A self-determination theory approach to teacher digital competence development

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ARTICLE INFO

ABSTRACT

Teacher Digital Competence (TDC) framework guides policy revision and professional development, empowering teachers for future classrooms by technologies such as artificial intelligence (AI) and metaverse. Falloon (2020) expanded the TPACK framework to include personal-ethic and personal-professional competencies, addressing ethical, safe, and productive functioning in diverse, digital environments for a new TDC framework. The two new sets of personal-competencies are very important to the use of AI and metaverse in education. However, research on implementation of Falloon's (2020) TDC framework that requires interdisciplinary collaboration among school members is limited. Teachers' engagement in TDC development activities is influenced by school digital learning policy and culture, and explained by three needs satisfaction in Self-determination Theory. Therefore, this study had two goals. First it proposed and examined a research model using school learning support as a predictor, needs satisfactions as mediating variable and the two new sets of TDC as criterion variables by analyzing questionnaire data. Second, it identifies needs-supportive strategies for digital education by analyzing interviews and school documents. The participants were 370 school teachers. The results showed that the positive effect of the school learning support on TDC, and needs satisfaction fully mediated the relationship between perceived school learning support and the two sets of personal competencies. We also suggested 12 ways for designing school digital policy and culture that satisfy teachers' needs, and validated instruments of the two sets of personal competencies. TDC that covers teacher artificial intelligence competence is important to the future teacher professional development.

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1. Introduction

Globally, educational research on COVID-19 and emerging technologies such as artificial intelligence (AI) has raised awareness of the need for better use of digital technology to enhance learning and teaching, as well as a solid understanding of the digital and data-intensive world (Chiu, 2021, 2023;Chiu, Sun, & Ismailov, 2022; Yates et al., 2021). Evidence on the necessity to promote the digital competence development of young students worldwide is obvious in this digital age (e.g., European Commission on Digital Education Action Plan, 2021; Organisation for Economic Co-operation and Development, 2021). They must continuously improve their digital competence from the standpoint of lifelong learning.

Digital education has become an increasingly important component of school education. However, the majority of in-service teachers lack digital competency in teaching and learning as well as knowledge of emerging technologies such as AI. In Hong Kong, the European Union, and the United States, for example, approximately 36%, 39%, and 38% of teachers felt well-prepared to use digital technologies in online teaching, respectively (European Commission on Digital Education Action Plan, 2021; Hamilton et al., 2020). Furthermore, AI education in schools is a critical global strategic undertaking for educating the next generation. The majority of in-service teachers have not had any necessary official training, and as a result, they are less qualified and confident in teaching with AI, which includes legal and ethical considerations, privacy, and security (Chiu et al., 2022). Digital competence should be a core ability for all school teachers today, more than ever, and should be included in all disciplines of teacher professional development, including basic teacher education (Falloon, 2020). This global advocacy is evidenced by the European Commission's Digital Education Action Plan, Australia's National Professional Standards for Teachers, the International Society for Technology in Education (ISTE)'s Standards for Educators, and Hong Kong's information technology in education policy documents and reports.

Teacher digital competence (TDC) frameworks, such as the substitution, augmentation, modification, and redefinition (SAMR) framework and the technological pedagogical content knowledge (TPACK) framework, have been used to design teacher professional development activities. Personal and socio-cultural aspects should be included in TDC. Falloon (2020) extended the TPACK framework into a broadly based TDC framework that recognises the increasingly complex knowledge and skills young students need to function ethically, safely, and productively in inclusive, diverse, and digitally mediated environments. Personal-ethic and personal-professional are two new sets of competencies included in the extended framework. These can provide guidelines for policy revision and professional development design, which helps prepare and empower school teachers to teach in future classrooms. TDC framework implementation should be done in an interdisciplinary fashion, be the responsibility of all school members and require all teachers to have a consistent scope and goals. However, because of its interdisciplinary nature, its implementation is challenging and unclear (Caena & Redecker, 2019; Lee et al., 2020).

Schools need to model and deliberate professional development activities, policies and culture to motivate in-service teachers to foster TDC (Chiu, 2017; Chiu & Churchill, 2016 Lee et al., 2020). Teacher motivation can be explained by the three basic psychological needs – autonomy (feeling freedom), competence (feeling capable), and relatedness (feeling relevant) in self-determination theory (SDT) (Ryan & Deci, 2017, 2020). Teachers are more invested in their schools, more eager to embrace new challenges and put-up extra effort to do their jobs, and more accepting of the school's vision and values when their three needs are satisfied. Thus, TDC may be developed by providing school learning support that meets the three SDT needs of teachers. Furthermore, Ryan and Deci (2020), the founders of SDT, stated that SDT research needs more studies on the motivations for teaching and for continuing professional learning (e.g., Chiu, Chai, Williams, & Lin, 2021; Gorozidis & Papaioannou, 2014a, 2014b; Guay et al., 2016). To address the global research focus and gaps, this paper used Falloon's (2020) TDC and needs satisfaction in SDT as the major framework to investigate how schools can foster teachers' digital competence by supporting their three SDT needs.

2. Literature review

2.1. TDC and its development

Digital competence involves the knowledge, skills and attitudes that enable individuals to use digital technologies in a creative, critical, meaningful and responsible manner in all spheres of life, both independently and with others (Hatlevik et al., 2015). Janssen et al. (2013) described digital competence necessitates understanding how to operate digital tools and the ability to communicate utilizing digital technologies and information. The Smart and healthy use of digital technologies calls for certain information, mindsets, and attitudes in the areas of law and ethics, privacy, and security, as well as an appreciation for digital technologies' place in modern society and a healthy perspective on their value. In order to use digital technologies in a responsible and healthy way, one must have specific knowledge, mindsets, and attitudes with regards to legal and ethical aspects, privacy, and security, as well as an appreciation for the role digital technologies play in society and a healthy perspective on technology. The need to nurture students' digital competence has placed new expectations and great demands on teachers (Lucas et al., 2021), resulting in the need for further research on TDC.

TDC is a complex concept that includes pedagogy, attitude, efficacy, society, and culture (Lucas et al., 2021). Various official documents and conceptual frameworks have been presented to describe the specific competencies that teachers require to be technologically or digitally competent (Chiu, 2022). They usually focus on pedagogy as well as technical and procedural skills that can be planned and tested based on professional standards. For example, the SAMR framework describes and maps different uses of educational technologies hierarchically in stages, and it is often used as a pragmatic guide or pathway for teachers to improve their educational technology integration by understanding development progress (Geer et al., 2017). The TPACK framework (Mishra & Koehler, 2006) illustrates how teachers' technological expertise and pedagogical subject knowledge combine for effective

technology-enhanced teaching (i.e., a holistic model theorizes the relationships between technological, pedagogical, and content knowledge). Recent studies have called for encompassing personal and socio-cultural aspects (e.g., ethics, safety, and security as well as digital judgement) to broaden TDC (e.g., Foulger et al., 2017; Falloon, 2020; Lucas et al., 2021; Salas-Pilco, 2013). TDC frameworks (e.g., the European Commission presents the Digital Competence Framework for Educators; Redecker, 2017) that include these competence aspects educate students about digital dangers, such as cyberbullying and digital harvesting of personal information (e.g., Richards et al., 2015).

Falloon (2020) extended TPACK competencies by adding two sets of competencies – personal-ethical and personal-professional – to present a broadly based TDC framework. This framework includes personal and socio-cultural aspects, moves beyond prevailing technical knowledge and recognises the increasingly complex knowledge and skills that young students need to function ethically, safely and productively in inclusive, diverse and digitally mediated environments (see Fig. 1). The TPACK competencies are strongly associated with curriculum competencies, concern the ability to make informed and beneficial decisions about the use of digital resources and facilitate the design of confident and effective digitally enhanced teaching practices. Personal-ethical competencies (e.g., awareness, concern and action) refer to the ability to access and use relevant digital resources in a sustainable, safe and ethical way. Personal-professional competencies are operational and functional abilities to manage digital resources (e.g., judge disinformation) and to actively and productively engage in continuous professional learning across various channels (e.g., online professional networks). This framework is used to guide teachers' attention towards areas of learning needing to be embedded in their different practices.

The two new sets of integrated competencies are very important in future education impacted by studies on the post-pandemic (e. g., schools' student engagement in remote and online learning) and emerging technologies (e.g., artificial intelligence education in schools and personalised learning). Such studies have increased awareness of the need for the improved use of digital technologies to support online learning and teaching and for a sound understanding of the digital and data-intensive world. For example, Chiu (2022), Chiu et al. (2021), and Darling-Hammond and Hyler (2020) suggested that K-12 teachers lack essential new digital skills for online teaching. Chiu and colleagues (2021) revealed that most in-service teachers received no formal education in artificial intelligence and needed to improve their relevant content (legal and ethical aspects, privacy and security). They also showed that teacher education is critical in educating students' artificial intelligence readiness, ethics and attitude. The European Commission on Digital Education Action Plan (2021–2027) was published to reset teacher training and education in the digital age. These studies and the action plan suggest that future TDC research should put more emphasis on online teaching and the emerging areas of digital skills, such as artificial intelligence and ethics, and on fighting disinformation. Doing so would ultimately result in the cultivation of more digitally competent and confident teachers.

Successful implementation of TDC frameworks is expected to enhance teacher motivation and well-being (Özgür, 2020; Lee et al., 2020; Chiu & Churchill, 2016). Schools need to understand how and where digital technologies can enhance education, provide appropriate resources and investment, empower teachers and support relevant organisational changes and a culture that values and rewards innovation (Özgür, 2020; Lee et al., 2020; Chiu, 2022). They have an important role to play in implementation to motivate teachers to foster TDC through modelling and deliberating professional development activities and policy for in-service teachers (Lee et al., 2020). Such teacher motivation can be explained and influenced by SDT.
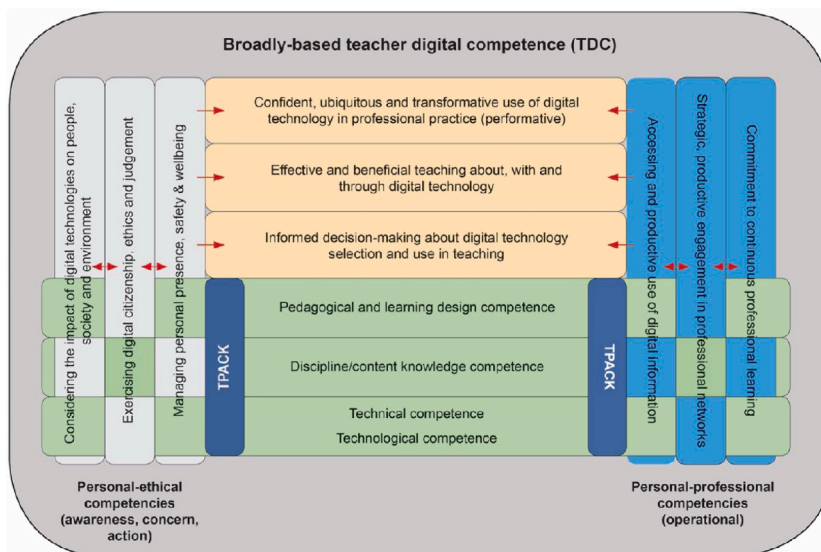

Fig. 1. Teacher digital competence framework (adapted from Falloon, 2020).

2.2. Needs satisfaction and teacher motivation

SDT presents a theoretical framework for motivation and well-being that has significant implications for face-to-face and digital teaching practice as well as educational polices (Ryan & Deci, 2017, 2020). This theory distinguishes autonomous from controlled motivation. An autonomously motivated person, as contrast to a controllably motivated one, may experience a sense of direction and control over their own lives. The theory takes into account the innate human propensity to seek happiness, well-being, development, growth within a sociocultural context. It suggests that everyone has three basic psychological needs that drive them to act: autonomy (feeling having choices, and a sense of ownership), competence (feeling achievable and capable), and relatedness (feeling warm and connected). Environments that promote an individual's autonomy, competence, and relatedness can foster high-quality types of motivation for greater engagement. When all three needs are satisfied, people are resilient and effective; when they are not, they may experience feelings of loneliness, helplessness, and inadequacy.

This theory has seen extensive use in a range of aspects, both digital and traditional, from elementary school through college (Ryan & Deci, 2017, 2020). Most of the SDT-based research focus on student motivation and engagement. Only a few SDT-based research have aimed to comprehend the ways in which both upper-level stakeholders (such as administrators and policymakers) and lower-level stakeholders (such as students and parents) affect teachers' motivation and sense of well-being in the workplace (Chiu, 2022; Chiu et al., 2021; Lee et al., 2020). There needs to be more research on what drives teachers to keep learning and improve their practice (e. g., Gorozidis & Papaioannou, 2014a, 2014b; Jansen in de Wal et al., 2014). This lack of study is in line with recent recommendations from SDT founders for an examination of the role of school leadership in inspiring teachers (Ryan & Deci, 2017, 2020).

Teachers are more invested in their schools, more accepting of the school's goals and beliefs, and more open to taking on more responsibilities and exerting more effort in their work when their schools satisfy their three SDT needs (Chiu, 2022; Lee et al., 2020). Therefore, the effects of needs-based school support on teachers' motivation to improve their digital competence can be understood via the lens of SDT. When given a choice, teachers can use the educational technology that they think most beneficial to their students' learning (autonomy). When given funding and space for training, teachers can enhance their proficiency in using a digital technology (competence). When given a learning community, teachers feel more connected to learning new pedagogies with digital devices (relatedness) (Chiu, 2017, 2022; Fathali & Okada, 2018). In sum, satisfying the three SDT needs can affect teachers' motivation and well-being in digital teaching and learning and teaching environments.

SDT-based studies showed that school leadership and environments affect teachers' motivation, engagement, and commitment (Chiu, 2022). Teachers' needs are more likely to be satisfied when their principals have transformational leaderships style (Hyseni Duraku & Hoxha, 2021) and provide support for professional development activities (Lee et al., 2020; Xie et al., 2021). Collegial support greatly influences teacher motivation. Teachers' needs can be supported by teacher learning circles ((Chiu, 2022) and praise from colleagues (Carson & Chase, 2009). School-based policies on digital technology integration affect teachers' needs, satisfaction, and intrinsic motivation (Chiu, 2017, 2022; Özgür, 2020). Thus, teachers TDC are more likely to be foster effectively when schools have strategies for needs support.
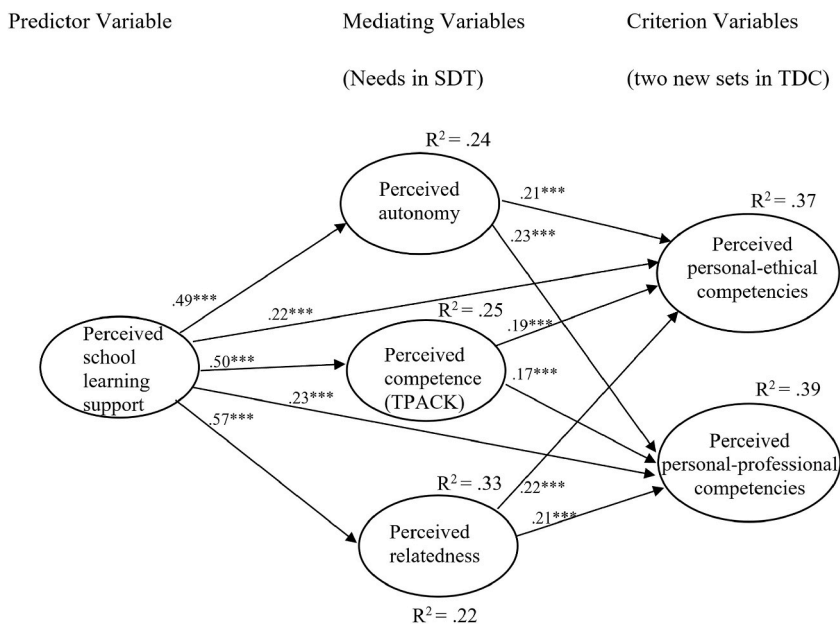

Fig. 2. Research Model.
Notes: $p < 0.001$ ***.

2.3. Current research gaps

As discussed earlier, very few studies have been conducted on TDC framework implementation (Caena & Redecker, 2019; Lee et al., 2020). The implementation of his TDC framework adopt an interdisciplinary approach and require the engagement of all teaching staff (Caena & Redecker, 2019; Lee et al., 2020; Falloon, 2020). School environments, including teacher professional development and digital learning polices and culture, play a key role in motivating teachers to learn digital skills (Chiu, 2022; Hyseni Duraku & Hoxha, 2021; Xie et al., 2021; Özgür, 2020). Needs satisfaction in SDT helps explain teachers' motivation to learn new skills. However, more SDT-based studies of teachers' motivations to continue learning are needed for the digital age, in line with recent calls from the founders of SDT (Ryan & Deci, 2017, 2020). Overall, the current understanding of how new TDC can be developed in schools from the needs satisfaction perspective is limited.

3. This study and method

3.1. Research questions

In the Falloon (2020)'s TDC framework, TPACK competence includes the three core competencies are (i) technical and techno-logical competence, (ii) discipline and content knowledge competence and (iii) pedagogical and learning design competence. Collectively, they can be viewed as competence (SDT) in teaching using technology. When teachers taught online, they became more aware of ethical issues and sought advice from professional communities (Chiu, 2022). This may indicate that TPACK competencies are associated with the personal-ethical and personal-professional competencies. Furthermore, the interdisciplinary implementation of the TDC framework approach would require all school members' participation. How schools' actions and strategies affect teacher moti-vation in developing their TDC (e.g., school-based teacher professional development and digital learning policies), referring to school learning support (Chiu, 2022).

By clarifying the relationships between perceived school learning support, needs satisfaction and the personal-ethical and personal-professional competencies, the study proposed and examine a research model, see Fig. 2. It (i) investigated the potential mediating role

Table 1
Questionnaire items.

Measures	Sample questions
Perceived school learning support (Lee et al., 2020)	My school helps me see areas in which I need more training on digital technologies.
	My school suggests ways to improve my digital competence.
	My school provides me with frequent opportunities to develop new skills for teaching with technologies.
	My school teaches me how to solve problems on my own when teaching with technologies.
Perceived autonomy (Chen et al., 2015)	When teaching with technologies in the classroom …
	I feel a sense of choice and freedom in the things I undertake.
	I feel that my decisions reflect what I really want.
	I feel my choices express who I really am.
	I feel I have been doing what really interests me.
Perceived relatedness (Chen et al., 2015)	When teaching with technologies in the classroom …
	I feel that the people I care about also care about me.
	I feel connected with the people who care for me and for whom I care.
	I feel close and connected with other people who are important to me.
	I experience a warm feeling with the people I spend time with.
Perceived competence (Schmidt et al., 2009)	When teaching with technologies in the classroom …
	I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.
	I can choose technologies that enhance my teaching subject content for a lesson.
	I can teach lessons that appropriately combine my teaching subject, technologies and teaching approaches.
	I can provide leadership in helping others to coordinate the use of subject content, technologies and teaching approaches at my school.
Personal-ethical competence (adapted from The European Framework for the Digital Competence of Educators)	I can protect my personal data from social networks.
	I effectively protect sensitive content (e.g., exams, students' grades and personal data).
	I can ensure my health and well-being while using mobiles.
	I teach students how to behave safely and responsibly online.
Personal-professional competence (adapted from The European Framework for the Digital Competence of Educators)	I am able to assess the reliability of information and to identify misinformation and bias.
	I can use different websites and search strategies to find and select a range of different digital resources.
	I am actively looking for continuous professional development activities outside school.
	I use digital technologies to work with colleagues inside and outside my educational organization.

of the satisfaction of teachers' needs in the relationship between perceived school learning support and perceived personal competencies (i.e., personal-ethical and personal-professional) and (ii) identify school policies and continuous professional development activities that effectively foster the two personal competencies by satisfying teachers' needs. Hence, the two following research questions will be explored.

RQ1. Does needs satisfaction mediate the relationships between perceived school learning support and the personal-ethical and personal-professional competencies?

RQ2. What school learning support would satisfy teachers' need to effectively foster their two sets of personal competencies?

To answer RQ1, the three hypotheses are.

H1. Perceived school learning support contributes positively to the satisfaction of each of the three needs.

H2. The satisfaction of each of the three needs contributes positively to each of the two personal competencies.

H3. Needs satisfaction mediates the relationship between perceived school learning support and the two personal competencies.

3.2. Research design and participants

This study entailed a sequential explanatory mixed-method study design. First, a quantitative design was adopted to obtain objective statistical findings to examine the research model in RQ1. The participants were 370 teachers from nine secondary schools in Hong Kong. This sample size is supported by the results of the A-Priori Sample Size Calculator for Structural Equation Models (Soper, 2020), which recommends a minimum sample size of 100 when the numbers of latent and observed variables are 7 and 28, respectively, and the power level is 0.8. The participating schools had plans to enhance TDC, and were recruited from a school–university partnership network. Stratified sampling was conducted to select students with difference academic performance. It is important to note that secondary schools in Hong Kong are categorised into three bands based on students' academic achievement. Three schools from each band in the pool were randomly selected. Second, to answer RQ2, we conducted focus group interviews and collected school-based documents to get the views from school leadership and teachers. In each school, a principal, one vice principal, and four panel heads and four subject teachers were the participants (total 90 teachers). Purposive sampling was used to include teachers with different subjects to address the interdisciplinary implementation of TDC.

3.3. Instruments

Table 1 shows all six measures and their items used in the questionnaire for RQ1. Each measure has four 5-Likerts scale items. The followings present all the items and their Cronbach's alpha coefficients (α).

- **Perceived school learning support.** Four items were adapted from the study of Lee et al. (2020) that measure in-service teacher perceived support from principals, with an original α of 0.86. An example is "My school helps me see areas in which I need more training on digital technologies.".
- **Perceived autonomy and relatedness.** Four items for each variable were adapted from the study of the Basic Psychological Needs Scale—Revised. (Chen et al., 2015) with a reliability of α > 0.71 with adults as participants. An example of perceived autonomy is "When teaching with technologies in the classroom, I feel a sense of choice and freedom in the things I undertake."; an example of perceived relatedness is "When teaching with technologies in the classroom, I feel connected with the people who care for me and for whom I care.".
- **Perceived competence.** Four items were adopted from the study of Schmidt et al. (2009) that measure teachers' TPACK competence, with a reliability of α = 0.92. An example is "When teaching with technologies in the classroom, I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.".
- **Personal-ethical and personal-professional competencies.** Items were adapted from The European Framework for the Digital Competence of Educators (Redecker, 2017). As these are new measures, one teacher education researcher and four teachers checked the items to fit the measures, the two measures were validated in this study. An example of personal-ethical competence is "I effectively protect sensitive content (e.g., exams, students' grades and personal data)"; an example of personal-professional competence is "I am able to assess the reliability of information and to identify misinformation and bias.".

3.4. Research procedure

The schools implemented their own TDC policy for at least one year. To answer RQ1, the teacher participants completed the questionnaire in 30 min. To answer RQ2, we collected all of the school-based documents, as well as observed at least three professional development activities. We held two focus group interviews with the principals and vice principals, each with nine participants and lasting approximately 90 min. We also conducted nine focus group interviews with the panel heads and teachers, with each group consisting of eight participants and lasting approximately 120 min. The interview protocol was developed based on the studies of Chiu (2022), and Chiu and colleagues (2021). The questions posed included the following: [overall] What do you think about your school's digital learning policy and culture? What kinds of professional development activities are you engaged in? [autonomy] How do you feel about your choices when you teach with technology under your school policy? Why? [competence] How do you feel about your

ability in terms of the instructional strategies suggested by your school policy? What have you learned from the professional development activities organised by your school? [relatedness] How do you relate to your school policy? How do you feel about your school's professional development? Why?

3.5. Data analysis

To answer RQ1, we used confirmatory factor analyses to evaluate the quality of the measurement model and the correlations between the latent variables in the questionnaire. Structural equation modelling was used to assess (i) the contributions of perceived school learning support to the three perceived needs, (ii) the contributions of the three perceived needs to the two personal competencies and (iii) the mediating role of needs satisfaction. To confirm the indirect effect in the research model, a bootstrapping approach is used. This approach avoids the problem of different standard error formulae yielding inconsistent results (Hayes, 2009), produces a more precise confidence interval and is the most ideal approach for testing mediating effects (Hayes, 2009; Taylor et al., 2008). Moreover, the reliability and validity of the quantitative design were discussed earlier in the measure and further examined in the results by statistical approaches.

To answer RQ2, we used SDT as an analysing framework and a deductive content analysis approach (Armat et al., 2018) to analyse the school documents and interview data collected in the study. The analyses revealed how school policies on digital learning satisfy teachers' innate needs in fostering their digital competence. Three main stages were used to analyse the data. First, two independent raters and moderators got acquainted with the data under the three main categories: autonomy, competence and relatedness in SDT. They also used the study of Chiu (2022) on how SDT support digital learning to establish initial sub-categories for each category: Autonomy: sharing culture, financial support, bottom up, and accessibility. Competency: self-learning, objective feedback, confidence, active sharing, and accessibility. Relatedness: relevance, self-belonging, celebration, benefits, active sharing. Second, the two independent raters examined all the data to identify the evidence to support each sub-category by coding. Another moderator made the final decision over disagreements between the raters. A rater proposed three new sub-categories but the other rater and the moderator disagree with the sub-categories. Third, the team renamed the sub-categories that provided a thorough understanding of the strategies, as well as their importance.

Six aspects of the validity of this qualitative design were examined (Cypress, 2017; Leung, 2015). They are (i) Appropriateness: This validity is examined in three parts. First, we modified a set of interview questions related to SDT-based blended and online teaching and learning that had been tested and used in at least three similar research projects in the same context (Chiu, 2021, 2022, 2024; Chiu et al., 2021). Second, in the research context, the leadership is democratic and delegative, and the schools use school-based management. Leaders are more open, and most policy formulation is done from hybrid approaches of the top down and from the bottom up. Teachers felt free to speak out about the school policies. Third, the main interviewer had 16 years of school leadership and teaching experience. He is also an international SDT scholar who collected qualitative data for numerous SDT-related projects. These indicate that the data collection tools and processes were appropriate for the research question and context. (ii) Triangulation: Multiple data sources, two independent raters, and an impartial moderator would avoid individual biases and provide a more comprehensive knowledge of how SDT supports TDC development.(iii) Credibility: The credibility of qualitative research is determined by the researcher's competence and effort to establish rigor in the research process. An international SDT scholar who has published over 20 journal papers on SDT in digital education, as well as the founder of TDC, are among the authors. The two raters and moderator employed SDT as a framework to examine data in three qualitative studies. (iv) Ethical procedures: This study received ethical approval from the corresponding authors' university, which addressed the moral issues of their qualitative design. This ensures that the data gathering respects the rights of the participants.(v) Transferability: This qualitative design used the purposive sampling method to select schools with diverse backgrounds and teachers with different positions and teaching backgrounds. This method provides a thick description and robust data with a wide possible range of information. (vi) Respondent validation: this study was supported by the Chiu (2022)'s previous intervention and co-design study. The Chiu (2022) co-designed an SDT-based intervention for digital learning—leader, expert support, and peer support—with 62 principals, panel heads, and teachers in one school, as well as analyse the impact of the three types of support. The findings revealed that the three types of support promote teacher digital integration. This previous study will guarantee that the findings are credible and valid. Moreover, the inter-rater reliability was 0.85.

4. Results

To answer RQ1, we employed structural equation modelling to investigate the predicted correlations between this study's variables

Table 2
Descriptive statistics for the questionnaire.

Variable	Mean	SD	Skewness	Kurtosis
Perceived school learning support	3.59	1.38	0.79	0.85
Perceived autonomy	3.56	1.31	0.18	0.61
Perceived competence	3.62	1.31	0.05	0.62
Perceived relatedness	3.59	1.20	0.02	0.58
Perceived Personal-ethical competencies	3.61	1.33	0.07	0.89
Perceived Personal-professional competencies	3.66	1.44	0.06	0.88

in the research model. Perceived school learning support was the predictor variable and the mediating variables were three types of innate needs satisfaction: autonomy, competence and relatedness. Perceived personal-ethical competencies and perceived personal-professional competencies were the criterion variables.

Table 2 shows descriptive statistics. All of the variables had strong factor loadings (>0.80) and Cronbach's alpha values > 0.90, which is considered to be internally reliable. The fitness indices of the measured items suggested a good model fit with regard to the measurement model's goodness-of-fit: $x^2/df = 1.79$ (<5.0); RMSEA = 0.05 (<0.08); SRMR = 0.01 (<0.05); GFI = 0.91 (>0.90); TLI = 0.99 (>0.90); CFI = 0.99 (>0.90). (Hair et al., 2010). The positive correlations between all of the variables were significant, with $p < 0.01$ m see Table 3.

The research model had a good fit to the data: $\chi^2/df = 1.84$ (<5.0); RMSEA = 0.05 (<0.08); SRMR = 0.04 (<0.05); GFI = 0.91 (>0.90); TLI = 0.99 (>0.90); CFI = 0.99 (>0.90). Fig. 2 depicts the path relations and coefficients among the variables. Table 4 displays the standardized direct, indirect, and total effects of the variables.

The Relationship Between Perceived School Learning Support **and Needs Satisfaction (**H1**).** Teachers' perceived school learning support positively and significantly predicted the satisfaction of each of the three needs: autonomy ($\beta = 0.49$, $p < 0.001$), competence ($\beta = 0.50$, $p < 0.001$) and relatedness ($\beta = 0.57$, $p < 0.001$).

The Relationship Between Needs Satisfaction and the Two Sets of Personal Competencies (H2**).** The results indicated that autonomy significantly predicted perceived personal-ethical competencies ($\beta = 0.21$, $p < 0.001$), and perceived personal-professional competencies ($\beta = 0.22$, p < 0.001); competence significantly predicted perceived personal-ethical competencies ($\beta = 0.17$, $p < 0.001$), and perceived personal-professional competencies ($\beta = 0.19$, $p < 0.001$); relatedness significantly predicted perceived personal-ethical competencies ($\beta = 0.22$, $p < 0.001$), and perceived personal-professional competencies ($\beta = 0.21$, $p < 0.001$).

The Mediating Role of Needs Satisfaction (H3**).** The results revealed direct relationships between perceived school learning support and each set of personal competencies. According to the mediation analysis, the three needs satisfaction mediated the relationships between perceived school learning support and the two sets of personal competencies, see Fig. 2. Perceived school learning support indirectly predicted both sets.

We adopted a bootstrapping strategy to confirm these indirect effects since it avoids the problem of multiple standard error formulae producing inconsistent results (Hayes, 2009). This strategy also yields a more precise confidence interval (CI) and is the best method for testing mediating effects (Hayes, 2009; Taylor et al., 2008). We used 95% CIs for testing the effects of school learning support on the two sets of personal competencies through bootstrapping using 2000 random samples. The coefficients of the indirect effect of school learning support on the personal-ethical competencies and personal-professional competencies were 0.31 (95% CI = [0.23, 0.40], $p = 0.001$), and 0.32 (95% CI = [0.24, 0.41], $p = 0.001$), respectively. Since the 95% CIs did not contain 0, school learning support was a significant indirect predictor of the two sets of personal competencies through needs satisfaction. The total effects of school learning support on the perceived personal-ethical competencies and perceived personal-professional competencies were 0.53 and 0.58, respectively.

To answer RQ2, we utilized SDT as a framework for analysis and a deductive technique to examine the school records and interview data acquired in the study. The followings reveal how school policies satisfy teachers' autonomy, competence and relatedness. They are all supported by school leaders and teachers in the interviews.

To support the needs for autonomy, the participants expressed that four school learning support strategies.

(1) **Creating s safe and open environments:** schools should provide a safe and open environment for teachers to freely communicate their thoughts and views about the two sets of competencies. Two excerpts are "*I can improve my skills by sharing my experience. … Safe and open are important.*", and "*We learn from other people's sharing and learning experiences.*". Moreover, the school documents indicated all the schools arranged open lessons or peer learning activities to create sharing opportunities. The activities are not parts related to performance review.

(2) **Providing financial support:** Schools could provide funding for teachers to take whichever professional development courses they find useful. Two examples in the focus groups are "*I really need this school to be able to afford the course I want to pursue.*", and "*I want to take a course at a university in another country, but it will be very expensive.*". In addition, the documents indicated that eight out of nine schools provide financial support to their teachers. For example, the teachers are expected to submit a one-page proposal for the support.

(3) **Involving in decision making:** They should get teachers involved in making decisions about the digital tools that are used in the classrooms. Two excerpts are "*The technology coordinator chose the digital tools we have to use, and I use my own tools.*", and

Table 3

Correlation among all the variables in research model.

Variables	1	2	3	4	5	6
1. Perceived technology learning support	–					
2. Perceived autonomy	0.48**	–				
3. Perceived competence	0.50**	0.30**	–			
4. Perceived relatedness	0.57**	0.38**	0.40**	–		
5. Perceived personal-ethical competencies	0.52**	0.44**	0.42**	0.48**	–	
6. Perceived personal-professional competencies	0.54**	0.45**	0.45**	0.49**	0.43**	–

Notes: **p < .01.

Table 4
Standardized direct, indirect and total effects among the variables of research model.

Predictor	Mediating/Criterion variable	Direct effect	Indirect effect	Total effect
Perceived school learning support	Perceived autonomy	0.49 ($p < 0.001$)	–	0.49
	Perceived competence	0.50 ($p < 0.001$)	–	0.50
	Perceived relatedness	0.57 ($p < 0.001$)	–	0.57
	Perceived personal-ethical competencies	0.22 ($p < 0.001$)	0.31	0.53
	Perceived personal-professional competencies	0.23 ($p < 0.001$)	0.32	0.55
Perceived autonomy	Perceived personal-ethical competencies	0.21 ($p < 0.001$)	–	0.21
	Perceived personal-professional competencies	0.23 ($p < 0.001$)	–	0.23
Perceived competence	Perceived personal-ethical competencies	0.17 ($p < 0.001$)	–	0.17
	Perceived personal-professional competencies	0.19 ($p < 0.001$)	–	0.19
Perceived relatedness	Perceived personal-ethical competencies	0.22 ($p < 0.001$)	–	0.22
	Perceived personal-professional competencies	0.21 ($p < 0.001$)	–	0.21

"*The schools did not subscribe the tools I recommend!*". Moreover, the school documents indicated that eight schools encouraged the teachers to suggest their choice of tools for subscriptions.

(4) **Providing easily accessible learning opportunities:** Schools should make it easy for teachers to learn on their own, whenever and wherever they want to. Two excerpts are "*There are no good local courses available! I am unable to learn the skills on my own.*", and "*There are no appropriate learning materials.*". Moreover, according to the documents, all the schools provided financial and non-financial assistance to their teachers so that they could take a course and purchase the digital learning materials they want.

To satisfy competence, the analyses revealed five support strategies.

(1) **Encouraging self-achievement settings:** Schools should encourage teachers to set their own achievement of TDC. It is difficult to measure or assess teachers' performance or progression against the different competencies. Standards and rubrics may discourage teachers from sharing and collaborative culture. Therefore, teachers should suggest where they are in the learning process and what they need to learn next. Two examples from the interviews are "*The two sets are very abstract. We do not know our standards.*", and "*we need a platform to assess our knowledge.*". Furthermore, according to the documents, all schools provided a self-reflective form that assisted teachers in setting their own goals. In sum, this strategy motivates teachers' engagement in what and how they develop their knowledge in the two sets of competencies. They are more likely to feel more capable in TDC development process.

(2) **Offering objective and stress-free feedback:** Teachers should receive mentoring and assistance from outside advisors. Other institutions, such as universities and educational service providers, can offer talks and seminars on teacher skills and give one-on-one consultations upon request from teachers. Teachers in the interviews expressed "*I would like to learn more about emerging technology from outsiders.*", and "*Professors at universities provide more objective, specific, and detailed feedback with minimal stress.*". Furthermore, all the schools participated in at least one school-university partnerships project on digital education. In the projects experts advised and commented teachers on how to use technology to observe lessons.

(3) **Building confidence:** Some teachers lack the confidence to use technology in the classroom and avoid acquiring digital skills. Schools should therefore encourage teachers to participate in digital learning and related professional development initiatives. Two excerpts are "*I am not interested in learning how to use technology in the classroom. I am terrible at this.*", and "*I do not feel at ease using online educational technology.*". Furthermore, all schools provided teacher substitution (time off) when they took part in related professional development events.

(4) **Encouraging sharing opportunities:** One of the most useful learning possibilities to satisfy the need for competence is sharing. Sharing digital learning culture within a school is not particularly rich. Schools should put greater effort into encouraging teachers to share their work, regardless of whether it is successful, with other teachers. Two excerpts are "*Teachers ought to demonstrate both good and terrible work.*", "*In our schools, there is a lack of a generous culture of sharing.*". In the documents, all of the schools encouraged teachers to share their work and ask for assistance by having shared digital spaces, social learning communities, and circles.

(5) **Providing easily accessible learning opportunities:** In the previous section on autonomy needs, this is covered. The greater the availability of resources for education, the more help teachers had in developing their skills.

Relatedness: The analyses revealed five strategies.

(1) **Designing relevant learning:** Schools should offer learning opportunities that are relevant and based on their own schools. The two sets are more personal and relevant to the situation. The learning is more contextual. Local cases (their own schools) are expected to use in teacher learning. Two excerpts are "*The two personal skills can be learned effectively in a more local setting.*", and "*The learning materials should take place in a school setting.*". Furthermore, the documents revealed that all that schools regard co-designing processes with external parties (e.g., universities, other schools, companies, and educational service providers) as professional learning activities.

(2) **Promoting self-belonging:** Schools should encourage teachers to start their own learning communities. For example, teachers can form learning circles to help each other. It will be more sustainable. These groups should get together regularly to talk about their experiences or share what they know about technology. Two examples were *"We could form learning circle to help each other learn."*, and *"We will feel more connected if we're in a long-term learning group."*. Moreover, the school documents showed that each school had at least three digital learning circles for digital education.

(3) **Celebrating achievements:** Schools should make a warm and positive place to work by recognizing the work of teacher teams. Any teacher, no matter how tech-savvy or AI-savvy they are, should be able to complete the achievements. Teachers in the interviews expressed *"We need to celebrate our hard work."*, and *"Individual success is less important than success as a part of a team."*. Furthermore, according to the records, the schools recognized teachers' any new initiatives for using technology in teaching and learning by emphasizing their names in meetings.

(4) **Highlighting benefits:** Schools should advocate the benefits of the TDC. Technologies will be used in classrooms in the future. Having good TDC will help teachers at work and in their personal lives. Two excerpts are *"Many teachers still do not want to use technologies in a way that are good for learning and teaching. They only use them in classrooms, and fail to teach them pedagogically. It is because they do not see how digital learning can help them."*, and *"We need to talk to teachers about the benefits and risks of digital learning."*. Moreover, the documents showed that the schools organised some seminars on future digital learning such as AI in education.

(5) **Encouraging sharing opportunities:** In the previous section on competence needs, this is covered. Teachers feel more comfortable and connected in judgement- and stress-free environments.

Overall, the quantitative results showed that perceived school learning support was related to TDC in a positive way. Also, perceived school learning support had an effect on TDC that was both direct and indirect, through needs satisfaction. The qualitative results pointed to 12 ways that schools could help students learn to satisfy the three needs. It is because "Providing easily accessible learning opportunities" is duplicate for autonomy and competence; "Encouraging sharing opportunities" is duplicate for competence and relatedness.

5. Discussion

This study examined how perceived school learning support affects TDC and the way that predicts how the teachers' three needs are satisfied and how well two new sets of personal competencies are achieved mediated by the needs. Interpretation and elaboration of the results are presented first – four empirical implications, followed by discussing three theoretical contribution, and four practical suggestions/challenges for future work.

5.1. Empirical implications

5.1.1. Perceived school learning support and teachers' needs satisfaction

The first implication is supported by findings indicating that school learning support is significantly related to teacher needs satisfaction (H1), which can lead to better teacher engagement in TDC development (Chiu, 2022; Ryan & Deci, 2017, 2020). Teachers felt safe and comfortable, and had more chances to teach with appropriate and safe digital tools and resources, actively shared their work with others and reflected on their experience (Gorozidis & Papaioannou, 2014a, 2014b; Louws et al., 2017). According to SDT, when schools satisfy teachers needs for autonomy, competence and relatedness, teachers are more likely to feel empowered to make informed decisions about the educational technologies they use in the classroom, confident in their ability to use digital environments to promote student learning in a pedagogically sound and ethical manner, and motivated to collaborate with their peers to develop their digital competence (Fathali & Okada, 2018). This is aligned with the previous studies suggesting leaders' learning support is related to teachers' commitment and change behaviours (Lee et al., 2020). The results indicate that digital learning policies in schools have a direct impact on the growth of teachers' digital competence.

5.1.2. Perceived school learning support and TDC

Second, there are direct correlations between the three main sets of TDC - TPACK competencies, personal-ethical competencies, and personal-professional competencies - and perceived school learning support (H1 and H2). This finding shows how crucial school work conditions (e.g., culture) are for promoting teachers' TDC. Teachers in educational institutions receive the same innates needs support as other employees do in workplaces (Adnan et al., 2020; Gomez-Baya & Lucia-Casademunt, 2018; Mathieu et al., 2014). TDC is a must for digital education in schools in order to properly develop future digital classrooms. Teachers with poor TDC are more likely to utilize technology in the classroom without taking child safety, good pedagogy, or legal concerns with account. For teachers, those with strong TDC will design and offer secure and efficient digital learning environments (Chiu et al., 2021). Therefore, teachers will pay attention to TPACK, be able to access and use relevant digital resources in a sustainable, safe, and ethical way, be able to manage digital resources, and be able to actively and productively engage in continuous professional learning across various channels when their school motivate teacher engagement in TDC development activities. Our findings complement earlier research that found an empirical connection between teacher needs satisfaction and educational innovation. (Gorozidis & Papaioannou, 2014a, 2014b; Chiu, 2022; Chiu et al., 2021, 2022; Louws et al., 2017; Lee et al., 2020). These findings further reinforce an underexplored empirical connection between perceived school learning support and TDC. Given the redefined roles of technology in education, our findings can shed light on how teachers can be better supported by implementing a needs-supportive school-based digital learning policy and culture that can

help teachers foster their digital competences in a secure and manageable environment.

5.1.3. The mediating role of teachers' needs satisfaction

Thirdly, the connection between perceived school learning support and the two sets of personal competences was mediated by the degree to which the students' needs were met. Our findings show that the satisfaction of the needs for autonomy, competence, and relatedness is an indirect predictor of personal-ethical and personal-professional competencies, with the former being a direct predictor of the latter (H3). Since these connections have not been thoroughly investigated and published in previous SDT-based research, our results can help to bridge this gap with empirical evidence.

5.1.4. Needs-supportive strategies and teachers' needs satisfaction

Finally, our qualitative results demonstrated that needs-supportive strategies are necessary for satisfying teachers' three needs (autonomy, competence and relatedness), which, in turn, foster their personal-ethical and personal-professional competencies. Thus, these strategies are necessary for advancing teachers' digital competence within the context of school digital policy. This is aligned with previous studies suggesting school environments are influential factors of teacher commitment and change behavior (Carson & Chase, 2009; Lee et al., 2020). When schools satisfy teachers needs for autonomy, competence and relatedness, teachers are more likely to feel empowered to make informed decisions about the educational technologies they use in the classroom, confident in their ability to use digital environments to promote student learning in a pedagogically sound and ethical manner, and motivated to collaborate with their peers to develop their digital competence. The results indicate that digital learning policies and culture in schools have a direct impact on the growth of teachers' digital competence.

Based on the findings, we suggest these 12 strategies to develop and implement a needs-supportive digital learning policy and culture that work for teachers. They are creating sharing opportunities, providing financial support, involving in decision making, providing easily accessible learning opportunities, encouraging self-achievement setting, offering objective and stress-free feedback, building confidence, encouraging sharing opportunities, offering relevant learning opportunities, promoting self-belonging, recognizing achievements, and highlighting benefits. These strategies intend to motivate teacher engagement in TDC activities, preparing them to teach in future classrooms (Chiu, 2022). It is noted that the strategies of providing easily accessible learning opportunities and encouraging sharing opportunities are identified simultaneously in needs for autonomy and competence, and needs for competence and relatedness, respectively. This suggests that providing easy-to-access learning materials and encouraging teachers to share their experiences should be better valued than other strategies for meeting the teachers' needs.

5.2. Theoretical contributions

The empirical implications of this study add a TDC component to the body of literature on SDT and provide more proof for the importance of school needs-supportive policies in the growth of TDC (Ryan & Deci, 2017, 2020). The focus of earlier SDT-based studies, which were conducted in corporation settings, was on the wellbeing and job satisfaction of the employees (Adnan et al., 2020; Gomez-Baya & Lucia-Casademunt, 2018; Mathieu et al., 2014). Additionally, the earlier research based on SDT in schools emphasize the commitment, well-being, and behavior change of teachers (Hobson & Maxwell, 2017; Lee et al., 2020). The majority of them emphasize how important teacher support is for students' learning (Bedenlier et al., 2020; Xie & Ke, 2011; Chiu, 2022). Studies based on SDT that look at how SDT transforms schools for digital education are overlooked. Unlike other innovations in education, digital education is disruptive. According to Falloon's TDC framework, teachers need to possess more competencies for successful digital education. This study adopted a distinct viewpoint, highlighting the significance of school needs support in TDC activities for teacher ongoing growth.

The second theoretical contribution makes use of TPACK as competence requirements. It is one of the first studies that use TPACK as a competency, as far as we are aware. As a result, this study helped to shed light on how TPACK satisfaction relates to the need for competence in SDT. More specifically, TPACK for teachers is seen as an innate need for classroom instruction. TPACK competence are primary requirements or abilities for teaching using technology in schools. This is consistent with research that recommends using TPACK as the foundational knowledge when designing pre- and in-service teacher development programs (Reyes Jr et al., 2017; Tondeur et al., 2017).

The instruments for the new two sets of TDC—personal-ethical competencies and personal-professional competencies—represent the final contribution. They were developed, tested and validated by us. TDC is associated with teacher AI competence. A teacher with good TDC is capable of teaching using AI. We advise using them while doing research on TDC, such as evaluating teacher preparation programs.

5.3. Practical suggestions and challenges

The implementation of TDC is very crucial for AI and metaverse-driven future classrooms by further addressing ethical, safe, and effective learning problems. Therefore, this study offers school leaders and teacher-educators three practical suggestions to satisfy teachers' three needs and foster their digital competencies. The first practical suggestion is that school leader should adopt needs-supportive approach and use 12 strategies as guidelines to design and implement their school-based digital learning policies and culture. The twelve strategies are driven by practitioners from nine schools. Some of them were used, and some of them are teachers' requests. One possible approach which international governments might consider is to incorporate this needs-supportive approach and the 12 strategies into relevant policy documents on their national digital competence and to build up strategic partnership with

relevant government ministries in education, commerce and science, teacher training institutes, techno-preneurs and school networks.

The second recommendation is that teacher educators should design and deliver teacher development programs utilizing TDC and needs-support approaches. TPACK is the key competencies that affects the other new sets of competencies, according to the study's findings. In order to ensure that teachers have strong TPACK competency before going on to the two personal digital competences. We suggest TPACK is a prerequisite for the professional ethics and conduct course. One possible approach is to integrate the TPACK into relevant government teacher competency framework for school leaders, middle managers and frontline teachers pitching at different level of competency requirements.

Our last recommendation is that most school leadership programs for digital education should be concerned with TPACK, and technology adoption and integration. We recommended that the program's coordinators recognize the significance of teachers' deep understanding of the potentials and risks of cutting-edge technology such as AI and metaverse, as well as the need for supportive school working environments. Relevant coordinators could further establish some tripartite-steering committees absorbing and re-engineering voices from teacher training institutes, technology enterprises and the government representatives for better alignment of industry-academic alignment for the programs they offer.

Aside from the three practical recommendations, this study highlights a significant challenge for adopting the TDC framework utilizing the SDT approach. Supporting teachers' innate needs for TDC entails more than simply establishing and implementing digital learning policies and culture. The implementation of the TDC framework could be disruptive in many educational environments that are demanding, competitive, and heavily focused on standardisation. The TDC framework is a holistic framework that represents more than the sum of their individual parts. It is difficult to define competencies in terms of separate or individual criterion on scales, rubrics, or in policy. It is equally difficult to measure or assess teachers' performance or progression against them. Competencies such as those contained in the TDC, especially personal-ethical and personal-professional, need to become part of the mindsets of teachers. They need to be modelled and demonstrated as part of teachers' ongoing and continuous practices; It requires changes in professional learning culture (increased sharing), mindsets of school leaders and teachers (growth mindsets), attitudes toward the two new sets of personal-ethical and personal-professional competencies, and teacher performance assessment. Therefore, mandating TDC competencies in policy or other official documents does not guarantee success. Implementing them successfully in educational environments is complex, and very much relies on the qualities of individuals and the nature of the institutional environment and culture in which they are being implemented. To satisfy teachers' needs for their TDC development, a whole-school or cross-school strategy may be required to build a more collaborative and sharing culture.

6. Limitations and future directions

This study includes five limitations and their directions. First, there might have been a discrepancy between how school instructors saw their TDC and how they actually applied those competencies (Porat et al., 2018), especially in the TPACK competencies. The results need to be validated and expanded upon by additional research utilizing objective metrics, such as tests and assessments or supervisors' observations. Moreover, the 12 suggested school needs-supportive learning strategies are also informed by qualitative data, which is the second limitation. Quantitative field testing is not done on them. Future studies should use experimental or Delphi methods to confirm their influence on needs satisfaction. Third, the study was conducted in an Eastern setting. The perspectives of teachers in schools in the East and West may differ Future research may use a comparative research design to examine how perceptions of need satisfaction are influenced by teacher reputation in society. Fourth, although some SDT-based studies have demonstrated that school leaders can motivate teachers to make educational improvements by satisfying their needs (Cai & Tang, 2022; Lee et al., 2020), it may be difficult to implement SDT in some schools. More empirical investigations should be undertaken to see how the suggested policies and practices work in schools with varied cultures. Lastly, this study did not investigate the challenges of implementation of TDC framework in higher education. Teachers in higher education should have good TDC; therefore, future studies should be conducted on how to implement this framework.

Availability of supporting data

- The datasets used for the current study are available from the corresponding author on reasonable request.

Conflicts of interest

- This study got ethical clearance from the author's university.
- There is no conflict of interests between the author and participants.

CRediT authorship contribution statement

Thomas K.F. Chiu: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Garry Falloon:** Writing – review & editing, Validation, Conceptualization. **Yanjie Song:** Writing – review & editing, Conceptualization. **Vincent W.L. Wong:** Writing – review & editing, Conceptualization. **Li Zhao:** Writing – review & editing. **Murod Ismailov:** Writing – review & editing.

Data availability

Data will be made available on request.

Acknowledgements

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