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A modified learning by design approach to support preservice teachers' technology integration into teaching

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ABSTRACT

Integrating technology into instructional practices continues to pose a substantial challenge for preservice teachers, a challenge that has not been sufficiently addressed by existing teacher education programs. This study seeks to bridge this gap by implementing, evaluating, and refining a modified learning by design (mLBD) approach through a two-cycle design-based research (DBR) methodology. The research was conducted with 27 preservice teachers in the first cycle and 29 in the second cycle. Data were collected through semi-structured interviews, group lesson plans, micro-teaching sessions, peer feedback, and group discussions. The content analysis and constant comparative analysis identified two key impediments to effective technology integration: i) a superficial understanding of teaching methods and approaches and ii) a lack of targeted instructional guidance. Conversely, three facilitating factors were found to support preservice teachers' technology integration: i) a deep understanding of teaching methods and approaches; ii) targeted guidance from the instructor; and iii) authentic experiences in collaborative curriculum design and redesign. These findings suggest that the mLBD approach offers valuable insights for enhancing teacher education programs' capacity to support preservice teachers in effectively integrating technology into their instructional practices.

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1. INTRODUCTION

In the 21st century, the pervasive presence of technology has significantly altered educational practices. When applied effectively, technological tools can significantly improve the processes of both instruction and learning [1]. Consequently, it is crucial for preservice teachers to develop the competencies needed to integrate technology into their pedagogical practices [2], [3]. However, contemporary research reveals that preservice teachers encounter difficulties in integrating technology into their instructional practices [4], [5]. Many of them frequently feel inadequately prepared to incorporate technology in their future classrooms [6], [7]. Teacher education programs recognize the importance of technology integration, but they have struggled to effectively and adequately prepare preservice teachers to integrate technology in their future classrooms [7].

Researchers and educators [8]–[14] have suggested strategies, models, and programs to assist preservice teachers in integrating technology, while most of these initiatives are grounded in case studies or quasi-experiments, with few being based on a specific design. Meanwhile, active participation in design and

redesign processes is an encouraging method for preservice teachers to enhance their skills in technology integration [15]. Therefore, a design-based research (DBR) approach is necessary to support preservice teachers in integrating technology into their teaching practices. To address this issue, this study implemented, evaluated, and refined a modified learning by design (mLBD) approach through a two-cycle DBR to support preservice teachers in integrating technology into their teaching practice.

DBR is structured around iterative cycles of design, implementation, evaluation, and refinement [16]. This aligns well with the goals of implementing, evaluating and refining the mLBD approach over time based on the experiences and outcomes of preservice teachers as they integrate technology into their teaching practice. Moreover, DBR is particularly effective in addressing real-world educational challenges, bridging the gap between theory and practice [17]. The current study aims to refine a theoretical approach (mLBD) and apply it in authentic educational settings, which DBR facilitates by continuously testing and improving the approach in real classrooms.

Technological pedagogical content knowledge (TPACK) has been recognized as an essential requirement for 21st century teachers, as it allows them to teach a specific subject matter competently with technology. TPACK stems from Shulman's foundational work on pedagogical content knowledge (PCK) [18], [19]. Shulman [18] defines PCK as the comprehension of how particular subjects, problems, or issues are organized, represented, and adapted to cater to the varying interests and capabilities of learners, and subsequently delivered in teaching. In 2006, Mishra and Koehler [20] suggested that while Shulman's concept remains valid, the rise of technology has significantly impacted educational discussions, making technology knowledge (TK) a crucial component of teacher knowledge. TPACK is fundamental to effective teaching, as it necessitates an understanding of how to present subject matter using pedagogical strategies that are enhanced by appropriate technology [20], [21]. It emphasizes the integration of technology throughout the learning and teaching process [22]. Therefore, it is essential for teacher education programs to offer preservice teacher's opportunities to explore and integrate technology into their teaching practices.

In the context of English as a foreign language (EFL), communicative language teaching (CLT) remains one of the most effective pedagogical approaches. CLT integrates grammatical and functional aspects of language instruction. In this approach, teaching students how to use language is considered as crucial as the language learning process itself [23]. According to Littlewood [24], CLT classroom activities in EFL learning include pre-communicative (structural and quasi-communicative) activities and communicative (functional communication and social interaction) activities. In structural activities, the teacher explicitly instructs students in specific language elements, facilitating their recognition and comprehension. Quasi-communicative activities blend communicative and structural aspects of the language [24]. In functional communication activities, the teacher creates scenarios where learners must bridge an information gap or solve a problem. This goes beyond simple question-and-answer exchanges, as learners use language to describe, suggest, seek clarification, and support one another. In social interaction activities, students are encouraged to move beyond basic meaning conveyance. These activities often involve producing speech that is socially appropriate for specific contexts and relationships [24].

The current mLBD approach has evolved through the integration of six distinct synthesis of qualitative data (SQD) strategies into the original learning by design (LBD) framework. This evolution aims to enhance preservice teachers' capacity for integrating technology into CLT, thereby fostering a more robust subject-specific TPACK. Tondeur *et al.* [8] synthesize findings from 19 qualitative studies on preparing preservice teachers to integrate technology into their future classrooms, identifying six key SQD strategies: role models, reflection, instructional design, peer collaboration, authentic experience, and continuous feedback. Similarly, Rowston *et al.* [25] underscore the significance of role modeling and instructional design in teacher education programs as essential for preparing preservice teachers for effective technology integration. Furthermore, role models play a crucial role in enhancing preservice teachers' instructional design capabilities by providing concrete examples that facilitate reflection on technology use, thereby improving their ability to critically evaluate and refine their instructional designs [26]. Moreover, the six SQD strategies have positive impact on preservice teachers' ability to integrate technology into their teaching, particularly when employed as interconnected strategies [9]. Nevertheless, not all six strategies receive adequate attention in current teacher education programs [2], [3]. To address this gap, Tondeur [10] suggests the use of preservice teacher design teams, drawing from Koehler and Mishra's original LBD approach. The original LBD approach aims to develop teachers' TPACK through the design and redesign of curriculum materials [27]. However, it lacks specific supporting strategies for implementation [28], [29]. Tondeur *et al.* [3] further advocate for embedding the six SQD strategies within the original LBD framework. However, it is noteworthy that study by Tondeur *et al.* [3] do not provide detailed explanations or practical demonstrations on how to implement these strategies cohesively. Therefore, this study incorporated the six individual SQD strategies into the original LBD approach, proposing the mLBD approach and implementing the six SQD strategies to support preservice teachers' integration of technology into their teaching.

2. METHOD

2.1. Research design

This study was guided by two central research questions:

i) What aspects of the mLBD approach impeded or facilitated preservice teachers' technology integration into their teaching practices?

ii) How can the mLBD approach be refined to more effectively support preservice teachers in integrating technology into teaching?

The mLBD approach was structured around five key design principles: i) engaging preservice teachers in authentic problems to address technology integration into teaching; ii) organizing activities around designing and redesigning technology integrated curriculum materials to solve authentic problems; iii) making preservice teachers collaborate in design teams to design and redesign curriculum materials; iv) creating comparatively long-term practical experience for preservice teachers' technology integration into teaching; and v) supporting preservice teachers with ongoing dialogues of technology integration.

A two-cycle DBR methodology was selected for this study due to its capacity to simultaneously develop theoretical insights that contribute to the broader field of educational practice, while also designing and implementing interventions that address practical, real-world challenges [30]. The iterative nature of DBR is particularly valuable, as it recognizes that educational interventions are rarely executed flawlessly and, therefore, necessitate ongoing refinement and reassessment to better meet the complexities of authentic learning environments [16], [17]. This cyclical process of continuous improvement aligns with the objectives of the study, ensuring that both theory and practice evolve in tandem.

Specifically, the first DBR cycle was 7-week long with three phases and a 1.5-hour class session for each week. As shown in Table 1, the first DBR cycle was carried out as planned but the second DBR cycle had an additional week in line with module refinement based on findings from the first cycle. The second DBR cycle had an additional phase of one-week "CLT consolidation" and lasted 8 weeks. In addition, the initial phase of "TPACK comprehension" was transformed into "CLT consolidation and TPACK comprehension." The phases of the two-cycle DBR study can be demonstrated in Table 1.

Table 1. Phases of the two-cycle DBR study

	First DBR cycle	Second DBR cycle
Phases of each cycle	Phase 1: TPACK comprehension (week 1)	Phase 1: CLT consolidation (week 1) Phase 2: CLT consolidation and TPACK comprehension (week 2)
	Phase 2: TPACK-based lesson planning (week 2-3)	Phase 3: TPACK-based lesson planning (week 3-4)
	Phase 3: TPACK-based micro-teaching (week 4-7)	Phase 4: TPACK-based micro-teaching (week 5-8)

2.2. Participants

Participation in this study was entirely voluntary, with informed consent obtained prior to the commencement of each DBR cycle. The study was approved by a university Research Ethics Committee. Given the highly situated nature of DBR studies, participants are often students within the researcher's own practice [31]. In this study, both cohorts of participants were enrolled in the English teaching methods and practice course, which the first author instructed. The mLBD approach was integrated as part of this course.

There were 27 preservice EFL teachers in cycle one and 29 in cycle two in a university, located in China, an EFL context. Their ages ranged from 19 to 22 years old. They were preservice teachers in China training to become junior high school English teachers. Prior to the DBR study, they had completed courses such as instructional technology and foreign language teaching methods and approaches, which should have prepared them to integrate technology into their teaching.

2.3. Data sources and analysis

Triangulation, detailed and comprehensive descriptions, as well as member checks, represent a robust set of strategies for enhancing the credibility and dependability of qualitative research [32]. In this DBR study, a triangulated and detailed data set was collected, comprising audio recordings of group discussions, peer feedback, semi-structured interviews, video recordings of micro-teaching sessions, and documents of participants' reflection diaries and group lesson plans. Additionally, all data were validated through member checks with participants. Content analysis and constant comparative analysis were used to address the aforementioned two research questions.

3. RESULTS AND DISCUSSION

The results from the first DBR cycle revealed two key impediments and one significant facilitator affecting preservice teachers' technology integration. In response, the mLBD approach was refined during

the second DBR cycle, which led to the identification of three facilitating factors. While certain findings from this two-cycle DBR study align with existing research, others present divergent perspectives, offering new insights into the complexities of technology integration in teacher education.

3.1. Participants' different understanding and application of teaching methods and approaches

A significant distinction between the TPACK framework and traditional approaches to technology integration lies in its emphasis on content-specific pedagogical strategies, rather than generic teaching methods [33]. Recent studies, such as Han [34], underscore that CLT remains highly effective for teaching EFL, particularly within Confucian heritage cultures like China. In the first DBR cycle, participants demonstrated inadequate technology integration in their teaching practice, a deficiency largely attributed to their superficial understanding of CLT. One of CLT's key features is its emphasis on both the functional and structural aspects of language [24], [35], [36]. However, group 2 in the first cohort of participants, for example, did not use technologies to support their assumed targeted communicative function, describing festivals and asking for information about festivals. Instead, they merely used a video solely as a kind of input because they failed to understand that the key point of CLT is to cultivate students' communicative ability. In addition, an EFL learner has no sense of the symbolic meaning of eggs in Easter, so the unfamiliar characters failed to encourage students to communicate ideas on Easter. In essence, the video failed to support students' meaningful communication on describing festivals and asking for information about festivals. Consequently, there was no technology integration into their somewhat shaky teaching approach.

To bolster the second cohort of participants' teaching approaches, specifically in CLT, as shown in Table 1, an additional phase was introduced at the outset of the second DBR cycle. In addition, the initial phase of TPACK comprehension in the first DBR cycle was transformed into CLT consolidation and TPACK comprehension in the second DBR cycle. As a result, the participants in the second DBR cycle demonstrated deeper understanding of teaching approaches which enabled them to integrate technology into CLT activities to support students' meaningful communication. Group 2 in the second cohort of participants, for example, used three video clips and an online learning application to create an information gap to facilitate students' meaningful communication on their targeted communicative function, asking for a description as well as describing something. Three distinct video clips related to the Spring Festival were utilized to achieve the intended communicative objectives. The first clip, which provided an overview of the Spring Festival, was allocated to group members 1 and 2. The second clip, detailing the timing of the festival, was assigned to group members 3 and 4. The third clip, focusing on the festival's celebration practices, was distributed to group members 5 and 6. Prior to the class session, these video clips were disseminated to different group members via an online learning application, thereby creating an information gap. During the in-class activity, students were required to engage in discussions and share descriptions of the different videos to collectively compile a comprehensive understanding of the spring festival.

The results of this two-cycle DBR study underscore the critical relationship between participants' understanding of teaching methods and approaches and their ability to integrate technology effectively into their teaching practice. These findings align with Pamuk [37] assertion that successful technology integration is underpinned by strong PCK. Similarly, Hosseini and Tee [38] emphasize that effective technology integration is contingent upon a solid foundation of PCK, as evidenced by the progression observed across both DBR cycles. Moreover, the results of this study also proved Beschorner and Kruse [12] assertion that developing a solid foundation of knowledge in each domain of TPACK independently may provide the foundation and allow preservice teachers to effectively integrate technology into teaching practice. However, this finding is somewhat different from Koehler *et al.* [33] suggestion that for preservice teachers, the pathway for TPACK is to try and develop PCK and TPACK simultaneously.

These findings emphasize the need for preservice teacher programs to prioritize a deep understanding of content-specific pedagogical approaches, such as CLT, before introducing complex frameworks like TPACK. Without a strong grasp of subject-specific pedagogy, technology integration efforts are likely to remain superficial and ineffective. Teacher education programs should consider embedding explicit training on subject-specific pedagogical approaches alongside technology integration strategies to ensure that preservice teachers can apply technology in ways that enhance learning outcomes. Meanwhile, policy initiatives should promote the development of foundational pedagogical skills before advancing toward more complex technology-enhanced teaching strategies.

3.2. The instructor's different guidance on group discussions and feedback

In the first DBR cycle, unfocused dialogues during discussions and feedback sessions hindered participants' ability to effectively integrate technology into their teaching practices. for example, during group 2's feedback on group 3's iterative micro-teaching, the discussion was dominated by superficial elements, such as the color schemes of PowerPoint slides and the instructor's pronunciation and intonation.

This focus neglected the critical aspect of technology integration into CLT activities, indicating that the implementation of the fifth design principle required further consideration.

In order to direct the second cohort of participants in the second DBR cycle towards technology integration, the following detailed guidelines were given to their group discussions and feedback.

- Are the technologies used in CLT activities English-level (speed, vocabulary, and topic) appropriate for the targeted students? If yes, why do you think so? If no, why not and how to redesign them?
- Are the technologies used in CLT activities context appropriate for EFL learning? If yes, why do you think so? If no, why not and how to redesign them?
- Are the technologies used in CLT activities communicative function appropriate? If yes, why do you think so? If no, why not and how to redesign them?

In alignment with the aforementioned guidelines for discussion and feedback, the participants in the second DBR cycle focused their discussion and feedback on technology integration into CLT activities to facilitate students' meaningful communication on their targeted communicative function. For example, understanding messages and descriptions as well as describing something or somebody was the communicative objective of group 1's micro-teaching. The following is an excerpt of group 2's feedback to group 1's iterative micro-teaching in terms of how to create more opportunities for the students to describe what they did with the internet as well as how to involve more students in understanding the shared descriptions.

> "*Group 1 fostered an environment for whole-class communication, wherein students shared their internet-related activities. Would it be better if some other students, who did the same activity with the internet as the student, Zhang San, help answer the other students' questions and share their experience in using the internet instead of Zhang San himself sharing all the time. This collaborative endeavor would distribute the responsibility of answering questions and the likelihood of more comprehensive class-wide interactions.*" (P7-G2-IMTF-G1-DBR2).

In the micro-teaching session, students were tasked with sharing their online activities from the previous night. While one student shared his experiences: "*I played games on the internet, chatted online with friends, and searched for information.*" He ultimately spent five minutes elaborating on his activities while the other students listened passively. To improve this dynamic, participant 7 from group 2 suggested that peers who engaged in similar online activities should also share their experiences, thereby fostering a more interactive classroom environment. Clearly, the feedback not only directed attention to integrated technology to support students' communication but also provided concrete suggestions for creating more opportunities for students to have meaningful communication.

The findings of this study underscore the critical need for teacher education programs to incorporate structured feedback mechanisms specifically targeting the integration of technology into pedagogical practices. By instituting clear guidelines and expectations for feedback, such programs can more effectively foster collaborative learning environments that enhance preservice teachers' competencies in embedding technology into instructional design. Policymakers should advocate for the incorporation of such frameworks in teacher education curricula, ensuring that future educators are well-equipped to effectively integrate technology into their teaching methods and approaches, thereby improving student learning outcomes.

3.3. The instructor's activities as a role model

In the first DBR cycle, a technology integrated micro-teaching model was incorporated through the use of a video. After class, the participants were required to watch the video by themselves and then proceed to design and redesign their group micro-teachings. However, it seemed that the participants could not discern and fully understand why and how a particular technology supported a certain CLT activity. The participants' poor technology integration in their micro-teachings proved that just watching by themselves without the instructor's guided detailed analysis on the video's technology integration was not enough. In order to address this issue, in the second DBR cycle, the instructor not only demonstrated a technology integrated micro-teaching model but also organized a detailed analysis on how and why a particular technology was used to support the targeted communicative function on retelling stories or events. As participant 18 and 16 observed:

> "*The instructor's micro-teaching model and the subsequent analysis of the model enabled us to understand the mechanics of how to identify and use appropriate technologies to support CLT activities*." (P18-G4-PI-DBR2).
> "*Without the instructor's TPACK-based micro-teaching, our own micro-teaching design would have been perplexing. It's akin to asking someone to run before they can even walk*." (P16-G3-PI-DBR2)

These expressions indicate that both the micro-teaching model and the in-depth analysis were instrumental in helping participants identify and integrate appropriate technologies to enhance student learning during the second DBR cycle.

The findings from the two-cycle DBR study underscore the critical need for targeted guidance to support preservice teachers in effectively integrating technology into their instructional practices. This aligns with Janssen and Lazonder [39] assertion that additional support is vital, particularly given preservice teachers' inexperience with incorporating technology into specific teaching methods. Furthermore, the results reinforce Akayoğlu *et al*. [1] recommendation for specific, targeted guidance, and Jong *et al*. [40] emphasize on the importance of support for learners with limited prior knowledge. It highlights the critical importance of incorporating live role models alongside detailed analyses of their practices in teacher preparation programs. Explicit, hands-on training that involves observing and analyzing role models effectively integrating technology into instruction is essential for developing preservice teachers' competencies in this area. This combination of observation and analysis fosters a deeper understanding of how to effectively apply technology in diverse instructional contexts, thereby better preparing preservice teachers for technology-integrated instructional practices.

3.4. Participants' benefit from the modified learning by design approach

Though as aforementioned there were flaws in the way of implementation of the mLBD approach in the first DBR cycle, the first cohort of participants did benefit from solving authentic problems in the process of designing and redesigning curriculum materials through peer collaboration and ongoing dialogues. For instance, participant 6 expressed in her post-interview:

> "*For me, the real learning happened during collaborative lesson planning and micro-teaching*." (P6-G2-PI-DBR1)

Similarly, participant 23 also articulated:

> "*Hands-on experience with group discussion, group design, implementation, evaluation and iterative group discussion, as well as refining and redesigning equip us to identify technologies for effective teaching*." (P23-G5-PI-DBR1)

Clearly, both the two participants expressed that they benefited from their engagement in authentic experience of (re)designing curriculum materials through group endeavors and constant group discussions. Therefore, the initial design principles were still somewhat effective though the participants in the first DBR cycle had poor technology integration. Furthermore, the second cohort of participants also expressed their benefits from collaborative activities of designing and redesigning as well as providing and receiving feedback in their reflection diary entries. For instance, participant 11 articulated as "*Providing feedback to other groups' technology integrated activities and receiving feedback to our own technology integrated activities from other groups is a valuable opportunity for us to evaluate, reflect and redesign*."

The proposed mLBD approach effectively demonstrated the integration of the six SQD strategies as interconnected elements within this two-cycle DBR study, addressing the current challenge of inconsistent implementation of these strategies as a cohesive set [2], [3]. Furthermore, this approach operationalized the recommendations of previous studies [3], [10] by embedding the six SQD strategies into the original LBD framework. Additionally, the study supports Howard *et al.* [26] claim that role models significantly enhance preservice teachers' instructional design by providing concrete examples that facilitate reflection on technology use and improve their ability to evaluate their own designs. However, the findings diverge from Howard *et al*. [26] assertion that peer collaboration and feedback have a lesser impact on preservice teachers' authentic experience and instructional design. In this study, it is challenging to determine which strategy is less contributory, as all hands-on activities were conducted through peer collaboration, with participants consistently providing and receiving process-oriented feedback on their designs, presentations, and practices. This discrepancy may be due to differences in methodology. Howard *et al*. [26] employed a questionnaire where preservice teachers rated their self-perceived experiences with SQD strategies on a scale from 'strongly agree' to 'strongly disagree'. In contrast, this study utilized a meticulously designed module that intentionally incorporated SQD strategies within the mLBD approach.

In terms of practical implications for educational practice and policy, these findings suggest that teacher preparation programs should prioritize collaborative, hands-on experiences in curriculum design. By intentionally incorporating structured feedback and discussion mechanisms and modeling effective instructional practices alongside detailed analysis, programs can better equip preservice teachers with the skills needed for successful technology integration. This approach not only enhances their instructional

design capabilities but also fosters a culture of continuous improvement and reflection, ultimately benefiting student learning outcomes. Moreover, policies that provide ongoing support and opportunities for iterative learning, such as DBR cycles, can help educators continuously refine their teaching practices to meet the evolving demands of digital learning environments.

4. CONCLUSION

This study designed, implemented, and refined a mLBD approach through a two-cycle DBR study. The findings indicate that a superficial understanding of subject-specific teaching methods and approaches and the absence of targeted instructional guidance were significant impediments to preservice teachers' integration of technology into their teaching practices. Conversely, factors that facilitated successful technology integration included a deeper understanding of subject-specific methods and approaches, targeted guidance from instructors, and the implementation of the six SQD strategies as an interconnected unit. This study was limited by the participation of only two cohorts of preservice teachers specializing in English in an EFL context. Future research with a larger and more diverse sample, including both preservice and in-service teachers across multiple disciplines, could yield more comprehensive insights into technology integration. Additionally, since participants in this study were engaged in lesson planning and micro-teaching rather than actual classroom practice, future research could investigate how these lesson plans are implemented in real-world teaching environments. Nevertheless, theoretically, the mLBD approach demonstrated its potential to enhance the original LBD approach by incorporating the six SQD strategies to support preservice teachers' technology integration. This study provides empirical evidence that, when guided by the five design principles, the SQD strategies can function effectively as interconnected elements within the mLBD approach, fostering positive outcomes in technology integration for preservice teachers. Practically, the mLBD approach and the identified impeding and facilitating factors offer valuable insights for teacher education programs and teacher educators. The findings can help guide teacher educators in preparing preservice teachers for technology integration in their future classrooms. The flexibility of the mLBD approach allows it to be adapted to various educational contexts, making its principles applicable across different teacher education programs.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the Universiti Malaya Research Ethics Guidelines and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [JWL], upon reasonable request.

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