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Technology-enriched learning through the lens of Bloom's Taxonomy: A practice-based framework from classroom observations

Paul Lai Chuen Lam [1] and Hilary Ka Yan Ng [2] *

*Correspondence:
hilaryngnky@gmail.com
School of Education and Languages,
Hong Kong Metropolitan University,
30 Shepherd Road, Homantin, Hong Kong
Full list of author information is available at the end of the article

Abstract

The benefits of incorporating technology into education are promising; however, there are limited suggestions on how to transform traditional classrooms into technology-enriched learning environments. To address this gap, this project adopts the grounded theory approach, framed within Bloom's Revised Taxonomy and outcome-based education principles. It involved observing sixty-six real-life classes across academic levels to gather teaching practices that involve the use of technology. The collected teaching practices were classified into five major categories based on their intended purpose and the alignment with cognitive learning levels from Bloom's Taxonomy: interactive learning activities (Remember/Understand), experiential learning activities (Apply), mutual learning activities (Analyze), innovative learning activities (Evaluate), and performance-based learning activities (Create). This categorization allows for a comprehensive understanding of how technology can be effectively integrated to achieve different cognitive learning outcomes. A panel of experienced teachers with doctoral degrees and at least five years of professional teaching experience evaluated these practices' desirability and transferability across educational contexts. Such an evaluation provides incremental insight into the essential factors underlying effective transformation while considering the transfer of learning principles central to outcome-based education. This project provides theoretical, practical, and methodological implications for the field and teaching practitioners.

Keywords: Teachers, Classroom observations, Teaching practice, Education technology, Technology-enriched learning, Digital learning, Bloom's Taxonomy, Outcome-based education

Introduction

The popularity of integrating technological tools in teaching and learning practices is growing globally. Technology shapes the ways we conduct teaching and learning. Schools have even turned to fully online learning models whilst coping with the recent coronavirus pandemic (Lam & Ng, 2023; Mourlam et al., 2023). With technology, students and teachers can interact not only through traditional face-to-face contact but also on different digital platforms (Fingrut & Ng, 2023). These digital platforms provide a medium for interactive learning activities to take place, where students and teachers can learn through simulations, videos, virtual experiments, and games in a fun and engaging manner (Cherrez & Gleason, 2022; Nash et al., 2023; Shulamit & Yossi, 2011). In our own experience with educational technology implementation, we have observed that these platforms significantly enhance student engagement when properly integrated into lesson planning. Empirical research documented the promising results of technology-enriched learning in both learning outcomes (Eom, 2014; Hidayat et al., 2022; Ng & Lam, 2023b; Park & Choi, 2014; Tang & Zhang, 2025) and learning experiences (Erdoğdu & Çakıroğlu, 2021; Ng & Lam, 2022, 2023a; Strijbos & Weinberger, 2010; Tang & Zhang, 2025).

Teachers occupy a central position in bringing pedagogical changes (Keiler, 2018). A recent study showed that teachers possessed welcoming attitudes toward using digital technologies in education and considered it extremely facilitative (Wang et al., 2019). However, around 70% of teachers expressed that they did not approve of, modestly, or extremely disagreed with teaching in a technology-enriched learning environment as easy. To transform the classroom into a technology-enriched one, teachers are required to overcome various difficulties. Some of these difficulties are external to the teachers, such as students' preparedness, school culture, and management support (Johler et al., 2022; Kay, 2006; So & Swatman, 2006; Spiteri & Chang, 2020). Some of these difficulties are internal to the teachers, such as the lack of time, insufficient skills, and personal fear of technology (e.g., Ertmer, 1999; Liu et al., 2021; Spiteri & Chang, 2020). In our professional development workshops with Hong Kong teachers, we consistently find that technological confidence is the most significant barrier to adoption. This observation aligns with Nikolić and colleagues (2019), who provided a list of difficulties teachers experienced when using education technologies in teaching. Their results showed that almost half of the respondents regarded having insufficient technological skills in teaching as the major difficulty, far beyond other factors, including the unavailability of school equipment (26.53%), lack of internet access (8.16%), and other factors (17.34%). These difficulties in incorporating technology have hindered realizing its full potential benefits for learning experiences and outcomes.

In fact, insufficient skill is detrimental when adopting technology in their practices (Fernández-Batanero et al., 2022; Guillén-Gámez et al., 2022; Ng, 2023). Teachers are required to spend extra time and collaborative training to transform their classrooms (Spiteri & Chang, 2020). This not only increases their workload but also discourages them from adopting innovative approaches. There are recent attempts to share teaching practice with the use of single case studies (e.g., Appova et al., 2022; Bartholomew et al., 2018; Parry & Taylor, 2021). However, there remains a lack of comprehensive guidance based on real-life practices for teachers. While, as Kong and colleagues (2014) have pointed out, there was a repository for using technologies in different disciplines at both primary and secondary school levels (Education Bureau, 2012), the depository is based on subject level. Given that teachers from different subjects and levels can employ similar teaching activities and pedagogical approaches, and that educators can draw inspiration from how other subjects integrate technology into their teaching, subject-specific guides have inherent limitations.

Providing the promising benefits of technology on learning (e.g., Lam et al., 2021), a comprehensive, practice-based guideline is important to optimize the use of educational technology and its associated benefits. Additionally, it can improve the effectiveness of the digital technology used. Therefore, the objective of the research is to develop guidelines with a wide range of teaching practices to facilitate teachers' use of technology in their classrooms.

This guideline is grounded in real-life classroom observations across Hong Kong's K-12 system. eLearning continues to be an important agenda in Hong Kong's education system, especially during the COVID-19 pandemic when school closures necessitated remote learning (e.g., Lam & Ng, 2023). Hong Kong has a robust technological infrastructure, including high-speed internet and widespread device usage, providing a favorable environment for technology-enriched learning (Education Bureau, 2024; HKSAR, 2022). We have personally witnessed the rapid digital transformation of Hong Kong classrooms during this period, with many teachers developing innovative solutions despite minimal preparation time.

The developed guidelines can provide concrete strategies on how teachers can adapt to their specific contexts and teaching goals for leveraging technology's pedagogical affordances. The findings can contribute to the broader literature by empirically deriving a taxonomy of technology integration practices mapped to their intended learning purposes. This guideline would provide useful information to prepare the pre-service, in-service, and other teaching practitioners to use digital technologies in their pedagogy. Teachers in different territorial contexts should face similar issues in starting, choosing, and refining the strategy to incorporate digital technology tools in teaching and learning practice. This guideline would thus provide added benefits to teachers across the globe.

Theoretical framework

The integration of technology in education requires a structured approach to ensure meaningful learning outcomes. Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001) provides a robust framework for understanding and designing educational activities across different cognitive levels. The taxonomy consists of six hierarchical levels of cognitive processes: Remember, Understand, Apply, Analyze, Evaluate, and Create. Each level represents increasingly complex forms of thinking and learning, making it particularly relevant for technology integration that aims to develop higher-order thinking skills.

This framework aligns closely with outcome-based education principles, which emphasize the importance of clear learning objectives and measurable outcomes (Spady, 1994). In the context of technology-enriched learning, this means designing activities that not only utilize digital tools but also target specific cognitive levels and facilitate the transfer of learning across different contexts. Transfer of learning, defined as the ability to apply knowledge and skills acquired in one situation to new situations (Perkins & Salomon, 2012), is crucial for ensuring that technology integration leads to meaningful and lasting educational impacts.

Applying Bloom's Revised Taxonomy to technology-enriched learning environments offers several advantages. First, it provides a systematic way to ensure that technological tools are used to support various cognitive processes rather than just lower-order thinking skills. Second, it helps teachers design activities that progressively develop students' cognitive abilities while leveraging technology's affordances. Third, it facilitates the assessment of learning outcomes and the evaluation of technology's effectiveness in supporting different types of learning objectives.

The present project

The present project aims to develop practice-based guidelines to provide solid suggestions on how to incorporate technology into the classroom. In addition, we also adopt Bloom's Revised Taxonomy as an analytical framework to ensure that the collected practices not only represent diverse uses of technology but also target different cognitive levels of learning. Classroom observations were conducted to collect real-life practices. Unlike other research methods, such as surveys and interviews, classroom observations can gather more detailed evidence on the entire learning process from beginning to end (Babbie, 2014). It can provide the opportunity to understand the effect of specific teaching practices on students' learning behaviors. Hence, classroom observation is best suited to describe instructional practices. It allows us to observe the actual events of how technology is used in classrooms across teachers, subjects, and curricula. To facilitate teachers' adoption of the practice, all the collected practices are categorized according to their teaching purposes and, additionally, the corresponding cognitive levels in Bloom's Taxonomy. Such categorization enables teachers to conveniently choose from a list of strategies according to their pedagogical aims and desired learning outcomes.

Method

The grounded theory approach was adopted to collect and analyze practical suggestions on how different forms of teaching and learning activities can be conducted in the technology-enriched learning environment, with particular attention to their cognitive complexity levels as defined by the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001). This approach enables researchers to examine real-life phenomena without presumptions (Babbie, 2014) while systematically categorizing observed learning activities according to their cognitive demands.

The present study focused on Hong Kong's education system and was part of a three-year longitudinal project commissioned by the Education Bureau of Hong Kong (EDB). The education system in Hong Kong follows a structured and compulsory framework. The present study covered diverse age groups, including 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). Hong Kong's education system is known for its competitive and examination-oriented nature, with students facing a series of examinations such as the Territory-wide System Assessment (TSA) in primary school and the Hong Kong Diploma of Secondary Education (HKDSE) in secondary school (Education Bureau, 2018). These examinations play a crucial role in assessing students' academic performance and determining their progression to higher levels of education, especially for the HKDSE, which determines the chance of entering university.

The present sampling covered a large part of the K-12 setting. For better illustration, we have grouped the study levels into different key stages. The frequency distribution of subjects in each key stage is summarized in Table 1.

Analysis framework

Our analysis integrated the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001) within the context of outcome-based education to examine how different teaching practices engage students across cognitive levels while promoting knowledge transfer. The revised Bloom's Taxonomy provides a framework for understanding the cognitive complexity of

Table 1 Numbers of classroom observations in each study level

	Key Stage 1 (P1 - P3)	Key Stage 2 (P4 - P6)	Key Stage 3 (S1 - S3)	Key Stage 4 (S4 - S6)	Total
English	9	5	7	1	22
Mathematics	0	14	1	2	17
Chinese	0	4	2	1	7
General Studies / Liberal Studies	0	5	0	7	12
Other Subjects	0	0	5	3	8
Total	9	28	15	14	66

Note. P: Primary School. S: Secondary School.

learning activities, ranging from basic recall and comprehension to sophisticated evaluation and creation. This framework was particularly relevant given Hong Kong's emphasis on developing higher-order thinking skills within its examination-oriented system. When analyzing teaching practices, we considered both their immediate cognitive demands and their potential for knowledge transfer across different contexts, aligning with outcome-based education's emphasis on demonstrable learning outcomes (Spady, 1994).

Data collection procedure

Each class was observed by at least two researchers, who completed the Classroom Observation Protocol for Undergraduate STEM (Smith et al., 2013; COPUS) independently during the class and discussed their discrepancies until they reached a consensus. The COPUS contained various teaching and learning behaviors in the classrooms, including taking notes, individual thinking, asking questions, lecturing, following up, and playing videos. These different teaching and learning behaviors were categorized according to a specific time point during the lesson (Smith et al., 2013). This method can provide an opportunity to understand the consequences of students' behaviors when different teaching practices have been adopted. This instrument has previously been adopted to understand the effect of mobile learning (Jolley & Ayala, 2015; Wilkinson, 2017).

In addition, we have also invited an expert teacher panel to evaluate the collected practices. The qualitative feedback obtained from expert evaluations would also highlight crucial implementation factors. These provide valuable insight into the important considerations for successfully transitioning to technology-rich learning environments.

Results

The five categories of teaching practice across subjects, levels, and cognitive domains

The analysis identified a total of 28 unique real-life technology-enriched teaching practices observed across 66 classes in Hong Kong's K-12 education system (see Table 2). These practices were categorized into five major categories based on their intended pedagogical purposes and analyzed according to their cognitive demands using Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Following the principles of outcome-based education (Spady, 1994), we examined both the immediate learning outcomes and the potential for knowledge transfer. We observed some distinct patterns in how these categories of practices were implemented across subject areas between primary and secondary school levels, with varying levels of cognitive engagement and transfer potential:

Table 2 Descriptions of teaching practices in each category with examples

Teaching Practices	Descriptions
Category 1: Interactive Learning Activities	
1.1. Competitive Games	Students form small groups to finish computer-based learning games.
1.2. Student Presentation	Students deliver presentations based on their information searching on the internet.
1.3. Individual Games	Students play computer-based games independently.
1.4. Multimedia Watching	Students watch a variety of multimedia software, such as text, audio, images, animations, video, and interactive content for learning.
Category 2: Experiential Learning Activities	
2.1. Object Simulation	Students learn by educational simulations in which computers turn the abstract concept into virtual simulations with tactile feedback from students.
2.2. Process Simulation	Students learn by process simulation in which computers visualize the sequence of steps.
2.3. Multimedia Production	Students produce multimedia output as the learning outcomes.
2.4. Digital Tools	Students use a variety of online tools for learning.
2.5. Online Searching	Students search for information online through different search engines.
2.6. Online Community	Students visit websites to browse information and complete some pre-designed learning activities.
Category 3: Mutual Learning Activities	
3.1. Cooperative Tasks	Students form groups to achieve different shared learning goals with similar responsibilities.
3.2. Collaborative Tasks	Students form groups to achieve different shared learning goals with differentiated responsibilities.
3.3. Peer Illustration	Students learn from the sharing of representative work on the internet.
3.4. Peer Discussion	Students form groups for small group discussions to achieve their learning outcomes.
3.5. Peer Commenting	Students review peer work and provide comments on other classmates' learning outcomes through the internet and computing devices.
3.6. Peer Teaching	Students design questions for their classmates' tests.
3.7. Online Community	An online learning community can be formed when teachers allow students to access and comment on other students' learning outcomes.
3.8. Collaborative Sharing	Students form groups to discuss an issue from different group-based perspectives and share their group's point of view to the whole class through computers.
Category 4: Innovative Learning Activities	
4.1. Flip Strategy	Students study online learning materials before the class, and then teachers use class time for in-depth learning.
4.2. Facilitating Strategy	Teachers use technological tools for illustration to convey their explanations in clear and concise ways.
4.3. Inductive Strategy	Teachers introduce the concepts based on the online exercises completed by students.
4.4. Electronic Resources Strategy	Teachers select learning content and create eTextbooks in PDF format to assist the teaching. The eTextbooks also include web addresses for students' extended learning.
4.5. Visualizing Strategy	Teachers create animations in gif format to illustrate the abstract concept clearly.
4.6. Differentiated Strategy	Students can learn at their own pace with the use of technological tools.

Category 5: Performance-based Learning Activities	
5.1. Multiple-Choice Questions	A series of computer-based multiple-choice questions can be designed by the teachers to facilitate their teaching.
5.2. Digital Platform Exercises	Teachers make use of the exercises provided in the eTextbook or the digital platform.
5.3. Open-ended Questions	Teachers provide students with exercises in the format of open-ended questions such that students' direct text responses can be assessed.
5.4. Multimedia Sharing	Students upload their multimedia products, such as pictures, videos, and voice recordings to the cloud system.

Interactive Learning Activities were widely adopted across subjects like mathematics, languages, and general studies in both primary and secondary classes. This category aims to enhance classroom interaction among students and teachers. Such classroom interactions can increase students' attention span and motivate students to participate in the learning activities, fostering a more engaging and student-centered learning environment. Four different kinds of practices fall into this category. The first one is *Competitive Games* – students form small groups to finish computer-based learning games. For example, students competed on Quizlet to learn the calculation of percentages in a Primary 5 mathematics class. The second one is *Student Presentation* – students deliver presentations based on their information searching on the internet. For example, learning about different ethnic minority groups in China by searching for information on the internet in a Primary 5 general studies class. The third one is *Individual Games* – students play computer-based games independently. For example, learning English vocabulary by a game on Nearpod in a Primary 3 English class or learning to calculate the circumferences of different shapes online in a Primary 6 mathematics class. The final one is *Multimedia Watching* – students watch a variety of multimedia materials, such as text, audio, images, animations, video, and interactive content for learning. For example, students watched videos to learn percentages in a Primary 6 mathematics class and parabola in a Secondary 4 physics class.

Experiential Learning Activities provide opportunities to learn by doing. Such learning activities enable students to learn by exploring the learning materials independently. Six different kinds of practices fall into this category. This category is more common in Science, Technology, Engineering, and Mathematics (STEM) compared to humanities subjects. The first two are related to simulation. One of them is *Object Simulation* – students learn through educational simulations in which computers turn abstract concepts into virtual simulations with tactile feedback from students. For example, the three-dimensional figures simulations in a Primary 6 mathematics class and the symmetrical figures simulations in a Primary 4 mathematics class. Another is *Process Simulation* – students learn by process simulation in which computers visualize the sequence of steps. For example, the process of converting the capacity of liquid to volume in a Primary 5 mathematics class. The third one is *Multimedia Production* – students produce multimedia output as the learning outcomes. For example, students recorded oral presentations and uploaded them to the internet for sharing in a Secondary 3 English class and a Secondary 5 tourism and hospitality studies class. The fourth one is *Digital Tools* – students use a variety of online tools for learning, for example, Google Earth to learn time zone in a Primary 5 general studies class, gMaths to learn polar coordinates in a Secondary 1 mathematics class, and online dictionaries to learn vocabularies in a Secondary 5 English class. The next one is *Online Searching* – students search for information online through different search engines. For example, finding the diameter of a basketball to learn circumferences in a Primary 6 mathematics lesson. The final one in this category is visiting *Online Community* – students visit websites to browse information and complete some pre-designed learning activities. For example, students visited a website to watch the video before completing multiple-choice questions in a Primary 3 English class or read the historical areas of Hong Kong from a few websites before completing a writing task in a Primary 4 general studies class.

Mutual Learning Activities aim to provide students with mediums to learn from peers. It is more commonly used in humanities and language subjects to develop social skills in addition to understanding the learning contents. There are eight different scenarios identified in this category. The first one is *Cooperative Tasks* – students form groups to achieve different shared learning goals with similar responsibilities. For example, cooperating to circle and highlight all the numbers in percentages with the use of computers in a Primary 5 mathematics class and cooperating to build a complete circuit and upload a photo of it in a Secondary 1 integrated science class. The second one is *Collaborative Tasks* – students form groups to achieve different shared learning goals with differentiated responsibilities. For example, cooperatively conducting a computer-based presentation on insects, with one student being the facilitator while another one controlled the computer in a Primary 6 general studies class and role-playing the stories of surrogacy in a Secondary 5 liberal studies class. The third one is *Peer Illustration* – students learn from the sharing of representative work on the internet. For example, learning the steps of conducting a science experiment in a Secondary 1 class. The next one is *Peer Discussion* – students form groups for small group discussion to achieve their learning outcomes. For example, students completed tasks on factors of production with discussion and uploaded the learning outcomes to the internet to facilitate teachers' review in a Secondary 4 economics class. The fifth one is *Peer Commenting* – students review peer work and provide comments on other classmates' learning outcomes through the internet and computing devices. Students expressed their comments by giving 'like' in a Primary 1 English class, voting for their top three classmates in a Primary 6 mathematics class, or giving written comments to classmates in a Secondary 3 biology class. The sixth one is *Peer Teaching* – students design questions for their classmates' tests. For example, a calculation competition in a Primary 6 mathematics class. The next one is *Online Community* – students join to form an online learning community when teachers allow students to access and comment on other students' learning outcomes. For example, learning the association between temperature and length of bubbles in a Secondary 3 biology class. The final one is *Collaborative Sharing* – students form groups to discuss an issue from different group-based perspectives and share their group's point of view with the entire class through computers. For example, learning the effect of the one-child policy in a Secondary 5 liberal studies class.

The next category is *Innovative Learning Activities*, which aims to provide different teaching and learning experiences. This category was mostly observed in STEM subjects to stimulate students' interest in learning. There are six identified scenarios related to this category. The first one is the *Flip Strategy* – students study online learning materials before the class, and then teachers use class time for in-depth learning. For example, learning tenses usage in a Primary 5 English class. The second one is *Facilitating Strategy* – Teachers use technological tools for illustration to convey their explanations in clear and concise ways. For example, explaining a complicated graph in a Secondary 4 mathematics class or giving comments with illustrations in a Secondary 4 liberal studies class. The third one is the *Inductive Strategy* – teachers introduce the concepts based on the online exercises completed by students. For example, learning how to calculate the perimeter of a circle in a Primary 6 mathematics class. The fourth one is the *Electronic Resources Strategy* – teachers select learning content and create electronic textbooks in PDF format to assist the teaching. The electronic textbooks also include web addresses for students' extended learning. For example, learning about the rotation of the Earth in a Primary 5 general studies class. The next one is the *Visualizing Strategy* – teachers create animations in gif format to illustrate abstract concepts clearly. For example, illustrating the difference between a continuous action and an action at a particular time point in a Primary 5 English class to learn the usage of the tenses. The final one is *Differentiated Strategy* – students can learn at their own pace with the use of technological tools. For example, practicing the pronunciations with a set of earphones and microphones in a Primary 3 English class or choosing a topic related to ethnic minority groups in China for their presentation in a Primary 5 general studies class.

The final category is *Performance-based Learning Activities*, which aims to provide a variety of tools with different formats to understand students' learning progress and performance. Such understanding can facilitate teachers to adjust their teaching plans and strategies. Four scenarios fall into this category. The first one is the use of *Multiple-Choice Questions*, in which a series of computer-based multiple-choice questions can be designed by the teachers to facilitate their teaching. For example, learning the format of the proposal in a Secondary 3 English class, the tense usage in a Primary 5 English class, or argumentative writing in a Secondary 3 Chinese class. The second one is the use of *Digital Platform Exercises* – teachers make use of the exercises provided in electronic textbooks or digital platforms. For example, completing exercises to learn symmetrical graphics in a Primary 4 mathematics class, learning vocabulary in a Primary 3 English class, or learning reading and comprehension skills in a Primary 4 Chinese class. The third one is the use of *Open-ended Questions* – teachers provide students with exercises in the format of open-ended questions such that students' direct text responses can be assessed. This is useful, for example, to learn to give directions in a Primary 3 English class. The final one is *Multimedia Sharing* – students upload their multimedia products, such as pictures, videos, and voice recordings to the cloud system. For example, learning negotiation skills in a Secondary 3 Chinese class. This category is relatively widely used in Primary classes compared to Secondary classes, possibly due to greater emphasis on formative assessments and practice exercises in early education (Lam & Wong, 2020).

Overall, while all five categories had instances across subjects and levels, their adoption was shaped by the nature of the subject and the developmental stage of the students. In general, STEM subjects showed greater adoption of experiential and innovative practices, whereas humanities subjects adopted more interactive and mutual learning practices.

Additional study: Panel evaluation of teaching practice

To further understand the desirability of these different practices, the research team recruited three teaching experts to evaluate the desirability of different collected practices. The three expert panelists were purposively selected as they met the criteria of having a doctoral degree and possessing at least five years of professional teaching experience, ensuring they had sufficient expertise to evaluate the teaching practices. The experts were asked to evaluate a list of videos based on the extent to which they would put effort into adopting a specific practice in their classes from 1 (very unlikely) to 10 (very likely). It assesses the likelihood of an instructor putting effort into adopting a given practice, which reflects its perceived benefits, ease of use, and overall desirability. Spaces were also provided to fill in their comments next to their ratings. The list consisted of 28 video clips selected from our classroom observations, with each clip demonstrating a specific teaching practice in Table 2. Using videos instead of descriptions enhanced the authenticity of the evaluation task for the expert panelists. Randomizing the video order minimized potential order effects. While the small expert panel limits generalizability, the in-depth video-based evaluation process allowed us to gather rich qualitative insights on the desirability of the practices from highly experienced teachers. Such evaluation enables us to explore the selection and refinement of practices for inclusion in the final practice-based guideline. The mean, standard deviation, minimum and maximum values obtained from the three panel judges are presented in Table 3.

Table 3 Descriptive statistics of teaching practices by Bloom's Taxonomy category and their potential for learning transfer

Teaching Practices	Mean	Standard Deviation	Cognitive Levels	Transfer Potential
Category 1: Interactive Learning Activities				
1.1 Competitive Games	8.20	1.05	Remember, Understand, Apply	Near Transfer
1.2 Student Presentation	7.87	1.15	Analyze, Evaluate, Create	Far Transfer
1.3 Individual Games	7.00	1.73	Remember, Understand	Near Transfer
1.4 Multimedia Watching	4.50	2.12	Remember, Understand	Near/Far Transfer
Category 2: Experiential Learning Activities				
2.1 Object Simulation	8.00	0.00	Understand, Apply	Far Transfer
2.2 Process Simulation	8.00	0.00	Understand, Apply, Analyze	Far Transfer
2.3 Multimedia Production	7.83	1.26	Apply, Analyze, Evaluate, Create	Far Transfer
2.4 Digital Tools	7.67	0.28	Understand, Apply, Analyze	Near/Far Transfer
2.5 Online Searching	7.00	1.90	Analyze, Evaluate	Far Transfer
2.6 Online Community	4.67	2.08	Remember, Understand, Apply	Near/Far Transfer
Category 3: Mutual Learning Activities				
3.1 Cooperative Tasks	8.17	1.94	Understand, Apply, Analyze, Evaluate	Near/Far Transfer
3.2 Collaborative Tasks	7.87	1.33	Analyze, Evaluate, Create	Far Transfer
3.3 Peer Illustration	7.33	1.33	Understand, Analyze, Evaluate	Near/Far Transfer
3.4 Peer Discussion	7.17	0.26	Analyze, Evaluate	Far Transfer
3.5 Peer Commenting	4.83	0.29	Analyze, Evaluate	Near/Far Transfer
3.6 Peer Teaching	8.67	0.28	Evaluate, Create	Far Transfer
3.7 Online Community	5.83	2.02	Multiple Levels	Far Transfer
3.8 Collaborative Sharing	5.50	0.50	Analyze, Evaluate, Create	Far Transfer
Category 4: Innovative Learning Activities				
4.1 Flip Strategy	8.00	1.00	Understand, Apply, Analyze	Near/Far Transfer
4.2 Facilitating Strategy	7.67	1.53	Understand, Analyze, Evaluate	Near/Far Transfer
Category 5: Performance-based Learning Activities				
5.1 Multiple-Choice Questions	8.00	1.00	Remember, Understand, Apply	Near Transfer
5.2 Digital Platform Exercises	5.33	1.04	Understand, Apply, Analyze	Near/Far Transfer
5.3 Open-ended Questions	5.33	0.58	Analyze, Evaluate, Create	Far Transfer
5.4 Multimedia Sharing	4.17	0.29	Create, Evaluate	Far Transfer

The panel regarded those practices that could engage students as more desirable. Category 1 – Interactive Learning Activities – scored the highest group average (mean = 7.29), followed by Category 2 – Experiential Learning Activities (mean = 7.20), Category 3 – Mutual Learning Activities (mean = 6.90), Category 4 – Innovative Learning Activities (mean = 6.83), and finally Category 5 – Performance-based Learning Activities (mean = 6.08). This finding suggests that teaching purposes can be an influential factor in technology-enriched learning. However, the discrepancy of the means within each category is large, ranging from 1.50 to 3.33. In other words, there are both desirable and undesirable practices in each category. That is, the desirability of a particular practice is not influenced by teaching purposes. Nonetheless, the panel of experts preferred the practices that facilitated classroom interaction.

Panel judges regarded 3.1 Cooperative Task (mean = 8.17) as the most desirable, followed by five different practices with the same mean, i.e., 1.1 Competitive Games; 4.1 Flip Strategy; 2.1 Object Simulation; 2.2 Process Simulation; and 5.1 Multiple-Choice Questions; all means = 8.00. Among them, two of the practices focus on enriching the learning environment with cooperative (3.1 Cooperative Task) and competitive (1.1 Competitive Games) elements. The other two practices focus on enriching the learning materials delivery process by simulating the process (2.2 Process Simulation) and object properties (2.1 Object Simulation). One of the practices can change the traditional face-to-face instructional method (4.1 Flip Strategy). The remaining one can increase the efficiency of the assessment (5.1 Multiple-Choice Questions). These findings suggest that practices enhancing the whole teaching and learning process, from learning materials delivery to teaching workload reduction, were more desirable.

In contrast, panel judges considered 2.6 Online Community (mean = 4.67) as the least desirable, followed by 5.4 Multimedia Product (mean = 5.17), 4.6 Differentiated Strategy (mean = 5.33), 5.3 Open-ended Questions (mean = 5.33), 3.8 Collaborative Sharing (mean = 5.50). It is noteworthy that none of the bottom five belongs to Category 1 – Interactive Learning Activities. Specifically, technology is regarded as the only source of learning tools in two of the practices (4.6 Differentiated Strategy; 2.6 Online Community), as a channel for sharing in another two practices (5.4 Multimedia Sharing; 3.8 Collaborative Sharing), or as a tool for assessment (5.3 Open-ended Questions). The panel remarked that teachers in these examples had not made full use of technology. This is because the teacher should review students' responses instantly and provide immediate feedback to students. They added that if there was no face-to-face interaction with teachers, it would be better to ask students to do the activities at home. Hence, these practices do not show a balance between traditional and technology-enriched learning environments. As a result, education technology cannot replace face-to-face interaction in the classrooms.

General discussion

In view of the insufficient suggestions for teachers to use digital technology in their practice, this project attempts to develop a practice-based guideline on how to incorporate technology into teaching and learning practices. In this project, a repertoire of real-life teaching practices was collected from naturalistic classroom observations, and then a panel of judges was set up to evaluate the desirability of each technology-enriched practice. The project extended the focus to primary and secondary school students. Most of the existing research focused on teaching university students (e.g., Lam et al., 2021). With the increase of technology-enriched practices in primary and secondary schools in Hong Kong (Wang et al., 2019) and the K-12 education setting in the United States (Kay, 2006), research on incorporating digital technology in the primary and secondary education setting is still inadequate, especially on the ways to implement the effective and innovative use of digital technology in the classrooms. Other than this, this project can bring 1) practical advancement to the teachers across levels to incorporate technology into their practice, 2) theoretical advancement to the underlying influential factors of effective incorporation of digital technology into teaching and learning, and 3) methodological advancement on how to investigate the technology-enriched teaching practice.

The developed repertoire of real-life technology-enriched practices

First, the repertoire of 28 technology-enriched practices developed in this project may serve as a helpful starting point for teachers aiming to transform their classrooms. The guideline demonstrated diverse ways technology can serve different teaching purposes and be used in different ways. Both pre-service and in-service teachers can choose according to their teaching purpose and select the most suitable practices from a list of 28 unique technology-enriched practices. These 28 unique technology-enriched practices were further classified into five different categories, aligned with cognitive learning levels from Bloom's Taxonomy (Anderson & Krathwohl, 2001):

Category 1 – Interactive Learning Activities (Remember/Understand):

This category intends to enhance classroom interaction and supports the foundational cognitive processes of remembering and understanding. Practices such as competitive games, student presentations, individual games, and multimedia watching create dynamic classroom environments that stimulate students' attention, motivation, and involvement in the learning process. In contrast to the traditional lecture-based classroom, in which students were largely passive, previous reviews have shown the benefits of interactive strategies in enhancing academic achievement, student attitudes, and student retention (Saleem et al., 2022).

Importantly, interactive learning activities can address the prevalent issue of cultivating rote learning approaches in the Hong Kong educational context. Students in Hong Kong are usually pressured by the city's highly examination-oriented elite educational systems, especially in the early stage of education, to compete for good-quality secondary schools and universities (Kember, 2016). These pressures push students to resort to coaching for examinations and remembering model answers. Such traditional instructional norms in Hong Kong tend to prioritize content transmission over interactive pedagogies, cultivating passive learners (Chan & Rao, 2010). By actively engaging students through these interactive learning activities, students can be better prepared for the demands of 21st-century learning goals in becoming active learners (Chan, 2010).

Beyond Hong Kong, the value of interactive learning is well-established across diverse educational settings (Saleem et al., 2022). These approaches resonate with constructivist learning theories that emphasize the active construction of knowledge through social interactions and hands-on experiences (Lam et al., 2021). As such, the developed practice-based guidelines can provide a robust framework on how to conduct interactive learning activities in real-life settings that apply to global educators.

Category 2 – Experiential Learning Activities (Apply):

This category is rooted in the education philosophy of "learning by doing", providing students with opportunities for hands-on learning and the application of knowledge. Practices such as object simulations, process simulations, multimedia production, use of digital tools, online searching, and online community can provide authentic, contextualized learning experiences to students.

Experiential Learning Activities are closely aligned with the principles of problem-based and self-directed learning, which have been found to enhance essential 21st-century competencies such as deep thinking, knowledge application, and logical reasoning (Chu et al., 2017). With the use of experiential learning activities, students can gain authentic experience with real-world challenges and develop a deeper understanding of complex concepts.

In Hong Kong, Experiential Learning Activities resonate with recent curriculum reforms emphasizing student-centered and self-directed learning approaches for whole-person development to meet future challenges in the real world. These approaches can help counterbalance the traditional emphasis on rote memorization and teacher-centered lecturing (Kember, 2016). Moreover, the developed real-life practice-based guidelines can provide a framework for educators worldwide to provide authentic, hands-on learning experiences to their students.

Category 3 – Mutual Learning Activities (Analyze):

This category places a strong emphasis on facilitating peer learning, collaboration, and social skills development in tandem with content mastery, promoting analytical thinking through social interactions. Practices such as cooperative tasks, collaborative tasks, peer illustration, peer discussion, peer commenting, peer teaching, online community, and collaborative sharing create opportunities for students to learn from and with one another.

The benefits of collaborative and cooperative learning strategies are well-documented in education literature. These approaches have been shown to enrich learning experiences and enhance learning outcomes (e.g., Almogren, 2023; Lam et al., 2021). Through engaging in peer-based learning activities, students can actively construct knowledge through social interactions, compromising, and synthesizing different perspectives (Yang, 2023).

In the Hong Kong context, Mutual Learning Activities align closely with the collectivistic values that emphasize social harmony, interdependence, and respect for group-oriented goals (Cross et al., 2011). These activities can prepare students for the collaborative work environments they are likely to encounter in Hong Kong's modern, service-driven economy. A review showed that peer interaction was effective in promoting learning across different nations (Tenenbaum et al., 2020). As such, these practice-based guidelines can provide a valuable resource for educators to provide peer-based, socially oriented learning experiences for students.

Category 4 – Innovative Learning Activities (Evaluate):

This category aims to introduce novel teaching and learning experiences to supplement conventional teacher-centered learning, encouraging students to make evaluative judgments. Practices such as flipped strategy, facilitating strategy, inductive strategy, electronic resources strategy, visualizing strategy, and differentiated strategy can reinvent the learning experiences.

All these strategies align with the rationale of constructivist pedagogies to put students at the center of learning (Lam et al., 2021). These strategies enable students to actively engage in higher-order thinking processes, structured discovery processes, and independent learning that can enhance learning outcomes (Höffler & Leutner, 2007; Ng & Lam, 2025; Tomlinson, 2014). With the use of technological tools, personalized learning can also be actualized by systems that provide questions according to students' learning progress (Lam et al., 2021).

In Hong Kong, Innovative Learning Activities resonate with the education reform to place more emphasis on student-centered pedagogies, addressing concerns over excessive rote learning in the city's historically didactic instructional approaches (Kember, 2016). By introducing innovative, engaging, and personalized learning experiences, these strategies can better prepare students for the demands of the 21st-century knowledge economy (Lam et al., 2021).

Category 5 – Performance-based Learning Activities (Create):

This category encompasses assessment strategies to evaluate students' learning progress formatively and provides opportunities for students to engage in creative synthesis of knowledge. Practices such as multiple-choice questions and open-ended questions are common in obtaining students' formative feedback. However, the emergence of technological tools enables these assessments to be conducted in a more interesting and engaging manner. Other practices, such as exercises on learning platforms and multimedia sharing, also emerged.

All these strategies focus on gauging and understanding students' learning progress through an evidence-based approach. They can be used for different purposes within Bloom's Taxonomy (Anderson & Krathwohl, 2001). The integration of close-ended questions, such as multiple-choice questions and exercises on learning platforms, allows for the efficient assessment of core concepts, specifically, knowledge and comprehension of foundational knowledge. The integration of open-ended questions and multimedia sharing facilitates the evaluation of higher-order thinking abilities, such as application, analysis, synthesis, and evaluation (Dixson & Worrell, 2016).

In the Hong Kong context, Performance-based Learning Activities resonate with the societal emphasis on academic achievement, particularly in preparation for the competitive university admission examinations (Kember, 2016). These activities can provide a comprehensive understanding of student progress, documenting evidence of practice for evidence-based decisions on instructional approaches and solutions to parental concerns about academic preparedness (Stefl-Mabry, 2018). Meanwhile, the principles underpinning Performance-based Learning Activities align with global trends in assessment reform, which advocate for the integration of authentic, performance-based assessments to better evaluate students' mastery of 21st-century skills (Darling-Hammond & Adamson, 2010). As such, these practice-based guidelines can provide real-life practice to enhance assessment practices, contributing to the broader field of education worldwide.

Therefore, the developed practice-based guidelines for technology integration hold relevance not only within the Hong Kong context but also promise applicability in other educational settings. Although this repertoire of real-life technology-enriched practices may not be exhaustive, its suitability can be adapted to suit various study levels, contexts, and disciplines. This list provided valuable suggestions on how technology can be purposefully employed to achieve different teaching objectives. Teachers can further modify and refine this repertoire of technology-enriched practices to suit their specific instructional goals and curricular needs. While this guideline is rooted in the local Hong Kong context, its underlying principles and practices resonate with broader global trends emphasizing the integration of technology to enrich the learning experience and enhance learning outcomes. Therefore, this practice-based framework contributes to the growing body of knowledge on effective technology integration strategies, thus offering a transferable model for educators worldwide seeking to leverage technological affordances to transform and enrich their pedagogical approaches.

It is worth noting that our observations primarily focused on English, Mathematics, and Liberal Studies, which naturally influenced the preferences and rankings in our findings. Different subject combinations might yield different rankings of preferred technology-enriched practices, and practitioners should consider their specific subject domain when adopting these practices.

The implications of the three important factors

The project has taken a step further to set up a panel to evaluate the desirability of each technology-enriched practice from experienced teachers. This guideline can help not only teachers but also school management in making more informed decisions on choosing the more appropriate technological facilities, thus reducing detours and saving time and resources for them. This is important because incorporating digital technology usually incurs expensive initial set-up and long-term maintenance costs. For example, school management needs to invest time and money in the technological infrastructure and digital content (Fielden, 2002; Morris, 2008). Students and teachers, likewise, need to devote effort to becoming familiar with the devices and software (Weller, 2004). Difficulties can also be related to obtaining and managing technological resources (Ertmer, 1999), such as financial issues (Gedik et al., 2012) and support systems (Abrami et al., 2011; Kahu, 2013). Our project serves as an exploratory approach to understanding the desirability of practice. Further investigation can extend the current scope from the teachers' perspectives to other stakeholders, such as students.

This project revealed three important factors that contribute to the success of technology-enriched learning. First, interacting with students via face-to-face conversation is an important factor in achieving learning success. The interactive, self-paced, repetitious, and customizable features of eLearning tools can enrich students' learning experience (Huffaker & Calvert, 2003; Twigg, 2002) and are promising in facilitating different constructive teaching pedagogies (Lam et al., 2021). However, the teacher panel favored strategies that provided sufficient opportunities for teachers and students to interact. It is reasonable since teacher-student interaction is the key component to differentiating technology-enriched learning from fully asynchronous learning. In asynchronous learning environments, students are required to complete self-paced online training on their own. Students and teachers are not required to be online at the same time. Hence, interaction has been regarded as one of the important factors in incorporating technological tools in the face-to-face learning environment. This is also one of the concerns during the shutdown of schools in facing the COVID-19 pandemic (Lam & Ng, 2023). While the panel favored practices facilitating interaction, the relatively small differences in average desirability ratings across the five practice categories (ranging from 6.08 to 7.29 out of 10) suggest that opportunities for interaction alone did not definitively predict a practice's perceived value. There was substantial variability in ratings within each category as well (ranging from 1.50 to 3.33), indicating other crucial factors beyond just the teaching purpose impact a practice's desirability.

The second factor is the importance of timely feedback. The opportunity to provide students with immediate feedback is continuously valued by educators in the field (Wang & Zhang, 2020) and has been regarded as an established principle of good teaching practice. For students, 'action without feedback is completely unproductive' (Laurillard, 2013, p. 55). For teachers, continually monitoring students' learning progress during the lessons is beneficial. Such teaching strategies would enable teachers to adjust their teaching progress by, for example, providing further clarifications whenever needed. This is also why synchronous technology-enriched learning is more popular than asynchronous learning, even during the sudden closure of schools amidst the recent coronavirus pandemic outbreak from 2019 to 2022. However, the panel's feedback reveals that simply providing technological capabilities for timely feedback was insufficient on its own. Practices viewed as least desirable often diminished or removed the teacher's instructional presence and real-time facilitation abilities. The qualitative comments emphasized how feedback and monitoring from teachers remain essential for productive learning, even when digital tools permit automated responses.

Third, the teacher panel considered the teachers' facilitation skills as essential. Technological tools can be standalone to serve as an efficient and effective medium to facilitate the learning process. However, if students only learn from technological tools without explanations from teachers, face-to-face learning, then, becomes a self-learning process that can occur in asynchronous mode. The teacher panel believed that such a learning environment could not achieve the true value of face-to-face learning. In fact, in every learning environment, students require individual and dynamic guidance and facilitation to obtain success (Hwang, 2014). Therefore, teachers' facilitation skills are also important in the technology-enriched learning environment. The emphasis on maintaining meaningful teacher roles and facilitation aligns with the finding that practices fully replacing instructors with independent technology-based activities were rated as least desirable overall. While technology offers powerful capabilities, the expert panel's insights suggest that strategic integration supplementing and amplifying the teacher's guidance, rather than the removal of the teacher's presence, is most conducive to effective learning environments.

All in all, a good practice should be able to integrate digital technology while maintaining the traditional teaching and learning components. There are cases in which some learning activities would not be possible without the assistance of technology (e.g., a student response system). As with any teaching method, creating an effective teaching and learning practice requires continuous adaptation and adjustments. This guide serves as an important foundation to prepare teachers from different levels to adopt digital technology in their teaching practices.

Our findings extend current practices in Hong Kong and globally in several ways. In the Hong Kong context, where traditional teacher-centered approaches have dominated, our guidelines provide concrete strategies for implementing student-centered, interactive approaches while maintaining the rigor expected in Hong Kong's achievement-oriented educational culture. Globally, our findings reinforce the importance of maintaining the teacher's role as facilitator rather than simply replacing teachers with technology, a nuance that adds to international discussions about technology integration in education. Future research can investigate the different uses of emerging technologies, such as generative artificial intelligence (e.g., Kwan, 2024). Meanwhile, the developed practice-based guideline can facilitate future research examining which practice types are most effective for achieving different learning outcomes.

It is important to acknowledge that our recommendation system is designed to be assistive and optional, recognizing that teachers have diverse teaching styles and preferences based on their experiences with different class demographics. Similar to the widespread adoption of tools like ChatGPT, we believe technology integration recommendations should be available on-demand rather than prescriptive, allowing teachers to maintain their autonomy while benefiting from evidence-based suggestions when desired.

Methodological implications

The project has adopted classroom observations to collect teaching practices in technology-enriched learning environments. This goes beyond common research methods of investigating with surveys and interviews (e.g., Childs et al., 2005; Jang, 2008). Using classroom observations enables us to record the entire learning process during a given time interval. That is, it can provide detailed descriptions of teaching and learning practice. Hence, classroom observations are suitable for describing instructional practices and are appropriate for us to observe the actual practice in which digital technology is used in classrooms for teaching and learning and to scrutinize specifically the underlying factors of effective use of digital technology in teaching and learning practices.

Conclusion

To conclude, the project intends to provide a repertoire of teaching and learning practices with digital technology that helps different kinds of teachers, especially during the school's sudden closure in response to external incidents. Specifically, teachers who are struggling with how to start implementing technology-enriched practices can gain insights into applying digital technology in their practices from the developed repertoire. Teachers who are considering alternative ways to conduct technology-enriched teaching practices can refer to the developed repertoire. Teachers who are concerned with refining their own teaching practices can understand the core successful factors.

Our classification of practices according to Bloom's Taxonomy provides teachers with a framework to select appropriate technology-enriched activities based on their specific cognitive learning objectives, whether they aim to promote remembering and understanding (Interactive Learning Activities), application (Experiential Learning Activities), analysis (Mutual Learning Activities), evaluation (Innovative Learning Activities), or creation (Performance-based Learning Activities). This alignment with established learning theories extends both existing Hong Kong educational practices, which have traditionally emphasized lower-order thinking skills, and global practices by providing concrete examples of how technology can support the full spectrum of cognitive processes.

The recommendations are designed to be adaptable and assistive rather than prescriptive, honoring teachers' preferences to teach according to their own styles and experiences with different class demographics. This approach to technology integration—offering evidence-based options on demand rather than mandating specific approaches—mirrors the success factors behind widely adopted technologies like ChatGPT and respects teacher autonomy while still providing valuable guidance.

Thus, this project could provide exemplary illustrations of using digital technology effectively, creatively, and innovatively, no matter the pre-service, in-service, and other teaching practitioners.

Abbreviations

COPUS: Classroom Observation Protocol for Undergraduate STEM; HKDSE: Hong Kong Diploma of Secondary Education; STEM: Science, Technology, Engineering, and Mathematics.

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Authors' contributions

Paul LC Lam: Funding acquisition, Investigation, Methodology, Project administration; Hilary Ka Yan Ng: Conceptualization, Writing – original draft, Writing – review & editing, Formal analysis.

Authors' information

Dr. Paul Lai Chuen Lam is an Associate Professor at the Centre for Learning Enhancement And Research, The Chinese University of Hong Kong. He has extensive interest and experience in teaching and learning principles, case-based teaching and learning, web-assisted teaching and learning, and evaluation of eLearning and mLearning. He also has experience in designing educational tools. uReply (http://web.ureply.mobi) is a classroom student response system developed under his supervision.

Dr Hilary Ng is currently an Assistant Professor of The School of Education and Languages at the Hong Kong Metropolitan University, Hong Kong. She is continuously developing herself with expertise across positive education, social psychology, cross-cultural psychology, digital technologies, and educational science. Her research interest centers on the individual difference in learning and well-being, and teaching and learning in the digital world.

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Availability of data and materials
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Declarations

Competing interests
The authors declare that they have no competing interests.

Author details
[1] Centre for Learning Enhancement And Research, The Chinese University of Hong Kong, Shatin, Hong Kong.

[2] School of Education and Languages, Hong Kong Metropolitan University, Homantin, Hong Kong.

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