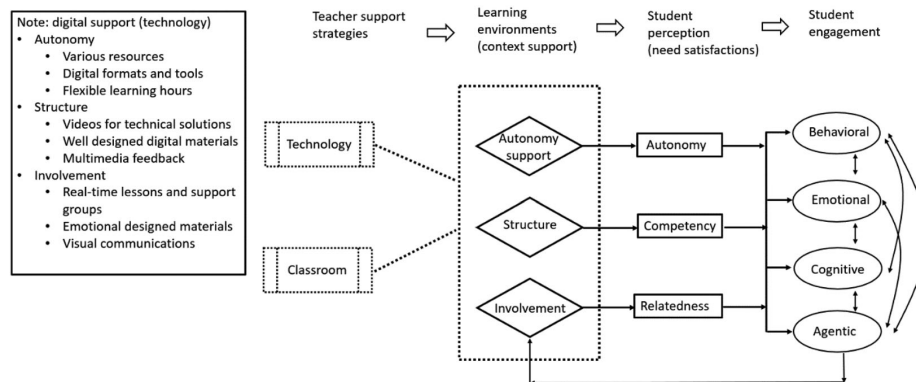
Figure 2. The proposed model of student engagement in online learning.

and help (Vonderwell et al., 2007), and foster the development of trust relationships among students in collaborative learning environments (Xie & Ke, 2011) and in small discussion groups (Alamri et al., 2020). Then, students will feel more welcome, safe, efficacious, and autonomous, and will internalize their experience and evince greater engagement (Reeve, 2013; Ryan & Deci, 2017, 2020). Relatedness can predict student behavioral, emotional, and agentic engagement, because good teacher–student relationships can encourage students to participate in course activities (behavioral engagement), foster students' positive feelings toward the course and its activities (emotional engagement), give students confidence to complete challenging tasks (cognitive engagement), and encourage students to speak up regarding their learning needs (agentic engagement) (Furrer & Skinner, 2003; Reeve, 2013; Ruzek et al., 2016; Vollet et al., 2017).

The present study

The proposed model of student engagement in online learning

The pandemic has encouraged both scholars and practitioners to rethink future education, particularly the role of technology in education; therefore, students' and teachers' motivation to use technology as a tool for learning is an active research area (Ryan & Deci, 2020). This study took the four dimensions of student engagement from Reeve's model (2013) and the three needs in SDT to propose a model of student engagement in online learning (Figure 2). The model invoked "digital support," as a distinct entity from classroom support, to satisfy the needs of autonomy, competence, and relatedness, which results in students being behaviorally, cognitively, and agentically engaged in online learning. The model took the affordances of educational technology to add digital aspects to each of the teacher support dimensions, as shown in the following suggested teaching strategies for digital support.

Autonomy support

Teachers will (i) offer and recommend various digital resources (i.e. links, videos, and slides) and will indicate their relevance to students (Bedenlier et al., 2020; Trenshaw et al., 2016); (ii) allow students to use any digital formats such as slides, videos, blogs, and tools to complete their tasks (Trenshaw et al., 2016); and (iii) allow students to study anytime and anywhere.

Structure

Teachers will (i) provide students with clear instructions and requirements for digital submissions (e.g. size and formats) and videos for technical problems (Bedenlier et al., 2020); (ii) teach with well-designed learning materials in the heavily cognitive load-demanding online environment, for example, applying multimedia learning principles to the design of digital materials and designing for small screens (Chiu & Churchill, 2015; Chiu & Mok, 2017); and (iii) give competence-relevant multimedia feedback to student discussions in asynchronous forums.

Involvement

Teachers will (i) host interactive real-time lessons and small teacher–student support groups of no more than five people, through instant message systems; (ii) teach with emotionally designed materials (Chiu et al., 2020); and (iii) use visual aids, such as images and emoji, for communication to avoid misunderstanding and to promote a positive atmosphere.

Research goals and questions

Collectively, the process by which teachers can support student psychological needs to foster student engagement in online learning in K-12 education is seriously understudied. Adolescents partaking in online learning are more likely than adults to experience stress from this form of education, and often struggle to stay engaged and to keep up with their academic trajectories. The applications of SDT to student engagement in this context are poorly established.

As we have discussed, perceived need satisfaction can foster the four dimensions of student engagement, clearly implying the mediating role of motivation in explaining the relationships between perceived need satisfaction and student engagement. Therefore, this study had two objectives: (i) to investigate the roles of the effect of autonomy, competence, and relatedness on student engagement in online learning through digital support within the framework of SDT; and (ii) to use these findings to suggest teaching strategies in online learning. More specifically, this study used Hong Kong middle schools as the context to understand these three needs in predicting behavioral, cognitive, emotional, and agentic engagement. Accordingly, the two research questions were as follows:

> RQ1: Does the proposed digital support increase perceived autonomy, competency, and relatedness in online learning?

> RQ2: To what extent do perceived autonomy, competency, and relatedness predict student engagement in online learning?

The proposed research model to achieve these goals is shown in Figure 3. As discussed in the literature review, all three perceived needs contribute to each of the four student engagement dimensions, as formulated by the following five research hypotheses.

- perceived autonomy, competence, and relatedness in the post-questionnaire are significantly improved (RQ1).
- perceived autonomy, competence, and relatedness are significantly related to behavioral engagement (RQ2).
- perceived autonomy, competence, and relatedness are significantly related to cognitive engagement (RQ2).
- perceived autonomy, competence, and relatedness are significantly related to emotional engagement (RQ2).
- perceived autonomy, competence, and relatedness are significantly related to agentic engagement (RQ2).
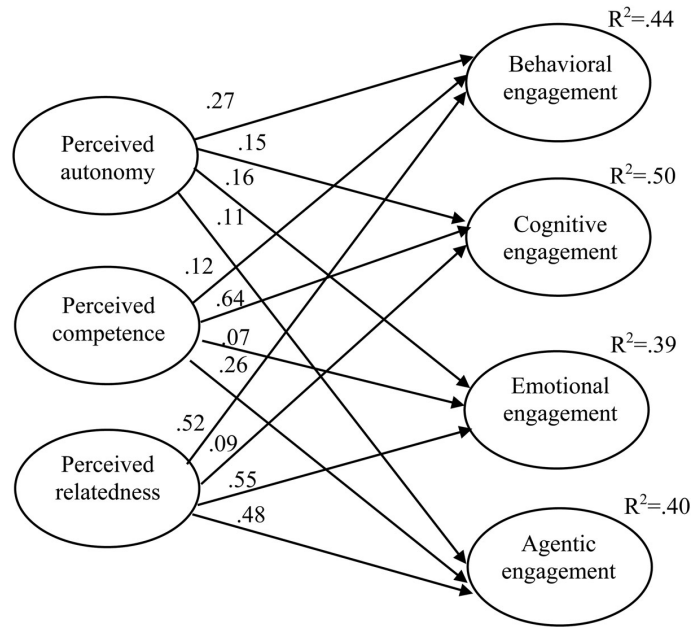
Figure 3. Structure method.
Note: all p values <0.001.

Hong Kong pandemic situation

During the pandemic, Hong Kong did not enforce a city lockdown, but schools closed from January 26, 2020 and resumed classes in stages from May 27, 2020. To help students continue to learn during school closures, all mainstream middle schools began to provide both asynchronous and synchronous learning opportunities from the beginning of February 2020; nonprofit organizations and schools facilitated access to online learning for students who did not have equipment by offering them Internet data plans and computers. Therefore, Hong Kong society made considerable efforts to support students' online learning.

Method

Participants

Stratified sampling was conducted, based on the broad categorization of students' academic ability, to randomly select two schools from each band from the pool of 48 partnership schools. (Middle schools in Hong Kong are categorized into three bands based on student academic achievement, i.e. students in Band 1 schools are considered to be the top 33%, and those in Band 3 are considered to be the bottom 33% of all Hong Kong students. Students are assigned to the bands based on the annual national assessment of student intake.) Approximately 200 Grade 8 and 9 students, all of Hong Kong Chinese descent, were selected randomly from each selected school. This resulted in six schools and 1201 student participants. The participants were between 13 and 16 years old, with an average age of 14.1 years. None had difficulties in accessing the digital resources or joining real-time lessons, and 52% were female.

Research design and procedure

The research team consisted of an SDT international scholar, two experienced teachers, and three research assistants. Previous studies on supporting student needs have used surveys to explore how students feel about teaching (Ahn et al., 2019). To achieve this study's goals, pre- and post-test self-reported questionnaires were used to collect the students' views on perceived support for technological needs and on their engagement in online learning.

We first obtained ethical approval from the author's institution, and received the consent of the participants and their parents. The team conducted a pilot study of five lessons with 120 Grade 8 and 9 students to confirm that the digital support used in the main study could significantly enhance students' need satisfaction. The students in the pilot study did not participate in the main study.

The main study was conducted during school closures from February to May. We first administered a pretest self-reported questionnaire online to the students in late February when most schools began to deliver real-time lessons. Then, in the first week of March, we ran five 3-hour online training workshops during one week for all of the Grade 8 and 9 mathematics teachers from the six schools involved. In the workshops, the roles of digital support (see the subsection "The proposed model of student engagement in online learning") were emphasized, explained, and demonstrated. In the first four sessions, the team first presented an introduction to SDT and digital support, shared how to teach the two topics, and discussed with the teachers how digital support satisfies students' psychological needs. In the last workshop, the teachers presented their own methods of teaching with digital support. All of the presentations were shared among the teachers. The main purpose of the workshops was to increase the consistency of delivery of digital support across the schools. After the workshops, the teachers used digital support to teach the students online for 6 weeks during the pandemic. Finally, all of the participants completed the post-questionnaire online in mid-May.

Instruments

Apart from demographic data, the pre- and post-questionnaires included seven variables in two categories: need satisfaction and student engagement. Each of the variables was scored using 5-point Likert scale items that were adapted from previous studies; reliability and validity were strong, as specified below. The items were also checked by two experienced teachers to make sure that the wording and language were understandable. Details of the instruments are described below.

Need satisfaction

To assess the degree to which the students experienced satisfaction of the three needs, this study used two previously validated questionnaires. To measure the students' sense of autonomy, this study adapted five items from previous work conducted in the context of British children by Standage et al. (2005), with acceptable internal reliability (Cronbach's $\alpha = .80$). The items were slightly modified to fit this study goal. Examples of items include "I have some choice in what I want to learn," "I have a say regarding what skills I want to learn," and "I can decide which activities and tools I want to learn."

Perceived competence toward online learning was measured using five items from the study on perceived competence by Standage et al. (2005), which showed acceptable reliability ($\alpha = .87$) in similarly aged groups. Two example items are "When I have participated in online learning, I feel pretty competent" and "I am pretty skilled at learning online."

Participant-perceived relatedness to teachers was measured using the acceptance subscale of the items ($\alpha = .87$) from Standage et al. (2005). Originally developed to assess the need for relatedness in physical education, the question was modified in this study as follows: "With the other students in my online learning, I feel XXX," followed by five options including "close," "valued," and "supported."

Student engagement dimensions

Behavioral engagement in online learning was measured using five items from the study of Skinner et al. (2009) with acceptable reliability ($\alpha = .72$). Their participants were school students who were at the same education level as the students in this study. Their items were modified to fit our research goal, for example, "When I'm in online learning, I listen and read very carefully," "I try hard to do well in online learning activities," and "When I'm in online learning, I participate in synchronous and asynchronous discussions."

Emotional engagement was assessed using five items with acceptable reliability ($\alpha =. 82$) from the study of behavioral engagement by Skinner et al. (2009). Three example items are "When we work on something in online learning, I feel interested," "This online learning is fun," and "I enjoy learning new things in online learning."

Cognitive engagement was measured using five items adapted from the study by Wang et al. (2016). They validated and verified items to measure middle and high school students' cognitive engagement in science and mathematics, which exhibited high internal consistency ($\alpha \geq .75$). These items suited our participants and subject domains: for example, "I go through the work for online learning and make sure that it's right" and "I think about different ways to solve a problem."

To measure the students' agentic engagement, this study adapted five items from the work of Reeve (2013), who defined the concept of agentic engagement, for example, "I let my teacher know what I need and want in online learning," "During online learning, I express my preferences and opinions," and "When I need something in online learning, I'll ask the teacher for it."

Results

Research analytics approach

RQ1 examined whether digital support can enhance the three perceived needs; therefore, one-sample paired t-tests were used to compare the means of perceived autonomy, competence, and relatedness in the pre- and post-questionnaires.

RQ2 investigated how these three needs relate to student engagement. Hence, confirmatory factor analyses first evaluated the quality of the measurement model and the correlations between the latent variables. Then, structural equation modeling (Figure 3) was used to assess the contributions of the three perceived needs to the four dimensions of student engagement in the post-questionnaire.

Descriptive statistics and scale reliability

Descriptive statistics and α values (Cronbach, 1951) for all latent variables are presented in Table 1. All of the variables were internally reliable, as all of the α values were greater than .90 (where good > .80; Warner, 2013), and had sufficiently normal distributions (i.e., skewness less than 2.3, Lei & Lomax, 2005; kurtosis less than 7.0, Byrne, 2010). Moreover, the average intraclass correlation coefficients indicated high degrees of reliability of the pre- and post-questionnaires, with values of .97 for perceived autonomy, .97 for perceived competence, and .96 for perceived

Table 1. Descriptive statistics.

Variables	Pre-questionnaire				Post-questionnaire			
	Mean	SD	Skewness	Kurtosis	Mean	SD	Skewness	Kurtosis
Perceived autonomy	3.11	.75	.06	−.89	3.98	.78	.09	−1.07
Perceived competence	2.69	.86	.20	−.45	3.41	.86	.01	−.09
Perceived relatedness	2.96	.75	.09	−.21	3.74	.69	.18	−.07
Behavioral engagement	–	–	–	–	3.83	.82	.27	−.25
Cognitive engagement	–	–	–	–	3.58	.90	.13	−.39
Emotional engagement	–	–	–	–	3.73	.67	.43	.37
Agentic engagement	–	–	–	–	3.85	.75	.63	.60

Table 2. Correlation among latent variables.

Independent variables	1	2	3	4	5	6	7
1. Perceived autonomy	–						
2. Perceived competence	.12**	–					
3. Perceived relatedness	.16**	.26**	–				
4. Behavioral engagement	.36**	.28**	.59**	–			
5. Cognitive engagement	.24**	.66**	.28**	.22**	–		
6. Emotional engagement	.30**	.43**	.60**	.52**	.54**	–	
7. Agentic engagement	.21**	.38**	.55**	.54**	.35**	.57**	–

$**p < 0.01$.

relatedness (where good > .75, excellent > .90, Koo & Li, 2016). These results indicated that there was no clustering effect in the data. Accordingly, all of the assumptions were met for conducting paired t-tests for RQ1.

With respect to the goodness-of-fit of the measurement model, the fitness indices of the measured items indicated a good model fit: $\chi^2/df = 4.43$ (<5.0); RMSEA = .05 (<.08); SRMR = .02 (<.05); GFI = .92 (>.90); TLI = .98 (>.90); CFI = .98 (>.90). One item was dropped from each of the variables, except perceived competence, due to weak factor loadings. The positive correlations between all of the variables were significant, with $p < .01$ (Table 2). The results suggested that all of the assumptions were met for conducting structural equation modeling for RQ2.

Paired t-tests

The paired t-tests showed a significant increase in student perceived autonomy, competence, and relatedness after digital support, with $t(1200) = 132.27$ ($p < .001$), $t(1200) = 86.00$ ($p < .001$), and $t(1200) = 100.17$ ($p < .001$), respectively. These results showed that digital support increased students' sense of autonomy, competence, and relatedness.

Structural equation model

In the structural equation model, regression paths were specified from the three exogenous latent variables (psychological needs, i.e., perceived autonomy, competence, and relatedness) directly to the four endogenous latent variables (student engagement, i.e., behavioral, cognitive, emotional, agentic). The model had a good fit to the data: $\chi^2/df = 4.89$ (<5.0); RMSEA = .05 (<.08); SRMR = .04 (<.05); GFI = .91 (>.90); TLI = .97 (>.90); CFI = .98 (>.90).

The quality of the model was estimated using path coefficients and R-squared values (R^2). The path coefficients and R^2 indicate the strength of the relationships and the amount of variance of the dependent variables explained by the independent variables, respectively.

As shown in Figure 3, all hypothesized paths in the research model were significantly supported, with $p < .001$ (except for one of the p values with a value of .003). The three exogenous variables explained 44% of the variance in behavioral engagement (endogenous variable). Perceived relatedness had the largest effect ($\beta = .52$), followed by perceived autonomy ($\beta = .27$) and perceived competence ($\beta = .12$). Moreover, perceived competence, autonomy, and relatedness explained 50% of the variance in cognitive engagement with $\beta = .64$, $\beta = .15$, and $\beta = .09$, respectively. Furthermore, perceived relatedness had a stronger relationship with emotional engagement than did perceived autonomy and competence, with $\beta = .55$ for relatedness, $\beta = .16$ for autonomy, and $\beta = .07$ for competence. These three variables explained 39% of the variance in emotional engagement. In addition, they explained 40% of the variance in agentic engagement. Perceived relatedness had the largest effect ($\beta = .48$), followed by perceived competence ($\beta = .26$) and perceived autonomy ($\beta = .11$).

Overall, perceived autonomy, relatedness, and competency are significant predictors of the four student engagement dimensions. Perceived relatedness is the most important predictor of behavioral, emotional, and agentic engagement, and perceived competency is the most important predictor of cognitive engagement.

Discussions and conclusions

Considering that adolescence is a precarious stage for motivation (Eccles et al., 1997), this study provides a much-needed examination of the relationships between perceived need satisfaction and student engagement in online learning in the K-12 context during the COVID-19 pandemic. The findings provide three major empirical implications, make two theoretical contributions, and yield three practical suggestions for both researchers and practitioners.

Empirical implications

First, as predicted, the digital support strategies in the proposed model based on the teacher classroom support dimensions—autonomy, structure, and involvement (Lietaert et al., 2015; Roorda et al., 2011)—can better satisfy the needs for autonomy, competence, and relatedness in online learning. This implies that students' basic needs for learning in classrooms are the same in distance learning despite the lack of physical human interactions. In online learning, when teachers successfully satisfy these three needs, students feel a stronger sense of autonomy to choose their preferred technologies to learn with, a stronger sense of competence to access online learning (login, materials, platforms), and a stronger sense of relatedness to connect with teachers for communication. During a school closure, online learning is the only option for Grade 8 and 9 students, but they may face a range of technical problems; hence, it is very important for them to feel that they are capable of using the technology even if they cannot access instant help. During the pandemic, young children also have fewer opportunities to connect with other children and their teachers than they would in school. This may imply that satisfying perceived relatedness becomes more important during the school closure. This study tested three strategies for digital support: (i) autonomy, by providing various resources for learning, allowing choices in digital format and sharing tools, and agreeing flexible hours for learning; (ii) structure, by teaching with well-designed digital materials (i.e. demanding less cognitive load), using multimedia for student feedback, and making helpful information available for solving technical problems; and (iii) involvement, by adopting small support groups and real-time lessons, and applying an emotionally aware approach in teaching and communications. The finding from the t-tests suggested that the proposed strategies may satisfy students' basic needs in the SDT framework (RQ1); however, further and more in-depth studies are needed to confirm this result, because the one-group

pretest–post-test design may threaten internal validity (Shadish et al., 2002), such as confounding factors related to the perception of need satisfaction.

The second empirical implication is that satisfying the three needs is likely to foster the four student engagement dimensions in online learning, which implies that the three digital support strategies could motivate students to engage behaviorally, emotionally, cognitively, and agentically in learning with technology. These results are consistent with related studies conducted in face-to-face settings (Lietaert et al., 2015; Sierens et al., 2009; Vansteenkiste et al., 2009; Vollet et al., 2017).

The final empirical implication is that in online learning, perceived relatedness is the primary predictor of behavioral, emotional, and agentic engagement; perceived competence is the most important predictor of cognitive engagement; and perceived autonomy is a significant factor for all, but not the most influential factor for any, of the dimensions in student engagement. These results diverge from the majority of studies on SDT needs that have given primacy to autonomy support and have emphasized its importance for promoting intrinsic motivations for learning (La Guardia, 2009; Ruzek et al., 2016; Trenshaw et al., 2016). Three plausible reasons are discussed here. First, this finding is influenced by contextual factors including societal and/or public health crises and unfamiliar remote learning. Children have reported lower levels of affect due to not being able to play outdoors, meet friends, or engage in in-person school activities (Singh et al., 2020). They are anxious regarding the cancelation of examinations and competitions. Some of them are worried about their families' financial situations due to the global economic downturn (Singh et al., 2020). Therefore, relatedness support should be the focus during a time of challenges such as social distancing, school closures, and city lockdowns, and during unfamiliar learning situations that school students have never before faced. Second, young students engage differently in different learning environments, i.e., online learning and classrooms. Compared with online learning, young students in classrooms have less control of how they spend their time and what they study. Their education is their responsibility and that of their teachers and their parents. For example, teachers check whether students complete their homework and remind them if not. Therefore, teacher–student relationships (involvement and relatedness) play a very important role in learning (Ryan & Deci, 2017, 2020; Vansteenkiste et al., 2009). Other than learning subject knowledge, one of the main benefits of in-person schooling for students is the chance to connect with schools, teachers, and students. Compared with the classroom setting, online learning is less supervised (more autonomy support) and lacks physical human interactions (less relatedness support) (Chen & Jang, 2010; Lam et al., 2018). Therefore, most K-12 students may have fewer autonomy needs and more relatedness needs from online learning. Finally, our results may reflect cultural differences between Eastern and Western or individualistic and collectivistic cultures (Iyengar & Lepper, 1999; Ryan & Deci, 2020). The functional importance of autonomy is universal, as is well supported by many empirical studies. However, students from different cultures internalize their cultural practices differently. How students perceive contexts and how their basic needs are fulfilled vary between cultures (Ryan & Deci, 2020). This cross-cultural difference in the need for autonomy may explain some of the implications of this study. Moreover, the instruments used in data collection in this study were validated among British children; therefore, they may not accurately measure Asian students' perceived autonomy needs.

Theoretical contributions

The first two empirical implications of this study contribute to SDT by adding an educational technology dimension and presenting more evidence on how digital support in online learning relates to student engagement. Most SDT studies in this aspect have investigated and examined how the needs are satisfied in face-to-face teaching contexts, such as physical education and classroom management (Lietaert et al., 2015; Roorda et al., 2011). These studies have advocated that

teaching strategies such as teacher autonomy support, structure, and involvement (Lietaert et al., 2015; Roorda et al., 2011; Standage et al., 2005) can enable students' motivational orientation to progress from amotivation to extrinsic motivation to intrinsic motivation. This motivates students to engage in learning. Accordingly, the digital support strategies described in this study function in the same way as classroom support in motivating and engaging students in online learning.

The second theoretical contribution, driven by the third empirical implication, sheds light on how much the impact of the three needs on student engagement dimensions varies in different contexts, by investigating the relationships between need satisfaction and student engagement in online learning. The findings showed that the relationships have different strengths and vary between contexts. As previously discussed in the third empirical implication, autonomy seems to be one of the most influential factors in classrooms, but its effects were diminished in the context of online learning and K-12 education. This study posits that the nature of the learning environment and student educational level may determine the three need satisfaction levels for student engagement because students' psychological needs vary between education sectors and learning environments.

Practical suggestions

Other than the proposed digital support strategies, this study offers teachers two practical suggestions to satisfy the three needs for better engagement in technology-enhanced learning, and one practical suggestion to rapidly engage students during school closures in times of societal and/or public health crisis (e.g. COVID-19). The first suggestion for teachers is to design and produce teaching-efficient videos. The most effective videos have four key features. First, they use a multiple representation approach that better covers the complete domain and elicits a wider range of learning processes to provide various learning resources (see Autonomy (i) in the proposed model; Jaakkola & Veermans, 2020). Second, they apply Mayer's multimedia learning principles to provide guidance on how to create effective multimedia to develop teaching materials (see Competence (ii), Chiu & Churchill, 2015; Chiu & Churchill, 2016b). Third, they are designed for mobile technologies and small screens that require less bandwidth so that students, particularly the economically disadvantaged, can easily view and use learning materials via their phones (see Competence (ii); Chiu & Churchill, 2015). Last, they use an emotionally literate design approach to develop joyful and fun learning materials (see Relatedness (ii); Chiu et al., 2020).

The second suggestion for teachers is to improve their digital communication skills for technology-enhanced teaching (see Relatedness (iii)). Enhancing one's skill in evincing a positive attitude and enthusiasm online to foster relatedness can help positive teacher–student relationships and better emotionally engage students in learning. For example, emoji can be used in replies to messages in forums, and feedback can be given as warm and friendly audio messages.

The last suggestion is for schools and teachers to establish and activate an emergency transition to an online learning protocol in times of societal and/or public health crisis. Our findings indicated that relatedness is the most important among the three needs in student engagement (see the final empirical implications). Schools and teachers should ensure that the primary concern of online learning is supporting relatedness. Accordingly, this study suggests that schools should (i) redesign timetables to provide students with an online space to socially interact with their teachers and peers to build a stronger sense of belonging; (ii) arrange mental health activities to let students express their emotions, for example regarding life during school closure; and (iii) formulate online teaching strategies or curriculum guidelines, such as establishing online peer support groups, adopting "learning more and evaluating less" assessment approaches, and including more interdisciplinary learning activities.

Limitations and future directions

Five limitations of this study are noted here. First, although the results appear to suggest that the three digital support strategies can engage students in online learning with various levels of significance, the study was conducted during the pandemic. The unique combination of a public health crisis and social isolation may have affected students' perceptions (as the study relied on self-reported data) and the findings might not apply to online or distance learning in normal times. Therefore, additional studies using objective measures, such as the number of students' responses in the discussions, or using different contexts, such as flipped learning and collaborative learning (Chiu & Hew, 2018), are needed to validate the findings. Second, the study adopted a quantitative method over a short period and might not reveal the full effect of the digital support strategies on learning. Therefore, future studies with a mixed methods research design capable of deeper insights and/or a longitudinal research design that tracks learning activities should be undertaken to expand the findings and better inform future online pedagogical development. Third, we did not discuss how different types of motivation relate to the four engagement dimensions nor discuss the SDT framework comprehensively. Future studies should investigate the roles of different types of motivation in student engagement. Fourth, a single-group design was adopted to answer the first research question, which was unable to conclusively reflect the impact of digital support strategies. Future studies should use more rigorous experimental designs such as including a control group to confirm the effectiveness of digital support strategies. Finally, cultural differences may affect perceived autonomy (Iyengar & Lepper, 1999). Future studies are recommended to examine how cultural differences affect perceived needs and engagement and to validate perceived-need instruments for Asian students.

Overall, this study supports the application of SDT in online learning, and explains how the three needs affect student engagement during the pandemic. Therefore, satisfying students' needs is always important in online learning, but the relationships of these needs with student engagement have different strengths and vary between contexts.

Disclosure statement

- Readers who would like to access the data presented in this paper but who have no participant identification can send a request to the Faculty of Education, The Chinese University of Hong Kong, Hong Kong.
- There is no conflict of interest between the author and the participants.

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