Interdisciplinary Perspectives on Educational Technology Integration in K-12 Education: A Grounded Theory Study of Teachers' Conceptual, Pedagogical, Cultural, and Political E-learning Dilemmas

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Abstract—**Investigations into learning practices have converged to support the notion that digital learning technologies can be beneficial to educational experiences. However, turning a traditional classroom into a technology-integrated learning environment presents many challenges for teachers and other related stakeholders. In this paper, we attempt to systematically investigate the dilemmas from teachers' perspectives. Adopting a qualitative research design, we invited teachers from fourteen different primary and secondary schools in Hong Kong to hear their perspectives about their challenges when teaching in technology-mediated environments. Based on Windschitl's framework, the dilemmas gathered from teachers' interviews can be classified as the conceptual, pedagogical, cultural, and political frames of reference in adopting educational technology. All of these influenced teachers' willingness to adopt digital learning tools into their teaching. Other implications for educational technology practices are also discussed. All in all, these findings inform scalable Information and Communication Technology solutions and teacher professional development strategies to optimize technology integration. We hope this paper will stimulate further discussion on how to facilitate teachers' implementation of educational technology, in particular, assisting them to overcome the identified dilemmas.**

Keywords—**technology-enhanced learning, Information and Communication Technology (ICT) adoption, technology, dilemmas, teacher professional development, e-learning**

I. Introduction

Digital learning technologies have become increasingly prevalent in education across the globe [1, 2], with recent interest in incorporating artificial intelligence tools [3, 4]. Educational technology integration has been applied to diverse learning environments to enhance learning effectiveness and enrich the learning experience, such as blended learning [5] and the flipped classroom approach [6, 7]. Drawing on Kirkwood and Price's conceptualization [8], this research defines technology-enhanced learning as the systematic integration of digital tools, platforms, and resources to support and improve teaching and learning processes, encompassing both synchronous and asynchronous learning environments that utilize interactive technologies to facilitate knowledge construction and skill development. The interactive, self-paced, repetitious, and customizable features of digital learning environments have enabled educators to actualize a variety of pedagogical philosophies. For example, Lam and colleagues [9] have demonstrated how the pedagogies of active learning, student-centered learning, peer learning, personalized learning, and differentiated learning can be applied in real-world educational contexts with the use of educational technology. The importance of technology-enhanced learning is clearly illustrated in the global crisis [10, 11]. During the recent widespread coronavirus pandemic, many countries implemented city-wide lockdowns, only allowing residents to leave their homes twice a week or even fewer. In response to this special circumstance, many educators converted traditional day-to-day education into another form of teaching—virtual interactive learning. This form of teaching relies heavily on digital learning platforms, with the arrangement of conducting all teaching and learning activities online [12]. Rather than attending schools daily, teachers and students attended classes and met each other through web-cameras and computers [13, 14]. Teachers conducted lectures on the internet while students participated in in-class learning activities and completed all course assessments, including examinations, online. It is thus very likely that the practice of technology-enhanced learning will dominate the future of education, which in turn calls for further attention to understanding digital learning implementation from different perspectives.

There are a considerable number of studies evaluating the effectiveness of educational technology integration [15–17]. These studies converged to support that technology-enhanced learning is beneficial for teaching and learning [16, 18, 19]. For example, digital learning tools can facilitate the delivery of learning materials, student learning, peer collaboration, and teacher-parent communication [18]. There are also studies that examined how educational technology can be beneficial for learning [20], how to enhance traditional classroom teaching through technology integration [21, 22], and how web-based technology fosters changes in teaching pedagogies and their related challenges [23]. Even when switching teachers, teaching in a technology-enhanced medium does not affect the learning outcomes [24]. A recent scoping review by Yim and Su [25] examines 46 studies on Artificial Intelligence (AI) learning tools in K-12 education, highlighting how tools like block-based Machine Learning (ML) environments and Teachable Machine support student outcomes, including cognitive skills, affective and behavioral engagement, course satisfaction, and soft skills. Although the effect of digital learning environments on teaching and learning is promising and depends on students'

preferences [26], turning a traditional classroom into a technology-integrated classroom is not easy.

Adopting a new method of teaching creates many challenges and concerns for the related stakeholders. For example, Asiri and colleagues [27] presented a theoretical framework underlying the influential factors on the usage of the Jusur Learning Management System (Jusur LMS) in Saudi Arabian public universities. They classified the factors as internal to the faculty members, such as attitudes towards the system, beliefs about technology-enhanced learning, and competence in using the system, and external to the faculty members, such as barriers faced by the faculty members and demographic factors. However, existing theoretical frameworks in educational psychology, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), primarily focus on individual acceptance and usage intentions rather than the complex, multi-dimensional challenges teachers face during actual implementation. These models, while valuable for understanding initial adoption decisions, offer limited insight into the ongoing dilemmas teachers encounter when integrating educational technology into their daily practice. There are insufficient empirical investigations of the implementation dilemmas from the teachers' perspective systematically examined through a comprehensive theoretical lens that captures the full complexity of educational change processes.

To address this research gap, this study seeks to extend existing theoretical understanding by investigating the question of what specific implementation dilemmas teachers encounter when adopting technology-enhanced learning, and how these dilemmas manifest across different dimensions of educational practices. This study adopted a qualitative research design and invited teachers who had implemented comprehensive digital learning initiatives for interviews. We then adopted Windschitl's [28] framework to systematically investigate the dilemmas that teachers faced when adopting technology-integrated instruction. Data were analyzed using thematic analysis With both deductive coding (based on Windschitl's four frames) and inductive coding to identify emergent themes and patterns not captured by the original framework.

This study employs grounded theory methodology, which allows theoretical insights to emerge through systematic data analysis while using Windschitl's framework as an organizing lens. Consistent with established grounded theory procedures, data collection and analysis proceed iteratively via constant comparison until theoretical saturation is reached. That is, the point at which additional data no longer reveal new properties or dimensions of the dilemma categories [29]. Saturation was indicated by producing recurring patterns without introducing novel themes. This approach both validated Windschitl's framework and illuminated technology-specific manifestations of the four dilemma types.

Although Windschitl's framework originally described a theoretical account of practicing constructivism, it has also been applied to enhance the understanding of educational technology adoption, for example, teachers' perceptions of adopting technology-enhanced learning in their classroom [30]. However, the application of this framework to digital learning implementation represents a significant theoretical extension. While constructivism focuses on epistemological beliefs about knowledge construction, technology integration involves additional dimensions, including technical proficiency, digital pedagogy, and technology-mediated social interactions. This study proposes that Windschitl's framework, when applied to educational technology contexts, reveals unique interaction patterns among the four dilemma types that are not present in traditional constructivist implementations, thereby extending our theoretical understanding of educational change processes.

In Windschitl's [28] framework, he identified four frames of reference—conceptual, pedagogical, cultural, and political—to circumscribe the range of challenges faced by teachers. This multidisciplinary approach integrates psychological, pedagogical, sociological, and organizational dimensions of educational innovation, providing a comprehensive lens for examining the complexities of technology integration implementation. Specifically, the conceptual dilemmas refer to the challenges for teachers to understand the philosophy of new teaching pedagogies with their psychological and epistemological underpinnings. The pedagogical dilemmas denote the challenges for teachers to design curriculum and arrange teaching and learning activities in line with the demands of new teaching pedagogies. The cultural dilemmas represent the challenges that the changes in teaching and learning practices pose in a classroom-based culture. Finally, the political dilemmas refer to the challenges that teachers have when confronted with various stakeholders in the school community, such as the institutional norms and ordinary practices of the school. He concluded that efforts to implement new practices in schools are hampered by these four dilemmas that make the transformation of new learning practices difficult.

Building on this foundation, we propose that when applied to educational technology contexts, these four dilemma types interact in distinct ways to create unique implementation challenges. Unlike traditional pedagogical innovations, technology integration simultaneously demands changes across all four dimensions while introducing additional complexity through the technical layer of digital tools and platforms. This study contributes to the growing body of research on Information and Communication Technology (ICT) adoption in K–12 education, aligning with international efforts to integrate digital learning systems into everyday teaching while extending theoretical understanding of how educational change processes operate in technology-mediated environments.

II. Windschitl's Four Frames of References

In 2002, Windschitl introduced a framework that categorizes the challenges teachers face when implementing constructivist instruction [28]. Constructivism is a teaching philosophy that emphasizes student-centered learning, in which students actively construct knowledge through experience rather than passively receiving information. Windschitl's framework identifies four types of dilemmas—conceptual, pedagogical, cultural, and political—that teachers encounter, making it a valuable tool for understanding the challenges of teachers when adopting technology-enhanced learning from a multidisciplinary approach.

A. Conceptual Dilemmas

Conceptual dilemmas arise when teachers grapple with understanding the philosophical and psychological underpinnings of constructivism. Constructivism is rooted in the idea that learners construct knowledge based on their experiences [9], which contrasts with traditional, teacher-centered approaches. Teachers may struggle to reconcile their existing beliefs about teaching with constructivism's epistemological foundations, such as the emphasis on student-driven inquiry. For example, a teacher accustomed to lecturing may find it challenging to adopt a facilitator role that encourages students to explore ideas independently.

B. Pedagogical Dilemmas

Pedagogical dilemmas involve the practical challenges of designing and implementing constructivist-aligned curricula and learning experiences. Constructivist teaching often requires complex, student-centered activities, such as problem-based learning or collaborative projects, which demand significant planning and flexibility. Teachers may face difficulties in creating lessons that balance structure with student autonomy or in assessing student progress in non-traditional ways [31]. These challenges are compounded by time constraints and the need for professional development to master constructivist methods [32].

C. Cultural Dilemmas

Cultural dilemmas emerge as teachers and students reorient classroom roles and expectations to align with the constructivist ethos. In a constructivist classroom, teachers act as facilitators and students take on more active roles in their learning. This shift can disrupt established classroom norms, leading to resistance from students accustomed to traditional teaching or from colleagues who value conventional methods. For instance, students may initially resist engaging in-class activities if they are used to traditional learning environments, in which the teacher explains content and students work on practice problems [31]. Such a situation requires teachers to foster a new classroom culture.

D. Political Dilemmas

Political dilemmas arise when teachers face resistance from stakeholders, such as school administrators, parents, or policymakers, when they question institutional norms. Constructivist practices, which prioritize student inquiry over standardized testing, may conflict with school policies or parental expectations. Teachers may discover a lack of support systems to navigate the challenges [33] or even encounter pushback when advocating for innovative teaching methods that challenge authority or disrupt traditional power structures or existing norms in their education settings [31]. These dilemmas highlight the broader systemic barriers to adopting constructivist approaches.

III. Method

A. Research Design and Sampling

This study adopted a grounded theory approach to understand the challenges of implementing educational technology integration from the teachers' perspective. Such an approach allows researchers to systematically examine real-life phenomena through established theoretical lenses while remaining open to emergent themes [29]. The data for this project were collected in a three-year project commissioned jointly by [this identifying information is intended to be omitted during the review process]. This project aimed to evaluate the effectiveness of digital learning initiatives in the twelve-year compulsory education system in Hong Kong. The twelve-year compulsory education covers primary school (from primary 1, age 6, to primary 6, age 11) and secondary school (from secondary 1, age 12, to secondary 6, age 17). There were fourteen schools that participated in the project, with eight primary schools, four secondary schools, and two special education schools (see Table 1). All of them participated in the support scheme for e-Learning in schools (also known as "WiFi 100") from 2014 to 2016. The scheme targeted improving the WiFi infrastructure, such as ensuring that there were sufficient mobile computing devices for use in class. Five of these schools (Education Bureau of Hong Kong, 2015) also participated in the "Pilot Scheme on e-Learning in Schools" in 2012. As the first group of schools to adopt technology-mediated learning in the 12-year compulsory education in Hong Kong, these 14 schools were more experienced than other schools in Hong Kong in implementing e-Learning, and their teachers were better prepared to apply innovative teaching approaches. In sum, we interviewed 54 teachers who had adopted digital learning tools in their courses, covering diverse fields of study, including English, mathematics, Chinese, general studies/liberal studies, and others. All in all, these teachers revealed 21 types of difficulties that they encountered when adopting ICT-mediated instruction in their courses.

Table 1. Descriptive statistics for in-class observations

School Type	Number of participating schools	Number of teachers interviewed
Primary Schools	8	28
Secondary Schools	4	17
Special Education Schools	2	9

B. Data Collection

Semi-structured interviews with 54 teachers were conducted, guided by theoretical sampling. Purposive sampling initially targeted schools with comprehensive e-learning initiatives, and subsequent sampling expanded to teachers across diverse subjects and grade levels to capture the breadth of implementation experiences. Each interview lasted 45–60 minutes and was audio-recorded with participants' consent.

The interview protocol elicited teachers' lived experiences while remaining open to emergent themes. Core questions included: (1) experiences and motivations for technology integration; (2) challenges encountered; (3) beliefs about technology's role and subject-specific concerns; (4) preparation requirements compared to traditional lessons; (5) student responses and classroom management issues; and (6)

institutional and parental support. Follow-up probes (e.g., "Can you give a specific example?") encouraged elaboration and facilitated identification of cross-case patterns.

Classroom observations complemented the interviews by documenting technology use, student engagement, and instructional activities. While interview data remained primary, consistent with the focus of the grounded theory on participants' perspectives, observations provided contextual depth and enriched understanding of the challenges described.

C. Data Analysis

Analysis followed the three-stage coding process of grounded theory. Interviews were transcribed verbatim in Cantonese and analyzed in that language to preserve nuance, with representative quotes translated for presentation.

Open coding involved line-by-line analysis to identify concepts related to implementation challenges (e.g., "time pressure," "technical difficulties"), documented in analytic memos. *Axial coding* systematically related initial codes to broader categories, applying Windschitl's four-frame structure while remaining attentive to themes that did not fit neatly within it. For example, beliefs about subject appropriateness were grouped under conceptual dilemmas, while lesson preparation demands were categorized as pedagogical dilemmas.

Selective coding integrated these categories into a coherent framework, revealing how dilemmas in one dimension cascaded into others. For example, conceptual uncertainties contributed to inadequate planning (pedagogical dilemmas), which in turn led to classroom management difficulties (cultural dilemmas).

Throughout the analysis, memo writing captured emerging insights and guided subsequent data collection. For example, memos concerning impact on writing skills prompted targeted follow-up questions in later interviews. Regular team meetings resolved coding discrepancies through consensus, and theoretical saturation was achieved once later interviews yielded no new properties or dimensions.

IV. Results and Discussion

In this section, we present the findings from teacher interviews regarding the difficulties they encountered when implementing digital pedagogical approaches. We classify the feedback collected from teachers according to Windschitl's [28] four frames of reference: conceptual, pedagogical, cultural, and political dilemmas.

A. The Conceptual Dilemmas

The conceptual dilemmas refer to the challenges for teachers to understand the concept of the new teaching pedagogy. Our interviews revealed that teachers encountered several difficulties when adopting mobile learning technologies as an instructional strategy in their teaching (see Table 2).

An adequate and updated understanding of educational technology integration is a prerequisite to conducting digital learning effectively. Teachers reported that they were required to change their deeply rooted concepts of teaching and learning to incorporate the concept of ICT-mediated instruction, which required time and effort to become familiar with technology-mediated pedagogical frameworks. One teacher specifically noted that they needed to be aware of the latest trends in educational technology, including learning platforms and mobile devices, with their functions and usability in teaching and learning practices. However, the rapid advancement of technology posed challenges to teachers trying to keep current with the latest innovations. As teachers reported: "Every year there are new devices, new apps, new platforms. By the time we master one tool, there's already something newer," and "I feel like I'm always playing catch-up. The students sometimes know more about the devices than I do, which makes me hesitant to use them in class." Consequently, teachers needed to familiarize themselves with not only teaching pedagogies but also continuously advancing technological tools to maximize the benefits of digital learning environments, making it more time-consuming than traditional teacher-directed methods.

Table 2. Summary of the conceptual dilemmas

	Dilemmas	Number of teachers reported
Understanding of Educational Technology Integration	Teachers are required to continuously be familiar with the latest application of technological tools	1
	Teachers need additional time to become familiar with educational technology	5
Application of Digital Learning Tools	The content delivered in technology-mediated environments is not as in-depth as that in traditional teaching	1
	Educational technology might further intensify the performance between the capable students and those less capable	2
	Digital learning tools undermine Chinese and English writing skills	4
	ICT-mediated instruction is not suitable for high-level mathematics learning	1
	Technology integration is not good for developing students' reading habits or abilities	1
	Educational technology enhances students' abilities to find answers, although they do not know how to assess the validity of answers	2

Teachers also expressed concerns about educational technology practices, likely stemming from deep-rooted traditional concepts of teaching and learning. These concerns limit their use of technology-integrated approaches. Specifically, four teachers reported that digital learning tools should not be used to learn writing skills, and one teacher perceived that educational technology would not be useful for learning high-level mathematics. Two other teachers thought that ICT-mediated instruction might further enhance the learning performance of capable students but might not help those who are struggling academically. Even when they believed the learning content was applicable to technology-enhanced learning, they thought it should be delivered through traditional teaching and learning practices

or supplemented with them. These conceptions further reduced teachers' willingness to adopt digital pedagogical approaches despite being contrary to empirical findings. For example, Wang and Hirose [34] showed that mobile phones can enhance the learning performance of English reading comprehension skills because mobile devices can provide an interactive learning environment for students. Likewise, Fletcher and Nicholas [35] found that increased use of iPads and laptops for reading activities enhanced students' engagement and motivation in reading for contextual purposes.

B. The Pedagogical Dilemmas

The pedagogical dilemmas denote the challenges for teachers to design curriculum and related teaching activities targeted to fulfill the requirements of the new teaching pedagogy. Our interviews revealed that teachers needed to overcome challenges mainly related to resources, skills, and educational technology platforms (see Table 3).

Resource constraints were primarily related to the extra preparation time required when conducting technology-mediated instruction. It took additional time to select adequate technological resources to integrate with teaching content and design. Teachers needed to investigate the functions of different technological tools and evaluate which parts of their teaching materials were suitable for integration with digital platforms. In most circumstances, teachers still had to adapt their materials to the technological tools, even when the tools were suitable for their teaching content and design. Finally, they also needed to ensure all the technologies and tools were functioning properly. All of these procedures require preparation time much longer than traditional teaching methods. Teachers from 13 schools agreed that this was the prime challenge. One English teacher described: "For a traditional lesson, I might spend an hour preparing. For a technology-integrated lesson, it can take three or four hours, finding resources, testing whether they work, and creating backup plans if technology fails."

Skills-related challenges occurred when teachers found that it was necessary to equip students with adequate skills before implementing digital learning initiatives. However, teachers found it challenging to teach students to use and learn via technology. For instance, teachers needed to teach students basic skills to operate electronic devices for learning, adding to their already tight teaching schedules. They especially pointed out that it took extra time and effort for classes typically containing 30–40 students, and these extras hindered their teaching schedule.

Finding appropriate educational technology software and assessment tools was another major challenge. Sometimes, existing tools could not meet teaching objectives. For example, many digital assessment tools offer limited functions, lacking comprehensive and reliable evaluation of student learning performance. Teachers from 5 schools also suggested that existing software could not support their pedagogical design. For example, they could not input tailor-made exercises into the existing eTextbooks to address students' needs.

Technical difficulties on both teachers' and students' sides hindered the teaching and learning process. Teachers from about half of the schools encountered problems using technological resources. These problems included both hardware issues, such as unstable WiFi connections and obsolete electronic devices, and software problems. Students from eight schools also experienced problems related to hardware and software, including unstable WiFi connections, hardware crashes, accidentally locked up devices, malfunctioning devices (e.g., tablets crashed frequently), and eTextbooks that were difficult to use. Additionally, students from nine schools found it difficult to input words on tablets. These unexpected technical problems often delayed technology-integrated activities in class.

Table 3. Summary of the pedagogical dilemmas

	Dilemmas	Number of teachers reported
Resources Constraint	Increased time spent on preparation (e.g., preparing teaching materials, developing pedagogies, testing the devices)	13
Skills Constraint	Teachers find it difficult to solve technical problems during teaching without the assistance of a technician.	6
	Teachers find it time-consuming and challenging to train students with technological skills (i.e., the methods required to use the device for learning)	4
Technological Tools	Digital assessment tools (i.e., apps and the learning management system) cannot provide comprehensive, reliable, or quantitative evaluation of students' technology-mediated learning performance	5
	The functions of the software (i.e., the apps) cannot realize the teachers' pedagogical design	5
	Hardware problems hinder teaching and learning (e.g., unstable WiFi connections, obsolete device models, and software problems)	7
	Hardware broke down (i.e., an unstable WiFi connection, hardware crashes, and accidentally locked up)	8

C. The Cultural Dilemmas

The cultural dilemmas represent the challenges that arise from teaching and learning practices in a classroom-based culture. Our findings showed that technological tools may not always be facilitative but sometimes detrimental to learning performance (see Table 4).

Teachers in eleven schools reported that educational technology distracted students from learning. For example, one teacher described "The moment I say 'take out your tablets', students' eyes light up and attention shifts completely to screens. Then when I need them to listen, it's like pulling teeth to get their eyes back on me". Students were overly engaged in digital activities and then failed to respond to teachers' instructions or explanations. They were reluctant to stop working with their devices when teachers intended to move on to the next activity or topic. In extreme cases, some teachers reported that students did not feel they had learned from the lesson or did not concentrated on the learning materials. Rather, they had played with the iPads. This created an additional burden for in-class management. These classroom management challenges in technology-integrated environments echo the broader cultural shifts required when implementing digital learning platforms, as identified during crisis-driven online education transitions [12–14].

Apart from distracting students from learning, using educational technology also creates additional difficulties in maintaining teaching progress. Teachers from nine schools reported that their students took longer to type responses into the system and log in to the learning management system, making learning with educational technology less efficient. In the worst scenarios, students misused electronic devices to disrupt another student's learnings, such as locking another classmate's device, changing another classmate's password, and sending instant messages to other classmates.

Table 4. Summary of the cultural dilemmas

Dilemmas	Number of teachers reported
Additional burden for in-class management	11
Additional difficulties for maintaining the teaching progress when learning with an electronic device	9

D. The Political Dilemmas

The political dilemmas refer to the challenges that teachers face when adopting new teaching practices in their courses. Our interviews revealed that teachers needed to overcome difficulties from two main sources (see Table 5): insufficient institutional support and insufficient parental support.

Regarding institutional support, our data showed that school management often discouraged teachers from technology-integrated practices by imposing additional constraints. One teacher reported that the school conducted additional evaluations of teaching performance related to educational technology implementation. Two teachers from different institutions mentioned receiving inadequate support for designing new teaching materials and other resources. Their schools did not provide Learning Management Systems (LMS), preventing teachers from accessing resources from former teachers or systematically storing their materials to conduct digital learning initiatives. These measures imposed additional pressure on teachers and reduced their incentive to teach with educational technology in classrooms. This aligns with the external factors identified by Asiri and colleagues [27] that can hinder technology adoption, including institutional barriers and inadequate support systems.

Regarding parental support, most teachers agreed that successful technology-mediated instruction requires continuous support, understanding, and involvement from parents. However, teachers often found that parents misunderstood the reasons for educational technology integration and reacted negatively when students engaged with it. "A teacher shared: 'Some parents immediately assume we're just letting their children play games. One parent even asked if I was being lazy by using technology instead of 'real teaching'", indicating that parents often misunderstood students' learning with electronic devices as playing video games. Another primary school teacher reported that some parents prevented their children from using iPads because they believed learning performance deteriorated when learning with iPads. These skeptical attitudes toward educational technology posed additional challenges and demotivated teachers from adopting technology for teaching.

Table 5. Summary of the political dilemmas

	Dilemmas	Number of teachers reported
Institutional Support	The school did not have the infrastructure of Learning Management System (LMS) to store digital teaching materials and other digital resources	2
	The schools imposed additional pressure on educational technology practices by adding additional evaluations	1
Parental Support	Parents misunderstood students learning with the digital device as playing video games	1
	Parents' support, understanding, and involvement can enhance the successfulness of incorporating technology for learning	1

V. General Discussion

The process of changing existing teaching and learning practices into a new form is more difficult than many in education realize. However, there are insufficient empirical investigations to understand the difficulties, challenges, and dilemmas that teachers must overcome. In view of this, this study systematically investigated teachers' experiences of implementing educational technology integration. Following the framework of Windschitl [28], the reported difficulties from the teachers' perspective have been classified as conceptual, pedagogical, cultural, and political dilemmas.

A. Theoretical Contributions and Implications

This research extends existing theoretical understanding in several key ways.

First, our findings reveal that when applied to technology-mediated learning contexts, Windschitl's four dilemma types exhibit unique interaction patterns not observed in traditional constructivist implementations. Unlike pedagogical innovations that primarily challenge epistemological beliefs, digital learning integration simultaneously demands technical proficiency, pedagogical redesign, cultural adaptation, and political negotiation. Our interview data demonstrated that teachers experienced these dilemmas not as separate challenges but as interconnected and mutually reinforcing barriers. For instance, teachers' conceptual uncertainty about the pedagogical value of specific digital tools (conceptual dilemma) directly influenced their willingness to invest additional preparation time (pedagogical dilemma), which in turn affected their confidence in managing technology-mediated classroom dynamics (cultural dilemma).

Second, this study identified specific manifestations within each of Windschitl's original categories that are unique to educational technology contexts. Within conceptual dilemmas, teachers struggled with their deeply held assumptions about whether and how technology can enhance learning in their specific subject areas. Our findings revealed that teachers held misconceptions about the suitability of digital tools for certain subjects. Specifically, four teachers believed that technology-enhanced learning undermined Chinese and English writing skills, one teacher perceived it was not suitable for high-level mathematics learning, and two teachers thought it might intensify performance gaps between

capable and struggling students. These beliefs conflicted with empirical evidence supporting the benefits of educational technology [16, 34, 35]. These findings reveal deeper epistemological conflicts concerning the nature of learning itself. Such tensions extend beyond the dominant technology acceptance framework, which typically emphasizes individual acceptance and usage intentions.

Within pedagogical dilemmas, teachers identified a substantial increase in cognitive and temporal demands when integrating mobile technologies into instruction. Teachers reported that technology-enhanced learning implementation required significantly more preparation time than traditional methods, including investigating technological tools, adapting materials, and ensuring proper functionality. Additionally, some teachers found it challenging to troubleshoot technical problems during instruction without technical assistance, while others reported difficulty training students in technological skills. This finding extends the current framework by revealing that teachers experienced technology integration not merely as a skills gap but as a fundamental increase in professional workload and cognitive demands. These challenges align with research on enhancing traditional classroom teaching through technology integration [21, 22] and how educational technology can be beneficial for learning when properly supported [20, 24].

Within cultural dilemmas, our data revealed unique classroom management challenges specific to technology-enhanced learning environments. Teachers reported that educational technology distracted students from learning, with students becoming overly engaged in digital activities and failing to respond to teacher instructions. Teachers noted that mobile learning created additional difficulties in maintaining teaching progress, as students took longer to complete digital tasks and sometimes misused devices to disrupt classmates' learning. These findings suggest that mobile learning necessitates the establishment of new classroom cultures and norms that existing theoretical frameworks do not adequately address. The cultural shifts required for effective implementation became particularly evident during crisis-driven transitions to virtual interactive learning [12–14], highlighting how web-based technology fosters changes in teaching pedagogies while presenting related challenges [23].

Within political dilemmas, our analysis identified two primary sources of resistance: insufficient institutional support and inadequate parental understanding. Teachers reported that school administrators often imposed additional evaluation requirements for technology-enhanced teaching without providing corresponding support systems. Regarding parental support, teachers found that parents frequently misunderstood mobile learning activities as "playing games" rather than legitimate educational practices, leading to resistance and reduced home support for digital learning initiatives. This reflects the external factors identified by Asiri and colleagues [27] that influence technology adoption, including barriers faced by faculty members and institutional constraints. The challenges became particularly pronounced during the widespread adoption of online learning platforms [10, 11], demonstrating both the potential and the limitations of technology-enhanced learning at a large scale.

B. Interdisciplinary Significance

Another notable strength of this research is its interdisciplinary significance. The research does not just address technology-enhanced learning from a single perspective. Instead, it leverages insights from multiple disciplines to provide a comprehensive view of the challenges teachers face. By using Windschitl's framework, the paper classifies the dilemmas into four distinct dimensions that draw from different disciplinary traditions:

Drawing on educational psychology and epistemology, the dimension of conceptual dilemmas investigates how teachers' underlying beliefs about teaching and learning can either hinder or help the adoption of digital learning tools. Our findings revealed that teachers' beliefs about subject-specific technology applications operated as cognitive filters shaping their implementation decisions. For example, teachers who believed learning technologies undermined writing skills and another teacher who thought they were unsuitable for high-level mathematics demonstrated how epistemological beliefs about learning processes influence technology acceptance. This finding demonstrates how domain-specific beliefs mediate the relationship between technologies' features and actual usage patterns, even when contradicting empirical evidence supporting the effectiveness of these technologies in these areas [36, 37]. Drawing on Lam and colleagues' [9] work on pedagogical philosophies, this highlights the importance of addressing fundamental beliefs about teaching and learning when implementing new technologies.

Rooted in curriculum theory and instructional design, the perspective of pedagogical dilemmas examines the practical challenges of adapting traditional lessons and lesson plans for a technology-enhanced environment. Our study identified significant resource constraints, skills gaps, and technological limitations that teachers must overcome, highlighting the need for integrated approaches to curriculum development that address these practical challenges. This aligns with research showing how technology-enhanced learning can be effectively integrated into diverse learning environments, such as blended learning [5] and the flipped classroom approach [6, 7], yet such integration requires careful pedagogical planning and support.

Borrowing from sociological insights, the aspect of cultural dilemmas explores how established classroom norms and cultural expectations can conflict with the demands of a digital learning environment. The findings of students' difficulties transitioning between device use and teacher instruction point to the need for new classroom management approaches that incorporate digital literacy and digital citizenship concepts. These challenges became particularly evident during the global crisis, when educators rapidly converted traditional education to virtual, interactive learning formats [10–12], highlighting the cultural shifts required for effective technology-enhanced learning implementation.

The dimension of political dilemmas emerges at the intersection of educational policies and administrative practices, addressing how institutional constraints and stakeholder influences shape technology-enhanced learning implementation. Our results demonstrate the critical importance of administrative support and parental engagement for successful technology-enhanced learning

practices. This is particularly relevant given the widespread adoption of online learning platforms during recent global circumstances [13, 14], which demonstrated both the potential and the challenges of technology-enhanced learning at scale. By drawing on theories and methodologies from education, psychology, sociology, and political science, our paper reveals that the transformation of classroom practices involves a complex interplay of factors. This interdisciplinary approach enriches our understanding and demonstrates that successful technology-enhanced learning implementation requires attention not only to technological considerations but also to conceptual, pedagogical, cultural, and political dimensions. The multidisciplinary perspective illustrates that addressing only one aspect of technology-enhanced learning challenges (such as technology infrastructure) while neglecting others (such as teacher beliefs or institutional support) will likely result in incomplete and ineffective implementation.

Teachers' perspective reveals how implementation challenges threaten both professional identity and competence. When teachers describe "playing catch-up" with technology or question its appropriateness for particular subjects, they articulate domain-specific epistemological beliefs about how learning occurs—beliefs that general professional development often fails to address [36, 37]. These accounts highlight the limits of generic training programs and underscore the need for approaches that focus on subject-specific pedagogical concerns.

Classroom management challenges, such as "pulling teeth to get their eyes back on me", illuminate fundamental reconfigurations of teacher authority and the attention economies that shape technology-mediated environments. Such dilemmas extend beyond technical skill and point to deeper transformation in the relational dynamics of teaching.

Political dilemmas gain particular salience through parental questioning of "lazy teaching", which reflects broader societal tensions between technological progress and traditional educational values. Teachers are situated in this tension that simultaneously advocates for innovation while defending their professional judgment. This dual positioning represents a form of emotional labor that extends beyond technical and pedagogical demands.

Together, these findings elucidate why institutional support must encompass more than resources and training. Effective support requires explicit legitimation of teachers' professional judgment in adopting non-traditional approaches. This recognition is critical for maintaining teacher authority, reducing emotional strain, and ensuring that technology integration enhances rather than undermines professional identity.

C. Practical Implications

After identifying the four areas of challenge, we provide practical suggestions on how to overcome these challenges based on our empirical findings.

First, the identified conceptual dilemmas focused on teachers' understanding of technology-mediated pedagogies and beliefs about the consequences of implementing digital learning tools. The findings revealed that teachers held misconceptions about the pedagogical applications of specific technologies, often viewing them as replacements for, rather than enhancements to, traditional teaching methods. The success of educational technology integration depends largely on whether teachers develop accurate conceptual understanding and positive beliefs about technology's pedagogical potential. School management should organize targeted professional development that addresses not just technical skills but also pedagogical beliefs and epistemological assumptions about learning with technology [38].

Second, the pedagogical dilemmas identified by the teachers emphasize constraints on resources, skills, and technology-enhanced learning platforms. Teachers could consider setting up a network within the school to facilitate the distribution, development, and adoption of digital learning materials. Teachers could line up to share the additional responsibility related to the increased workload of implementing educational technology. For example, the workload would be largely reduced if each teacher were responsible for converting traditional teaching materials into electronic, or if teachers could take turns to test the device, or if teachers could share their knowledge in using technology-integrated tools, or if teachers could share their understanding of the recent trend of educational technology. During the lesson, technical issues could be resolved immediately if technical support staff provided in-class technical support, and thus the lesson would not be interrupted. If possible, school management could consider providing additional curriculum to help students master basic skills in learning with technology-enhanced learning tools.

The identified cultural dilemmas focused on the additional burden and difficulties for in-class management. Teachers also reported their experiences in overcoming these difficulties during the interviews. For example, teachers reported that they arranged technology-enhanced learning activities and explanations in different lessons so as to ensure that students would not be distracted by technological devices. Apart from reorganizing the teaching goals, teachers reported that they adopted additional measures to capture students' attention after using technology-enhanced learning tools for learning. These include, for example, requiring students to turn their iPad monitor towards the teachers or to clap or raise their hands instead of touching their digital devices. Teachers also reported the usefulness of the Mobile Device Management System. This system enables teachers to directly view students' instant digital footprints on a central device and, if necessary, lock students' devices. Teachers also mentioned that it is useful to deliver detailed instructions before using the device, reminding students that the technology-enhanced learning tools are for learning and not for playing, or even warning students with punishments for improper behaviors. Yet it takes time to train students to have the right attitude and habit of using technology-enhanced learning tools.

Last but not least, the identified political dilemmas are related to institutional and parental support in conducting technology-enhanced learning. While there is substantial evidence supporting the positive effects of technology-enhanced learning [39–41], school management should consider devoting additional resources to implement, support, and maintain technology-enhanced learning. School management could also organize seminars for parents to understand the importance, experiences, and reasons for

conducting technology-enhanced learning, thereby reducing their misunderstandings. Without their support, teachers cannot bring the pedagogy of technology-enhanced learning into real practice.

D. Limitations and Future Research

While this study provides valuable insights into teachers' experiences implementing educational technology, it has several limitations that should be acknowledged. The sample was limited to schools in Hong Kong that had participated in specific technology-enhanced learning initiatives, potentially limiting generalizability to other contexts and cultures.

The study focused primarily on teachers' perspectives and did not capture the views of students, parents, administrators, and other stakeholders. Hearing perspectives from different stakeholders would provide a more comprehensive understanding of implementation challenges. Future research could expand to include teachers from other academic levels and educational contexts, particularly examining how cultural factors influence implementation across different regions. Longitudinal studies tracking how teachers overcome challenges over time could yield valuable insights into effective support strategies. Specifically, future research could explore the questions of how teachers' beliefs about technology-enhanced learning evolve over extended periods, which institutional factors most strongly predict successful technology-enhanced learning adoption, and how student outcomes compare across the different implementation approaches identified in this study.

VI. Conclusion

Implementing technology-enhanced learning is not easy. This paper systematically investigated the challenges from a multidisciplinary approach that teachers must overcome to provide practical suggestions for school management, teachers, and parents to maximize the success of technology-enhanced learning. Through gathering diverse empirical evidence, we can gain confidence in nurturing our future generation to become digitally savvy. Such an investigation would be fruitful in facilitating our future generation to contribute to our increasingly technology-based society, especially as we now enter an era of new AI-driven educational technologies. The interdisciplinary framework presented here offers a comprehensive lens for understanding and addressing the complex challenges inherent in educational technology implementation, contributing to both theory and practice in the field.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

H.K.Y.N. and P.L.: conceptualization; H.K.Y.N.: Methodology, Formal analysis; P.L.: Funding acquisition; H.K.Y.N. and P.L.: Writing. Both authors had approved the final version. Both authors shared first authorship.

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