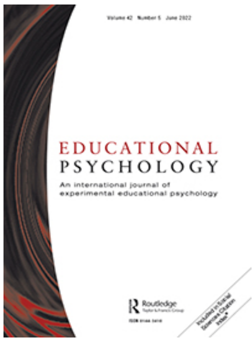

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Investigating the relationship of technology learning support to digital literacy from the perspective of self-determination theory

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ABSTRACT

Digital literacy, a prerequisite for online learning, is fostered by active engagement with technology, a concept that is explained by self-determination theory (SDT). This two-study project took the unique opportunity afforded by COVID-19 to explore the effect of technology learning support for SDT-needs satisfaction on digital literacy and the possible mediating effects of needs satisfaction on the relationship between perceived support and digital literacy. In Study 1, 63 Grade 10 students undertaking online learning were randomly assigned to groups that were either given or not given the support. Study 2 further explained the effect of the support by needs satisfaction, and involved 309 Grade 10 students to complete a questionnaire. The analyses showed that the positive effect of the support on digital literacy, and needs satisfaction partially mediated the relationship between perceived support and digital literacy, suggesting that autonomy and competence are more important than relatedness in developing digital literacy.

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Self-determination theory; needs satisfaction: learning support; digital literacy; learning technology; COVID-19 pandemic

The COVID-19 pandemic has overset all aspects of schooling. It not only has moved learning from classrooms to screens but also has altered the roles played by technology in learning and teaching (Chiu et al., 2021; Chiu & Churchill, 2016). These changes have afforded new opportunities to explore how to develop educational technology to achieve more effective learning. The use of technology to support learning in schools has increased significantly, resulting in technology-infused learning environments (e.g. remote, online or mobile learning). For most students, learning in technology-infused environments is more challenging than learning in classrooms (Chiu et al., 2021). Digital literacy that can be defined as literacies

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associated with the use of digital technologies, is a prerequisite for engaging in online learning behaviours such as interacting with teachers, peers and learning management systems (LMSs; Bergdahl et al., 2020; Chiu, 2021c; Eshet, 2004; Ng, 2012; Prior et al., 2016). Students with good digital literacy are more likely to initiate discussions with teachers, communicate with classmates effectively and post new messages on discussion forums. Digital literacy is developmental and builds on one's knowledge, skills and experience (Ng, 2012). To develop digital literacy, teachers should create learning opportunities for students to operate digital tools, analyse resources and reflect on their experiences (Prior et al., 2016). Digital literacy can be developed when students actively engage with digital resources, use multimodal communications and collaborate online (Blau et al., 2020; Chan et al., 2017; Ng, 2012; Prior et al., 2016; Reynolds, 2016). Accordingly, literature suggests digital literacy are seen as competence, skills, ability, and attitude that can be measured objectively and subjectively, i.e. digital literacy and digital competence belief (Ng, 2012; Prior et al., 2016). Such contexts highlight the importance of students' self-regulation and motivation, which can be explained by Self-determination Theory (SDT; Chiu, 2021a, 2022; Hartnett, 2016).

SDT is a motivational theory about how individuals' inherent growth tendencies that they naturally develop towards higher levels of psychosocial maturity as they grow older. The theory suggests the satisfactions of three innate psychological needs – autonomy, competence and relatedness – would affect their growth (Ryan & Deci, 2020). The thwarting of any of these three needs within a social context may have a detrimental impact on a person's engagement with a task and performance (Ryan & Deci, 2020). SDT has been used to design online learning activities and to support students' need for greater engagement (Hsu et al., 2019; Xie et al., 2006). Recently, Ryan and Deci (2020), who first developed SDT, stated that one of the great challenges of contemporary education is to foster students' engagement in technological learning tasks. They suggested that future SDT research should investigate how to design remote classrooms using technology that can motivate engagement and learning.

Past SDT-related research on learning technology has focussed on higher education rather than K–12 settings (Chiu, 2021a, 2022; Hsu et al., 2019). However, K–12 students differ from university students in motivation and engagement, and hence the findings of past studies might not apply to younger children. Moreover, to our knowledge, there has been no SDT-based research on digital literacy development. COVID-19 has presented an opportunity to fill the gap in this research area because of the mass use of technology-infused learning environments by school students, as digital tools and resources were used to facilitate children's remote learning through periods of school closure (Chiu, 2022; Chiu et al., 2021; Ismailov & Ono, 2021). Accordingly, in this study, a technology learning support intervention was designed using SDT principles, with the aims of examining the effect of the intervention on the development of digital literacy and investigating the mediating role of student needs satisfaction in the relationship between perceived technology learning support and digital literacy.

Theoretical framework

This study uses a digital literacy framework (Ng, 2012) and SDT (Ryan & Deci, 2020) to explain the findings both in the past literature and in this study.

Three dimensions of digital literacy

Digital literacy refers to the multiplicity of literacies associated with the use of digital technologies (Eshet, 2004; Hague & Payton, 2010, p. 2; Martin & Grudziecki, 2006; Ng, 2012). These technologies include hardware and software, such as mobile phones, game consoles, web technologies and resources, communication and collaborative tools, and information and multimedia resources. Digital literacy is defined as the awareness, attitude and ability of individuals to appropriately use technologies to identify, access, manage, analyse, evaluate, and synthesise digital resources, and to create, make and share meaning, and collaborate and communicate effectively with others in different modes and formats (Hague & Payton, 2010; Martin & Grudziecki, 2006). Digital literacy comprises five dimensions: photo-visual literacy (the ability to learn by reading from visuals), reproduction literacy (the ability to edit or combine different multimedia resources), branching literacy (the ability to use hypermedia), information literacy (the ability to effectively search, locate and assess web resources) and socio-emotional literacy (the ability to be highly critical and analytical in the context of online socialisation and collaboration; Eshet, 2004).

Ng (2012) further used the specific concept developed by Eshet (2004) pertaining to multiliteracies to posit that digital literacy has three intersecting dimensions: technical, cognitive and social-emotional. The technical dimension is associated with the technical and operational skills needed to use technology for learning and in everyday activities, i.e. photo-visual literacy, reproduction literacy branching literacy in Eshet (2004). This dimension is demonstrated when individuals adequately operate technologies to solve their own problems, such as connecting peripheral devices to computers or troubleshooting a problem by reading an online manual or watching a video. The cognitive dimension concerns the ability to think critically when searching, evaluating and creating digital information, i.e. information literacy in Eshet (2004). A digitally literate individual understands the legal, ethical and moral issues related to digital resources (e.g. copyrights, fraud and plagiarism). This dimension of literacy is demonstrated through, for example, assessing opinions from written materials, videos and images; adapting to new and emerging technologies quickly; and effectively navigating and identifying appropriate information in hypermedia environments to complete assignments. The social-emotional dimension is related to the ability to communicate and socialise online, i.e. socio-emotional literacy in Eshet (2004). A digitally literate individual can effectively and respectfully communicate over social networks using different multimedia resources. This dimension of literacy is demonstrated through, for example, using appropriate language and images to avoid misinterpretation and misunderstanding, protecting others' privacy and safety and easily picking up new semiotic language for communication. Becoming digitally literate therefore requires the development of a set of key skills that are technical, cognitive and social-emotional (Ng, 2012).

Digital literacy is developmental; it progressively builds on foundational and achieved skills and knowledge (Ng, 2012; Prior et al., 2016). To develop digital literacy, students should be given opportunities to practice them in ways that demonstrate the value of the choices they make (Ismailov & Ono, 2021). The development of digital literacy can be fostered by motivating student engagement with digital resources, multimodal communications and online collaborations (Blau et al., 2020; Chan et al., 2017; Hartnett, 2016; Prior et al., 2016; Reynolds, 2016). Engagement can be an outcome of motivational processes (Reeve, 2013); fostering different types of motivation can help students become engaged in technology-based learning, which can enhance their digital literacy. Therefore, SDT can explain the engagement of students in learning digital literacy (Ryan & Deci, 2017, 2020).

Students' innate needs satisfaction and technology

Deci and Ryan enumerated various intrinsic and extrinsic sources of motivation, differentiated between autonomous and controlled motivation and proposed three innate needs that are involved in self-determination (Ryan & Deci, 2020). These three needs are autonomy, competence and relatedness, and they motivate people to initiate behaviour and expend effort towards their own growth and well-being. Autonomy refers to the experience of behaviour as self-endorsed and voluntary; competence refers to the experience of behaviour as effectively achieved and challenged; and relatedness refers to the experience of feeling connected with others. The satisfaction of these innate needs can foster a high-quality form of motivation (i.e. autonomous motivation rather than controlled motivation) and engagement in activities. An individual with autonomous motivation may feel self-motivated and self-directed, whereas an individual whose motivation is controlled may feel forced, stressed and incapable (Ryan & Deci, 2017, 2020). From the perspective of SDT, student engagement can be understood to be an outcome of motivational processes; thus, autonomous motivation can be understood to be a factor that allows students to engage constructively in online learning activities (Chiu, 2021a, 2022).

Needs satisfaction support has been widely applied in various educational and workplace settings. Past studies on this topic have focussed on the needs support offered by teachers, coaches, facilitators and employers to learners or employees. In schools, needs support offered by teachers plays a crucial role in motivating students within technological learning environments. Taking an SDT approach, needs support can be categorised into three types: autonomy support (which supports students' autonomy), support for the learning structure (which aids competence), and teacher involvement (which increases relatedness; Chiu, 2021a, 2022; Lietaert et al., 2015; Vansteenkiste et al., 2009).

Autonomy support is the instructional effort that teachers provide during instruction. This type of support is offered first to identify, then to endorse and encourage and, eventually, to develop and strengthen students' autonomous motivation (Reeve, 2016). Within technological environments, teachers who are autonomy-supportive take the students' perspectives, allow them to make choices about their learning, provide explanatory rationales when a choice is forced and use non-pressuring language

(Trenshaw et al., 2016; Xie et al., 2006). Examples of autonomy support are when teachers provide students with various digital learning resources in several languages and formats, give descriptions that help them to navigate the environment better, explain the relevance of tasks to students (Bedenlier et al., 2020; Chiu, 2021a, 2022; Trenshaw et al., 2016), allow students to study anytime and anywhere and customise learning activities to help students have a more personalised learning experience (Alamri et al., 2020; Chiu, 2021a, 2022). These actions help students feel empowered in their learning because they are encouraged to make their own choices and decisions, express their thoughts and seek out paths towards their personal goals, which are suited to their learning capacity. Moreover, within technological environments, autonomy-supportive teaching fosters the three types of student engagement: behavioural, cognitive and emotional engagement (Chiu, 2021a, 2022). Behavioural engagement is fostered when better concentration and time management are encouraged (Vansteenkiste et al., 2009); cognitive engagement is fostered when students become more able to accomplish tasks (Chiu, 2021a, 2022); and emotional engagement is fostered when learning is more enjoyable (Skinner et al., 2008).

Learning structure is related to how well teachers' expectations are communicated to students (Sierens et al., 2009). In technological environments, teachers who provide learning structure may organise peer moderation to allow students to share information with each other, provide guidance to set the boundaries of learning activities (Xie & Ke, 2011), give competence-specific comments and use cognitive-effective resources to help students achieve the desired learning outcomes (Chiu & Lim, 2020; Chiu & Mok, 2017). Teachers who provide structure make students feel effective, capable and challenged. They help students become cognitively engaged in learning by helping them develop a strong sense of mastery (Skinner et al., 2008). When this need for competence is satisfied, students are encouraged to actively participate in technology-based activities (behavioural engagement) and feel positive about the activities (emotional engagement; Chiu, 2021a, 2022).

Finally, teacher involvement is related to teachers' behaviours that affect their relationship with their students. These behaviours may include teachers' actions, words and responses to students. Positive, caring and effective teachers develop a warm classroom climate, resulting in learning and teaching that is more fun and interactive (Skinner et al., 2008). Within technological environments, teachers who are involved help students to develop close relationships with each other, which facilitates collaborative activities (Xie & Ke, 2011) and small group discussions (Alamri et al., 2020). Rather than using direct language that may be impersonal, these teachers use more emotionally evocative communications, such as visual resources and emojis, that promote a positive learning atmosphere (Chiu et al., 2020). They conduct their lessons in real-time and encourage interaction and conversation, in contrast to merely giving lectures (Chiu, 2022). Such actions help students feel more accepted, welcome, safe, comfortable and expressive; this helps them internalise their innate motivational resources and evinces greater engagement (Reeve, 2016). Involved teachers who develop and maintain good teacher-student and student-student relationships help students to become more engaged in technology-based collaborative learning. They help students become more behaviourally engaged by encouraging increased attention and

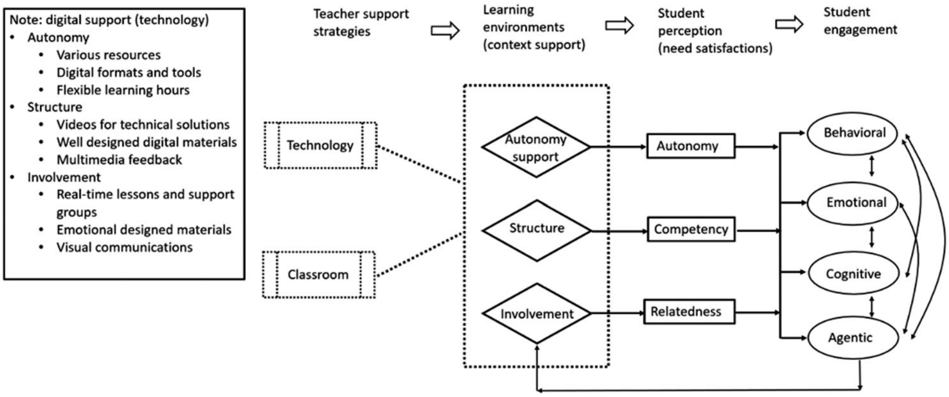

Figure 1. The proposed model of student engagement in online learning, adopted from Chiu (2022).

participation; more emotionally engaged by evoking positive feelings; and more cognitively engaged by giving more feedback and instilling a greater sense of confidence (Chiu, 2022; Reynolds, 2016). In sum, satisfying innate needs could foster students' engagement with technology, resulting in increased competence in digital literacy (Blau et al., 2020; Prior et al., 2016; Reynolds, 2016).

Previous SDT-based studies on learning and technology have provided teachers or instructors with suggested strategies for supporting students' innate needs to motivate greater engagement. These studies have emphasised that the teacher's presence is an important element of needs satisfaction support (Alamri et al., 2020; Trenshaw et al., 2016; Xie & Ke, 2011). They have suggested ways that teachers can use technology to support student engagement and examined how perceived teacher support relates to both intrinsic and extrinsic motivation and to engagement (Alamri et al., 2020; Bedenlier et al., 2020; Chiu, 2022; Trenshaw et al., 2016; 2016; Xie & Ke, 2011). For example, Chiu (2022) proposed a model of student engagement for online learning (see Figure 1). The model indicated that teachers could use two distinct types of support – digital (technology) and classroom – to motivate students' behavioural, cognitive, emotional and agentic engagement by satisfying the three innate needs in SDT; the forms of digital support proposed were derived from the three dimensions of teacher support. In these studies, perceived teacher support was the core component being studied; thus, the use of technology was designed to be personally executed or introduced by the teachers. However, in the types of technology-infused learning environments used by students during school closures, the perceived learning support that students receive from the technological environments themselves may be crucial for student engagement. Accordingly, perceived learning support may predict students' development of digital literacy.

Learning in COVID-19 and the research gap

Over one billion students have been affected by the closure of schools in response to COVID-19. School teachers have adapted their teaching practices, moving away from face-to-face teaching towards more technology-infused learning (e.g. online education). Unlike tertiary students, school learning received no online education before the pandemic. Most school students are young children who may not have the sophisticated digital literacy needed to maximise unfamiliar technology-infused learning environments; therefore, they may struggle to stay motivated and engaged (Chiu, 2021b). Moreover, this pandemic has been both a public health crisis and a widespread experience of social isolation, leading to anxiety and stress. The aggregation of stress and anxiety may have demotivated students with regard to their learning, because negative emotions impede learning (Pekrun et al., 2017). Past SDT-based studies have highlighted the importance of teacher support as perceived by students; however, the needs support that students perceive from technology-infused environments (i.e. perceived technology learning support) may be just as important as that which students perceive from teachers. Therefore, perceived technology learning support is a research area that needs attention. The pandemic provides unique research opportunities for us to learn more about how technology supports the needs of young children in developing digital literacy. However, to our knowledge, no SDT-based study has examined the relationship between perceived learning support and digital literacy. Recently, Ryan and Deci (2020) called on SDT researchers to extend their focus to learning and technology, thus further supporting the importance of research on this topic. They recommended that future SDT research examine how technology can be designed to motivate engagement and learning via educational media, online learning and remote classrooms.

The pandemic in Hong Kong

During the pandemic, Hong Kong did not enforce a citywide lockdown, but schools closed from 26 January 2020 and resumed classes in stages from 27 May 2020. Therefore, school teaching was conducted remotely, and Hong Kong society made considerable efforts to make the experience successful for students. Two of the most common tools that schools used were video conferences and LMSs. Schools and non-profit organisations offered underprivileged students digital and internet data plans to facilitate their access to remote learning.

This project

Instead of explaining how the public health crisis affected student motivation during COVID-19, this study took a different perspective – rethink education in the wake of COVID-19 – to innovate our school pedagogy for fostering digital literacy in online learning. As we discussed, digital literacy includes awareness, attitude and ability dimension. Therefore, this project focussed on attitude and awareness perspectives, and attempted to explore the relationship between perceived technology learning support and the self-reported development of digital literacy.

Research design strategy

This project adopted a two-study design approach to examine the effect of technology learning support on the development of digital literacy, and to investigate the mediating role that the satisfaction of students' needs may play in the relationship between perceived technology learning support and digital literacy. This design approach is supported by studies with similar goals (e.g. Chiu, 2021b; Du et al., 2020).

Study 1 examined the effects of our proposed SDT-based technology learning support on the three dimensions of digital literacy. This study does not explain how the needs satisfaction relates to the three dimensions remains unclear. Hence, Study 2 investigated how needs satisfaction mediate the effects by examining the relationships between perceived technology learning support and digital literacy in combination with the satisfaction of each of the three needs.

As the proposed technology learning support was adapted from the digital support suggested by Chiu (2021a), the support would satisfy participants' needs. Therefore, this study proposed the following hypotheses.

H1: The proposed technology learning support will be beneficial to the three dimensions of digital literacy: the technical, cognitive and social-emotional dimensions (Study 1).

H2: Perceived technology learning support will contribute positively to the satisfaction of each of the three needs (Study 2).

H3: The satisfaction of each of the three needs will contribute positively to each of the three dimensions of digital literacy (Study 2).

H4: Needs satisfaction will mediate the relationship between perceived technology learning support and the three dimensions of digital literacy (Study 2).

Study 1

Method

Participants and design. The participants in Study 1 were 63 Grade 10 students recruited from two classes at the same school. The mean age was 15.5 years, and the proportion of girls was 48%. Study 1 was conducted during the period when schools were physically closed, and the students' learning took place in an LMS course-room (a learning space for a group of a student). For this SDT-based intervention, an experimental research design with pre- and post-questionnaires was used. Thirty-two students were included in the experimental group and were offered technology learning support, whereas 31 were in the control group and were not offered support. The learning support given to the students in the experimental group was adapted from the digital support suggested by Chiu (2021a). The learning support in the course-room was designed to satisfy the three needs according to SDT: autonomy, competence and relatedness. The following strategies were used to address each need.

- To address the need for autonomy, the students were provided with various digital resources (e.g. text, videos, pictures) that indicated how the learning unit was relevant to them. Moreover, students were allowed to complete learning tasks using any format (e.g. text, image, audio) (Bedenlier et al., 2020; Trenshaw et al., 2016).

- To address the need for competence, videos that aimed to help students address technical problems were uploaded to the course-room. A peer moderator was also assigned to the students. Finally, students were given clear directions and formatting instructions for digital work that they were required to submit (Bedenlier et al., 2020; Chiu, 2022).
- To address the need for relatedness, students were allowed to communicate with each other using emotive tools such as emojis, photos and stickers. A group learning space was created. The course-room was decorated to create a warm atmosphere by including pictures of the school and photographs of the participants (Chiu, 2022; Chiu et al., 2020).

In the control group, the control room was designed using a 'business-as-usual' approach. Resources for the learning unit were either text-based or video-based. Only text-based formats were allowed for learning tasks and communications. No instructions for submissions nor videos addressing technical problems were provided. No peer moderator was assigned, and no group learning space was created. The course-room was not redesigned, and its interface was the default design of the LMS.

Participant questionnaire. The participant questionnaire assessed two categories of digital literacy and perceived technology learning support using four constructs. The measures for each construct comprised two or three items scored on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). All of the items in the questionnaire were checked by two experienced teachers to ensure that the items were comprehensible.

The items related to the three dimensions of digital literacy were adopted from the study of Ng (2012), which originally had an acceptable level of reliability (Cronbach's $\alpha = .90$). The items also had been used by Prior et al. (2016). The items ask students to rate the technical dimension of their digital literacy ('I know how to solve my own technical problems,' 'I can learn new technologies easily' and 'I know about a lot of different technologies'), the cognitive dimension of their digital literacy ('I am confident with my search and evaluation skills in regard to obtaining information from the web' and 'I am familiar with issues related to web-based activities [e.g. cyber safety, search issues]') and the social-emotional dimension of their digital literacy ('I frequently obtain help with my learning from my classmates over the Internet [e.g. through Zoom, Facebook, blogs]' and 'Technology enables me to collaborate better with my classmates on project work and other learning activities').

The items related to technology learning support were questions about learning support modified from the study of Lee et al. (2020), which had good reliability (Cronbach's $\alpha = .86$). The items ask students to rate their perceived learning support from the course-room using the following items: 'The course-room provides me with more opportunities to learn new digital skills or knowledge,' 'The course-room helps me see digital topics in which I need more learning' and 'The course-room makes me feel comfortable to learn new digital skills or knowledge.'

Research procedure. The participants were randomly assigned to a treatment group. First, they were given 15 min to read and sign an informed consent form and

Table 1. Descriptive statistics for pre- and post-questionnaires in Study 1.

		Pre-questionnaire		Post-questionnaire	
Group	Variable	Mean	SD	Mean	SD
Control ($N = 32$)	Perceived technology learning support	2.76	.75	3.03	.87
	Technical dimension	3.04	.81	3.18	.85
	Cognitive dimension	2.67	.56	2.80	.76
	Social-emotional dimension	2.56	.55	2.83	.75
Experimental ($N = 31$)	Perceived technology learning support	2.56	.63	3.96	.56
	Technical dimension	2.95	.79	4.05	.67
	Cognitive dimension	2.60	.68	3.58	.71
	Social-emotional dimension	2.61	.48	3.81	.48

complete the pre-questionnaire. Second, they spent 15 school days learning in the course-room that corresponded to their treatment group in regular school hours. Third, the participants were given 15 min to complete the post-questionnaire. This study got the ethical approval from the corresponding author's institutional review board, and adhered to ethical principles for conducting research with human subjects.

Results

A preliminary step was taken to examine whether the experimental and the control groups were equivalent in terms of perceived technology learning support and digital literacy before the intervention. Table 1 shows the mean and standard deviations of the pre-questionnaire scores for the two groups. One-way ANOVAs indicated that the groups did not differ significantly (all p values $> .50$) in the mean scores of perceived support, $F(1, 62) = 1.19$ and $p = .28$; the technical dimension of digital literacy, $F(1, 62) = .22$ and $p = .64$; the cognitive dimension, $F(1, 62) = 0.23$ and $p = .63$; and the social-emotional dimension, $F(1, 62) = 1.50$ and $p = .70$. The results concluded that the procedure of randomly assigning students to the groups successfully produced groups that did not differ in terms of their pre-questionnaire scores.

The primary purpose of this study was to determine whether technology learning support assisted in the development of students' digital literacy. Analyses of covariance (ANCOVAs) were conducted after the assumptions of homogeneity of variance were met, i.e. all p values were $>.50$ in Levene's tests. As summarised in Table 2, the analyses showed that the experimental group scored significantly better than the control group in terms of perceived technology learning support, $F(1, 60) = 49.27$, $p < 0.001$, and $\eta^2 = .45$; the technical dimension of digital literacy, $F(1, 60) = 53.08$, $p < 0.001$, and $\eta^2 = .47$; the cognitive dimension, $F(1, 60) = 67.64$, $p < 0.001$, and $\eta^2 = .53$; and the social-emotional dimension, $F(1, 60) = 79.88$, $p < 0.001$, and $\eta^2 = .57$. This is the primary empirical contribution of this study (H1).

Study 2

As Study 1 confirmed that perceived technology learning support was able to satisfy the participants' needs; it remains unclear how the needs satisfaction relates to the three dimensions of digital literacy. Accordingly, Study 2 is designed to better understand how the needs satisfaction led to the dimensions.

Method

Participants and design. The participants were 309 Grade 10 students randomly selected from three schools in Hong Kong (approximately 100 students from each school). The mean age was 15.6 years, and the proportion of girls was 49%. During the period when schools were closed, the students learned in course-rooms on the LMS. A questionnaire was used to examine a research model (see Figure 2) that describes how perceived technology learning support relates to the three dimensions of digital literacy in combination with the satisfaction of each of the three needs. The participants were given 20 min to complete the questionnaire, which was administered at school.

Table 2. ANCOVA results of post-questionnaire for the two groups in Study 1.

Post-questionnaire (pre-questionnaire as covariate)					
Variable	Group	Adjusted Mean	SE	*F*	η^2
Perceived technology learning support	Control	2.97	.10	49.27***	.45
	Experimental	4.02	.11		
Technical dimension	Control	3.14	.09	53.08***	.47
	Experimental	4.09	.09		
Cognitive dimension	Control	2.76	.07	67.64***	.53
	Experimental	3.62	.07		
Social-emotional dimension	Control	2.85	.07	79.88***	.57
	Experimental	3.78	.07		

Note: $*p < .05$, $**p < .01$, $***p < .001$.

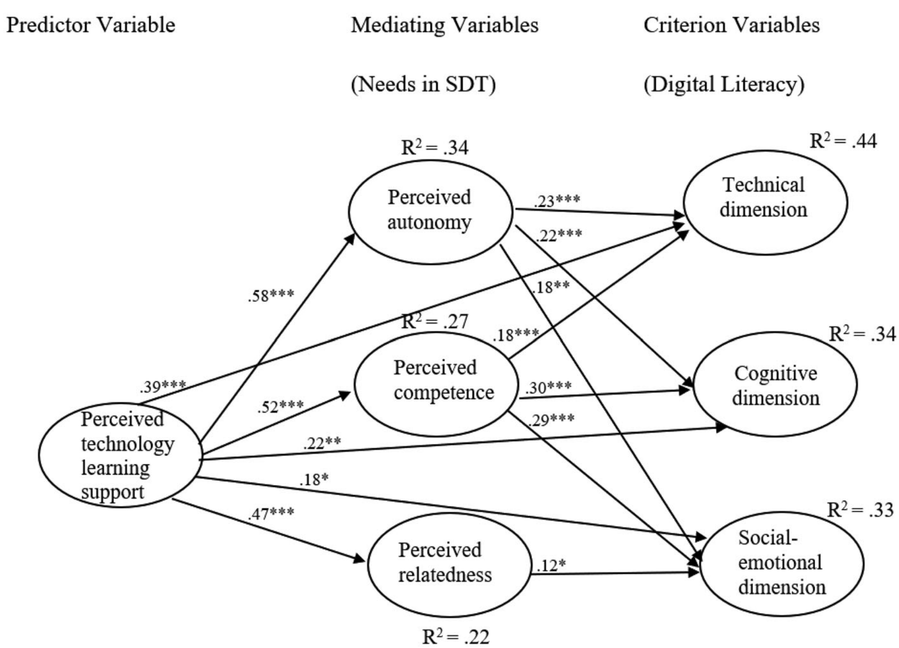

Figure 2. Research model.
Note: $*p < .05$, $**p < .01$, $***p < .001$.

Table 3. Descriptive statistics for the questionnaire in Study 2.

Variable	Mean	SD	Skewness	Kurtosis
Perceived technology learning support	3.66	1.02	.33	.76
Perceived autonomy	3.72	.95	.48	.27
Perceived competence	3.67	.91	.32	.34
Perceived relatedness	3.49	.86	.19	.51
Technical dimension	3.81	1.05	.62	.56
Cognitive dimension	3.73	.96	.30	.79
Social-emotional dimension	3.78	1.01	.55	.35

Table 4. Correlation among all the variables in Study 2.

Variables	1	2	3	4	5	6	7
1. Perceived technology learning support	–						
2. Perceived autonomy	.56**	–					
3. Perceived competence	.50**	.46**	–				
4. Perceived relatedness	.44**	.42**	.43**	–			
5. Technical dimension	.59**	.53**	.46**	.35**	–		
6. Cognitive dimension	.47**	.47**	.48**	.33**	.48**	–	
7. Cognitive dimension	.45**	.45**	.48**	.37**	.47**	.41**	–

Notes: $^{**}p < .01$.

Participant questionnaire. This study added questions related to the satisfaction of the three needs to the questionnaire used in Study 1. To assess students' needs satisfaction, this study used three subscales from the Basic Psychological Needs Scale–Revised (BPNS-R) with a Cronbach's $\alpha > .71$ for reliability (Chen et al., 2015). This study adapted three 3-item subscales, which included autonomy satisfaction ('I feel a sense of choice and freedom in the things I undertake,' and 'I feel I have been doing what really interests me' and 'I feel that my decisions reflect what I really want'), competence satisfaction ('I feel competent to achieve my goals,' 'I feel confident that I can do things well' and 'I feel capable at what I do') and relatedness satisfaction ('I feel that the course-room I care about is also a caring environment,' 'I experience a warm feeling in the course-room that I spend time in.' and 'I feel close and connected with the course-room, which is important to me'). The questionnaire began with the statement 'When learning in the LMS … ' to address the research context.

Results

Descriptive statistics for all of the variables are presented in Table 3. All of the variables were internally reliable, with Cronbach's α values >.90 (where good >.80; Warner, 2013) and strong factor loadings (>.80). With respect to the goodness-of-fit of the measurement model, the fitness indices of the measured items indicated a good model fit: $\chi^2/df = 1.17$ (<5.0); RMSEA = .02 (< .08); SRMR = 0.02 (<.05); GFI = .95 (>.90); TLI = .99 (>.90); CFI = .99 (>.90). The positive correlations between all of the variables were significant, with $p < .01$ (Table 4).

We used structural equation modelling to examine the predictive relationships between the variables of the study. The predictor variable was perceived technology learning support. The mediating variables were the three forms of innate needs satisfaction based on SDT: relatedness, competence and autonomy. The criterion variables were the three dimensions of digital literacy: technical, cognitive and social-emotional.

Table 5. Standardised direct, indirect and total effects among the variables of Study 2.

Predictor	Mediating/criterion variable	Direct effect	Indirect effect	Total effect
Perceived technology learning support	Perceived autonomy	.58 ($p < .001$)	–	.58
	Perceived competence	.52 ($p < .001$)	–	.52
	Perceived relatedness	.47 ($p < .001$)	–	.47
	Technical dimension	.39 ($p < .001$)	.23	.62
	Cognitive dimension	.22 ($p = .001$)	.28	.50
	Social-emotional dimension	.18 ($p = .014$)	.31	.49
Perceived autonomy	Technical dimension	.23 ($p < .001$)	–	.23
	Cognitive dimension	.22 ($p < .001$)	–	.22
	Social-emotional dimension	.18 ($p = .003$)	–	.18
Perceived competence	Technical dimension	.18 ($p < .001$)	–	.18
	Cognitive dimension	.30 ($p < .001$)	–	.30
	Social-emotional dimension	.29 ($p < .001$)	–	.29
Perceived relatedness	Technical dimension	–	–	–
	Cognitive dimension	–	–	–
	Social-emotional dimension	.12 ($p = .032$)	–	.12

The research model had a good fit to the data: $\chi^2/df = 1.65$ (< 5.0); RMSEA $= .04$ ($<.08$); SRMR $= .04$ ($<.05$); GFI $= .93$ ($>.90$); TLI $= .99$ ($>.90$); CFI $= .99$ ($>.90$). The path relations and coefficients among the variables are shown in Figure 1. The standardised direct, indirect and total effects among the variables are presented in Table 5.

The relationship between perceived technology learning support and needs satisfaction (H2). Students' perceived technology learning support positively and significantly predicted the satisfaction of each of the three needs: autonomy ($\beta = .58$, $p < .001$), competence ($\beta = .52$, $p < .001$) and relatedness ($\beta = .47$, $p < .001$).

The relationship between needs satisfaction and digital literacy (H3). The results indicated that autonomy significantly predicted the technical ($\beta = .23$, $p < .001$), cognitive ($\beta = .22$, $p < .001$) and social-emotional ($\beta = .18$, $p = .003$) dimensions of digital literacy; competence significantly predicted the technical ($\beta = .18$, $p < .001$), cognitive ($\beta = .30$, $p < .001$) and social-emotional ($\beta = .29$, $p < .001$) dimensions; and relatedness significantly predicted the social-emotional dimension ($\beta = .12$, $p = .032$), but not the technical ($p > .05$) and cognitive ($p > .05$) dimensions.

The mediating role of needs satisfaction (H4). The results indicated that there were direct relationships between perceived technology learning support and each of the dimensions of digital literacy. From the mediation analysis, the satisfaction of different needs mediated the relationships between perceived technology learning support and the three dimensions of digital literacy (see Figure 2). Perceived technology learning support indirectly predicted the technical dimension via autonomy and competence but not via relatedness. Accordingly, our results indicated that the three forms of needs satisfaction partially mediated the relationships between perceived technology learning support and the three dimensions of digital literacy.

We used a bootstrapping approach to further confirm these indirect effects, as this approach avoids the problem of different standard error formulae yielding inconsistent results (Hayes, 2009). It also produces a more precise confidence interval (CI) and is the most ideal approach to test mediating effects (Hayes, 2009; Taylor et al., 2008). Therefore, this analysis used 95% CIs for the effects of technology learning support on the three dimensions of digital literacy through bootstrapping using 1000 random samples. The coefficient of the indirect effect of technology learning support on the technical dimension was .23 (95% CI = [.15, .31], $p = .002$); on the cognitive dimension, it was .28 (95% CI = [.20, .38], $p = .001$); and on the social-emotional dimension, it was .31 (95% CI = [.21, .41], $p = .002$). The 95% CIs did not contain 0, hence, technology learning support was a significant indirect predictor of the three dimensions of digital literacy through needs satisfaction. The total effects of technology learning support on the technical, cognitive and social-emotional dimensions were .62, .50 and .49, respectively.

In sum, Study 1 demonstrated that the proposed technology learning support was beneficial to the development of digital literacy, whereas Study 2 indicated that perceived technology learning support was positively related to digital literacy; in addition, the effect of perceived technology learning support on digital literacy was direct and was also mediated by needs satisfaction.

Discussions and conclusions

This project examined the effect of technology learning support on the dimensions of digital literacy and investigated its predictive relationships with needs satisfaction and the three dimensions of digital literacy. This paper presents four empirical implications, two theoretical contributions and two practical suggestions for both researchers and practitioners.

Empirical implications

First, students who received the proposed technology learning support reported better digital literacy than those without (H1). The support drew from Chiu's (2021a, 2022) model of student engagement in online learning, which is derived from the three innate needs in SDT; this implies that active student engagement in technology-infused environments can foster their development of digital literacy. This implication is supported by findings indicating that the support successfully satisfied students' innate needs (H2), which can lead to better student engagement (Chiu, 2022; Ryan & Deci, 2020). The students felt safe and comfortable and had more chances to practice using the digital tools and resources, communicate with others online and reflect on their experience (Bergdahl et al., 2020; Ng, 2012). When technology-infused environments such as LMSs successfully satisfy these three needs, students feel a stronger sense of autonomy to choose their preferred technologies to identify, access, manage, analyse, evaluate and synthesise digital resources (a manifestation of the technical dimension of digital literacy); a stronger sense of competence to appropriately and ethically use technologies to create, make and share meaning (a manifestation of the cognitive dimension); and a stronger sense of relatedness to collaborate and communicate effectively with others in different modes and formats (a manifestation of the social-emotional dimension; Chiu, 2021a, 2021c; Eshet, 2004; Martin & Grudziecki, 2006; Hague & Payton, 2010). The findings suggest that the proposed technology learning support can effectively develop students' three dimensions of digital literacy.

The second empirical implication is the presence of direct relations between perceived technology learning support and digital literacy (H4). This finding reaffirms the importance of the design of technological learning environments in supporting students' digital literacy development (Bergdahl et al., 2020; Ng, 2012). The innate needs support that students receive from technology is the same as that received from teachers (Lietaert et al., 2015; Vansteenkiste et al., 2009). To successfully learn in technology-infused environments, digital literacy is a prerequisite for digital learning behaviours (Prior et al., 2016). When the environment motivates student engagement, students are more likely to pay attention to digital tools and resources and to respect and care for others in communications and collaborations, resulting in better digital literacy. Importantly, our findings corroborate those of previous studies that identified an empirical link between support for students' needs and learning with technology (Bedenlier et al., 2020; Trenshaw et al., 2016; Xie et al., 2006; Xie & Ke, 2011). These findings further establish an underexplored empirical link between perceived technology learning support and digital literacy. Given the reimagined roles of technology in learning and teaching, particularly in school education, our findings can contribute useful insights into how students may be better supported through the design of needs-supportive technological environments that can enable them to develop digital literacy effectively (Ng, 2012).

Third, needs satisfaction served as a predictor variable and played a mediating role in the relationships between perceived technology learning support and the three dimensions of digital literacy. Our findings indicate that perceived technology learning support indirectly predicted the technical and cognitive dimensions of digital literacy via satisfaction of the need for autonomy and competence, and predicted the social-emotional dimensions of digital literacy via satisfaction of each of the three needs (H3 and H4). Given that these relationships have not yet been extensively explored and reported in past SDT-based research, our findings can fill these empirical gaps.

Finally, our results showed that in promoting students' digital literacy, satisfying the need for autonomy and competence may be more important than satisfying the need for relatedness (H3 and H4). These findings imply that students' psychological experience might be more cognitive in nature in relation to learning skills and assessment (the technical and cognitive dimensions), but more affective in relation to communication and socialisation (the social-emotional dimension). They suggest that student outcomes associated with cognitive needs can be explained by the satisfaction of the autonomy and competence needs (Sierens et al., 2009), whereas outcomes associated with affection can be explained by the satisfaction of all three needs (Chiu, 2022; Ruzek et al., 2016).

Theoretical contributions

The empirical implications of this study contribute to the literature on SDT by adding a learning technology dimension and presenting more evidence for the role of technology learning support in the development of digital literacy (Ryan & Deci, 2020). Most previous related SDT-based studies have highlighted the importance of teacher support in both face-to-face and technological learning environments, i.e. how teachers supported students in their learning both with and without technology (Bedenlier et al., 2020; Trenshaw et al., 2016; Xie et al., 2006; Xie & Ke, 2011). This study took a different perspective, emphasising that support from the technology-infused environment is just as important as support from teachers.

Unlike many previous studies that adopted the construct of satisfaction of the three needs as a composite or aggregated variable (Chen & Jang, 2010; Hsu et al., 2019), this study contributed to the understanding of how satisfaction of each of the three needs independently contributes to active engagement with technology. The findings shed light on the varying degrees to which the satisfaction of each need affects the different dimensions of digital literacy by investigating the relationships between needs satisfaction and the three dimensions of digital literacy. The findings show that the relationships have different strengths and vary between the dimensions. The satisfaction of the need for relatedness appears to be one of the less influential factors in cognitive-based learning, but its effects were increased in the social-emotional context. This suggests that in relation to student engagement, the nature of the learning outcomes may determine the different levels of satisfaction of the three needs because students' innate needs vary according to the learning process in terms of cognition and affection (Chiu et al., 2020).

Practical suggestions

This study offers instructional designers and schools three practical suggestions to satisfy students' three needs and improve the development of digital literacy. The first practical suggestion is that instructional designers should ensure that learning technologies that aim or attempt to enhance digital literacy are designed to satisfy students' innate needs. For example, Technology learning support can foster autonomy by providing various digital resources, the relevance of which should be clearly indicated to students, and by allowing students to choose any digital format for the completion of their learning tasks. It can aid competence by providing videos that help students solve technical problems, by assigning peer moderators and by giving clear instructions and requirements for digital submissions. Finally, it can support relatedness by encouraging emotional communication and group learning, and by creating a warm learning atmosphere.

The second suggestion is for teachers to design learning strategies to effectively develop digital literacy. The findings of this study indicate that autonomy and competence were the most important of the three needs in terms of student engagement (see the third and final empirical implications). Teachers can use a scaffolding approach to enhance the technical and cognitive dimensions by supporting autonomy and competence, and then support relatedness to enhance the social-emotional dimension (Ismailov & Ono, 2021; Chiu & Hew, 2018). For example, teachers can ask their students to choose the tools they feel comfortable to complete individual learning activities and tasks, and then introduce some tools needed for learning. After students master their individual technical and cognitive dimensions, teachers can design peer learning tasks, such as group-based and discussion, to develop the social-emotional dimension. The individual tasks boost students confidences towards digital technologies that is crucial for peer learning.

Our final suggestion is that most teachers professional development programmes concerned about teacher technical knowledge or how they use technology pedagogically to support student learning. We suggested that school leaders should organise workshop for teachers to understand the important of needs support in technological learning environments, and introduce the concept of technology learning support in technology-infused environments.

Limitations and future directions

This study has four limitations. First, the results appear to suggest that the proposed technology learning support for an LMS can effectively develop students' digital literacy, with various levels of significance; however, the intervention was conducted during COVID-19. The unique condition of social isolation may have affected students' perceptions, and therefore the findings might not be applicable to normal times. More studies are needed to validate the findings. Second, there may have been a gap between the high school students' perception of their digital literacy and their actual performance of these skills (Porat et al., 2018), particularly in the social-emotional dimension. Additional studies using objective measures, such as assessments and tests or teachers' observations, are needed to validate and expand the findings. Third, how the participants used internet for the learning outside lessons cannot be measured during this project. This may affect the social-emotional dimensions of digital literacy. Future studies should adopt a laboratory approach to study the effects. Finally, the project used a quantitative method over a short period of time and therefore might not have revealed the full effect of the support on the development of digital literacy. Future studies may adopt a longitudinal research design that tracks students' learning progress or a qualitative method research design that explains phenomena that cannot be described numerically by the statistical data (Chiu, 2021a).

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