Innovative Teaching in the Digital Age: Exploring the Role of Teachers through Pre-Service Teachers' Lenses

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ABSTRACT

In the era of rapid digital transformation, the role of teachers extends beyond classroom instruction to include designing innovative digital learning materials. This study explores how pre-service teachers perceive the teacher's role in digital innovation, particularly in creating engaging and relevant digital learning content and drawing on qualitative data from 42 participants enrolled in a postgraduate teacher education programme in Malaysia, an open-ended online reflection was used to gather participants' views. Data were analysed thematically following Braun and Clarke's six-phase framework. Three central themes emerged: (1) teachers as designers of digital learning materials tailored to learners' needs; (2) technological competence and innovation culture; and (3) collaboration and knowledge sharing as enablers of digital practice. Findings indicate that pre-service teachers view teachers as proactive creators who require not only technical skills but also pedagogical creativity, reflective practice, and institutional support. The study proposes a conceptual framework linking digital design, technology integration, and professional collaboration as key components of teacher-led innovation. These insights contribute to understanding how future educators situate themselves within the digital landscape and provide guidance for improving teacher education curricula, professional development, and policy frameworks supporting digital transformation in education.

Keywords: Pre-Service Teachers

INTRODUCTION

Education systems around the world are undergoing a profound transformation driven by technological advancement and the evolving needs of twenty-first-century learners. Classrooms once defined by textbooks and whiteboards are now dynamic digital environments where technology mediates every aspect of teaching and learning. Digital platforms, interactive media, and online communication tools have become central to curriculum delivery, assessment, and student engagement [1]. These developments are prompting educators and policymakers to reconsider the nature of teaching, shifting emphasis from content transmission to creativity, collaboration, and digital fluency. Consequently, teachers' professional identity is being redefined. Teachers today are expected not only to facilitate learning but also to design, curate, and innovate within technology-rich educational ecosystems [2, 3].

Globally, there is growing recognition that digital literacy, creativity, and adaptability are essential competencies for teachers in the twenty-first century. International frameworks, as the UNESCO ICT Competency Framework for Teachers, emphasise the need for educators to move beyond basic technological use toward pedagogical innovation and digital leadership [4]. This global direction aligns with broader aims to prepare learners for participation in a technology-driven society that values critical thinking, problem solving, and lifelong learning.

Within this context, teachers play a crucial role in fostering learners' digital agency and ensuring equitable access to technology-enhanced education [5].

In Malaysia, these international priorities are reflected in reforms such as the Malaysia Education Blueprint 2013–2025 (MEB) and the Digital Education Policy (DEP). Both initiatives stress the importance of integrating digital competence into teacher education and ongoing professional development [6]. The MEB aspires to produce technologically capable teachers who can deliver student-centred, future-ready instruction. At the same time, the DEP reinforces this by promoting innovation, digital infrastructure, and data-informed pedagogy at all levels of education. Together, these policies mark a shift from conventional instruction toward digitally mediated, learner-centred practice. As a result, Malaysian teachers are increasingly positioned as facilitators of knowledge, designers of digital content, and collaborators in networked learning communities who shape not only what students learn but also how learning is experienced in the digital age [7, 8]

The integration of digital technologies has fundamentally transformed how knowledge is created, shared, and experienced in education. Digital platforms extend learning beyond the classroom, enabling interactive, flexible, and personalised teaching approaches. Tools such as Google Classroom, Quizizz, and Canva for Education allow teachers to design engaging lessons that accommodate diverse learning styles and promote active participation. The global transition toward online and hybrid learning has further highlighted the importance of digital innovation, compelling educators to rethink how instruction is designed and delivered in technology-enriched contexts [9, 10]. Over the past two decades, pedagogical models such as blended learning, flipped classrooms, gamified learning, adaptive systems, and fully online environments have become integral to modern education [11, 12]. Although many of these models existed before the COVID-19 pandemic, the crisis accelerated their adoption and demonstrated their potential for sustaining educational continuity. What was once an enhancement to traditional teaching has become a defining element of effective twenty-first-century education.

More recently, the emergence of generative artificial intelligence (AI) tools such as ChatGPT, Gemini, and DALL·E, along with adaptive learning systems, has further transformed the digital learning landscape. These technologies introduce both opportunities and challenges for educators, enabling personalisation and creativity while raising questions about authorship, data ethics, and pedagogical integrity. Consequently, teachers are expected to act as discerning mediators who integrate such technologies critically, ensuring that their use aligns with educational values and learning objectives rather than technological novelty alone.

From a theoretical perspective, frameworks such as the SAMR model (Substitution, Augmentation, Modification, Redefinition) and the Technological Pedagogical Content Knowledge (TPACK) framework provide lenses for understanding meaningful technology integration [13]. The SAMR model outlines how digital tools can evolve from substituting traditional tasks to transforming learning experiences, while TPACK emphasises the interplay between technology, pedagogy, and content knowledge. Both frameworks highlight that successful digital integration requires more than technical skill; it depends on pedagogical reasoning, thoughtful design, and purposeful application [14]. Ultimately, the effectiveness of digital learning lies not in the technology itself but in how teachers use it to enhance engagement, creativity, and understanding.

In this changing educational landscape, teachers play a central role as mediators between technology and pedagogy. They are no longer passive users of predesigned materials but active creators who design, adapt, and innovate digital content to meet diverse learning needs. This expanded role requires integrating pedagogical goals with digital tools to improve engagement, stimulate critical thinking, and support differentiated instruction [15, 16]. The success of digital education, therefore, depends on teachers' ability to make informed and creative decisions about technology use. Theoretical perspectives such as Rogers' Diffusion of Innovation Theory and the Technology Acceptance Model (TAM) explain how teachers adopt technology, showing that early adopters often catalyse change by modelling best practices and influencing peers [17, 18]. These frameworks reinforce that digital transformation in education is shaped not only by access to tools but by teachers' attitudes, competencies, and sense of agency.

Teacher agency refers to the capacity to make autonomous, reflective, and purposeful decisions about practice. Empowering teachers to exercise agency is essential for meaningful digital integration. When teachers see themselves as innovators rather than implementers, they are more likely to experiment, collaborate, and engage

in continuous improvement. This mindset strengthens instructional quality and nurtures a culture of innovation in schools and teacher education programmes. Research shows that teacher agency drives digital adoption, professional growth, and transformative practice, even under institutional or technological constraints [19, 20]. Understanding how teachers conceptualise their roles in digital innovation is therefore critical for shaping professional development and policy strategies that promote sustainable transformation.

Despite growing emphasis on digital innovation, many teachers face challenges in developing the required competencies. Common barriers include limited access to quality training [21], inadequate infrastructure [22], lack of time for experimentation [23], and low confidence in using new technologies [24]. These challenges are often intensified by disparities in resources across schools, leading to uneven implementation of digital initiatives. In Malaysia, although policies such as the Digital Education Policy and the Malaysia Education Blueprint provide strategic direction, classroom-level execution remains inconsistent, especially in under-resourced contexts [25]. Such constraints limit teachers' ability to design and deliver compelling digital learning experiences that respond to diverse learner needs. The European Framework for the Digital Competence of Educators (DigCompEdu) captures this complexity by outlining six areas of competence: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and supporting learners' digital competence [26, 27]. Developing these competencies requires structured professional learning, mentoring, and institutional support. Without these supports, digital innovation risks becoming fragmented and unsustainable.

Pre-service teachers, as future educators, represent the next generation of change agents in digital education. Their perceptions of digital innovation provide critical insight into how well teacher education programmes prepare them for modern classrooms. Studies show that while many pre-service teachers are eager to develop digital competencies and see themselves as creators and innovators, a significant number feel inadequately prepared to integrate digital learning into future practice [28, 29]. This sense of unpreparedness is especially evident among those outside STEM disciplines and those with greater teaching experience [30]. Many also express a need for more integrated, collaborative, and practice-based approaches rather than isolated coursework [31]. When pre-service teachers perceive themselves as unsupported, it highlights gaps in preparation that must be addressed to ensure readiness for digital education. Beliefs, attitudes, and self-efficacy developed during training, which strongly influence future teaching behaviour [32, 33]. Understanding these perspectives is therefore vital for improving teacher education curricula, strengthening professional development, and guiding national strategies for sustainable digital transformation (Habibi et al., 2022).

Although digital transformation has become integral to modern education, limited research has examined how pre-service teachers perceive their roles in this changing landscape, particularly in relation to digital innovation and the design of learning materials. Most existing studies focus on practising teachers, leaving a gap in understanding how teacher education programmes prepare future educators to integrate technology creatively and purposefully. This study addresses that gap by examining how pre-service teachers conceptualise the teacher's role in digital innovation, with particular emphasis on designing meaningful and engaging digital learning materials. Using qualitative reflections from postgraduate teacher . The study identifies key themes that capture the perceptions of teachers as designers, innovators, and collaborators in digital contexts. The findings contribute to understanding teacher readiness for digital education and offer insights for improving teacher training, curriculum design, and institutional support to strengthen innovation and professional competence in teaching.

METHODOLOGY

This study employed a qualitative research design to explore how pre-service teachers conceptualised the teacher's role in digital innovation, with particular focus on the design of digital learning materials. A qualitative approach was chosen to allow an in-depth understanding of participants' experiences and the meanings they attached to their professional learning. The study was grounded in an interpretive paradigm that views knowledge as socially constructed through participants' perspectives and interactions within their educational context. Within this framework, data were analysed thematically using Braun and Clarke's six-phase procedure. This approach enabled systematic and transparent identification of patterns and relationships across the dataset, offering rich insight into how participants made sense of digital innovation in teacher education [34, 35].

ATLAS.ti software was used to organise, code, and manage data efficiently, enhancing transparency, reliability, and traceability throughout the analytical process.

The study was conducted within a postgraduate teacher education programme at a public university in Malaysia. The programme emphasises digital pedagogy and educational innovation as core elements of teacher professional development, reflecting national priorities under Education 4.0 that promote digital competence and creative teaching practices [36]. Participants comprised 42 pre-service teachers enrolled in the programme during the relevant academic session. They represented diverse subject disciplines but were at a comparable stage of professional preparation. A total population sampling strategy was adopted, inviting all students registered for the course to participate. This approach ensured inclusivity and captured a broad range of perspectives within a single cohort [37]. Participation was voluntary, with no academic credit or grade incentives offered, thereby upholding ethical principles and minimising coercion. Including participants from different disciplines enabled a richer understanding of how pre-service teachers conceptualised digital pedagogy and educational innovation. This inclusive sampling design also aligns with recommendations in teacher education research that emphasise the importance of representing varied voices to inform continuous improvement in teacher education programmes, both in Malaysia and globally [38].

Data Collection

Data were collected through an online, open-ended written reflection administered during a scheduled class session. The reflection prompt invited participants to share their perspectives on the teacher's role in developing innovative digital learning materials and to reflect on the knowledge, skills, and values essential for that role. Written reflections were selected to allow participants to respond thoughtfully and at their own pace, thereby promoting authenticity and depth. Prior research supports the use of open-ended written reflections for capturing nuanced insights into pre-service teachers' beliefs, digital practices, and professional learning experiences [39]. Responses were submitted through a secure online form, anonymised immediately to maintain confidentiality, and imported into ATLAS.ti for analysis. Using a digital platform supported both participant comfort and data integrity. Employing a single qualitative method was considered appropriate for the exploratory aim of this study, , which seek to generate interpretive insights into participants' conceptualisations rather than to measure predetermined variables. This approach aligns with established practices in qualitative educational research, where reflective writing is valued for its capacity to reveal the complexity of teacher learning and innovation in digital contexts [40].

This research was conducted at a single public university in Malaysia and therefore reflects the experiences of a specific institutional and cultural setting. While the findings provide valuable insights into pre-service teachers' understanding of digital innovation, they should be interpreted within this bounded context. To enhance the credibility of the study, the researcher's reflexivity was maintained throughout the process. The research team, comprising members actively involved in teacher education, kept reflexive memos to monitor assumptions and minimise interpretive bias. Coding was collaboratively discussed and refined through peer debriefing to strengthen the dependability and transparency of the thematic analysis.

Data Analysis

Data analysis followed Braun and Clarke's six phase framework, recognised for its rigour and flexibility in qualitative research (Byrne, 2021). This process allowed systematic identification of recurring ideas, relationships, and, while maintaining the contextual depth of participants' reflections. ATLAS.ti facilitated transparent coding, linking,, and for retrieving textual evidence throughout the analysis.

Phase 1: Familiarisation with Data - All 42 written reflections were read several times to gain a comprehensive understanding of participants' perspectives. During this stage, the researchers recorded notes on emerging ideas related to creativity, technological literacy, collaboration, and innovation in digital learning. This familiarisation phase provided a holistic overview of how pre-service teachers perceived the evolving role of teachers in technology enhanced education [41].

Phase 2: Generating Initial Codes - The second phase involved systematically examining the data to identify meaningful text segments. Each segment was assigned descriptive codes that captured both explicit statements and underlying meanings. Coding was inductive, allowing themes to emerge directly from the data rather than from predefined theoretical frameworks. This approach ensured that the analysis remained grounded in participants' authentic experiences [42]. The resulting codes reflected diverse perspectives on teachers' roles as designers of digital materials, their creative processes, and their responsibilities in fostering innovation.

Phase 3: Searching for Themes - In this phase, related codes were clustered into broader categories that represent patterned meanings across the dataset. Relationships among codes were examined to identify potential themes and subthemes, marking the transition from descriptive to interpretive analysis. For instance, codes related to designing and adapting digital materials were grouped under Teachers as Designers of Digital Learning Materials; those addressing professional growth, digital confidence, and openness to innovation were organised under Technological Competence and Innovation Culture; while references to teamwork, mentoring, and resource sharing were categorised as Collaboration and Knowledge Sharing. This phase established the preliminary thematic structure and reflected the multifaceted roles pre-service teachers envisioned for themselves in technology-enhanced education [43].

Phase 4: Reviewing Themes - Emerging themes were refined and validated to ensure coherence and distinctiveness. Each theme was checked against the coded extracts and the full dataset to confirm internal consistency and conceptual clarity. Overlapping categories were merged or redefined to improve accuracy; for example, Digital Readiness and Technological Literacy were consolidated into Teacher Competence and Readiness. Data segments not aligned with the study's focus were excluded with transparent justification, ensuring the credibility and validity of the thematic structure.

Phase 5: Defining and Naming Themes - Each finalised theme was further refined to capture its essence and relevance to the research objectives. Three key themes were confirmed: Teachers as Designers of Digital Learning Materials, describing creative and adaptive roles in constructing meaningful digital resources; Technological Competence and Innovation Culture, reflecting capacity and willingness to engage with technology for continuous improvement; and Collaboration and Knowledge Sharing, highlighting the importance of professional interaction and peer learning in sustaining innovation. Each theme was accompanied by an analytical description that explained its significance for understanding pre-service teachers' conceptualisations of digital innovation.

Phase 6: Producing the Report - The final phase involved synthesising the themes into a coherent analytical narrative. Direct quotations from participants supported the interpretations, ensuring that the findings remained grounded in the data. The themes were contextualised using theoretical perspectives such as the Technological Pedagogical Content Knowledge (TPACK) framework and Rogers' Diffusion of Innovation Theory, both of which explain how teachers integrate technology and how individual innovativeness influences adoption (Byrne, 2021). The use of ATLAS.ti throughout the process, ti enhanced transparency, traceability, and confirmability by systematically linking codes, data segments, and analytic memos.

Overall, the six-phase thematic analysis generated deep insights into how pre-service teachers conceptualised the teacher's role as a creative designer, competent technologist, and collaborative innovator in the digital era.

RESULTS & DISCUSSION

The thematic analysis of 42 responses from pre-service teachers revealed three central, interrelated themes that describe their perceptions of the teacher's role in developing innovative digital learning materials. This study explored how pre-service teachers understand the role of teachers in creating innovative digital learning materials. The findings suggest that they perceive teachers as creative designers, competent technology users, and active collaborators in professional communities. These perceptions reflect a broader transformation in education, in which the teacher's role extends beyond classroom instruction to encompass design, adaptation, and innovation in digital pedagogy. The themes are (1) Teachers as Designers of Digital Learning Materials, (2) Technological Competence and Innovation Culture and (3) Collaboration and Knowledge Sharing. Together,

these themes provide a holistic understanding of how future educators conceptualise the teacher's identity as a creative designer, technologically competent practitioner, and collaborative innovator in the digital era.

TABLE I THEMES, SUBTHEMES, AND REPRESENTATIVE RESPONSES ON TEACHERS' ROLE IN DEVELOPING INNOVATIVE DIGITAL LEARNING MATERIALS

Theme	Subtheme	Description (Interpretation)	Illustrative Quote (Participant)
1. Teachers as Designers of Digital Learning Materials	Creative and purposeful design	Teachers create digital materials that are interactive, appealing, and aligned with learning goals.	"Teachers should design learning experiences, not just slides or notes." (R12)
	Adaptation to learners' needs	Materials must be tailored to students' levels and learning styles.	"Digital materials must be designed according to students' abilities and aligned with outcomes." (R28)
	Pedagogical innovation	Innovation involves rethinking how content is presented, not just adding technology.	"It's about creating learning that helps students explore, not only using gadgets." (R06)
2. Technological Competence and Innovation Culture	Digital literacy and confidence	Teachers need confidence and practical skills to use digital tools effectively.	"Teachers today must be digitally literate and confident." (R6)
	Continuous professional learning	Ongoing training is needed to keep up with fast-changing technology.	"Teachers should always upgrade themselves with new tools and methods." (R19)
	Institutional and resource barriers	Time, infrastructure, and limited training can restrict innovation.	"It's hard to innovate when schools lack stable internet and training." (R32)
3. Collaboration and Knowledge Sharing	Peer support and teamwork	Teachers learn and innovate through collective discussion and resource sharing.	"When teachers share ideas and resources, innovation spreads faster." (R35)
	Professional learning communities	Collaboration builds shared growth and supports creativity.	"Teachers need communities that support them to explore new ideas together." (R27)
	Shared professional identity	Collaboration fosters motivation and shared responsibility for improvement.	"Working together helps us feel confident to try new approaches." (R41)

Recognising innovation as an ongoing process requires educators to cultivate a flexible and reflective mindset. This assertion is grounded in the understanding that teaching is not merely about implementing technologies but about leveraging them to enhance pedagogical practices. When teachers perceive technology as a means to facilitate learning rather than an end in itself, they tend to integrate it more effectively into their instructional strategies, thereby fostering a creative and purposeful educational environment [44, 45]. This perspective aligns with the notion that teacher preparation programs must prioritise digital literacy alongside traditional pedagogical reasoning, equipping pre-service educators with the necessary skills to apply technology for addressing instructional challenges, personalising learning experiences, and promoting active student engagement [46, 47].

Moreover, the importance of digital literacy in current educational landscapes cannot be overstated, especially in preparing students for the demands of the 21st century. Teachers who recognize the value of digital competencies are better positioned to integrate these skills into their teaching practices, ultimately enhancing student readiness for future academic and professional pursuits. For instance, findings indicate that integrating digital literacy equips students with essential skills such as critical thinking, creativity, collaboration, and

effective communication [48]. Teachers' self-efficacy plays a crucial role in this dynamic as it influences their willingness to embrace digital tools and pedagogical innovations in their classrooms [49, 50]. Thus, fostering a supportive environment that enhances educators' self-efficacy in using technology can significantly improve their ability to incorporate digital literacy into their teaching practices [51, 52].

In this context, it becomes evident that teacher preparation must address the multifaceted nature of digital literacy. Emphasizing training that encompasses not only technological proficiency, but also ethical considerations and safety awareness is vital for nurturing responsible digital citizens among students [53, 54]. As teachers refine their digital competencies, they not only serve as role models for their students but also play an integral part in shaping a generation that can navigate the complexities of the digital age effectively [55]. Therefore, a concerted effort to enrich teacher training with a robust framework for digital literacy is essential for fostering an adaptable, reflective, and innovative teaching workforce.

Teachers as Designers of Digital Learning Materials

The theme highlights that teachers should not merely act as implementers of ready-made resources but as active designers of learning experiences. Many pre-service teachers viewed teachers as professionals who create engaging, interactive, and contextually relevant digital content that aligns with students' needs and learning outcomes. Participants emphasised that teachers must be able to design materials that are both pedagogically meaningful and technologically appealing.

Some responses described innovative teaching as the ability to "design learning experiences, not just slides or notes," reflecting an understanding that digital innovation is deeply connected to pedagogical creativity rather than technology alone. Others highlighted the importance of adapting materials for different learning levels, with one participant noting that "digital materials must be designed according to students' abilities and aligned with learning outcomes, not just copied from online resources." These insights position teachers as learning architects who curate content to engage students meaningfully. This view strongly aligns with the Technological Pedagogical Content Knowledge (TPACK) framework, which integrates technological, pedagogical, and content knowledge to support purposeful technology integration into instructional design.

Thus, teachers acting as designers of digital learning materials demonstrate an awareness that effective digital teaching requires creativity, intentional design, and in pedagogical planning. Pre-service teachers view teachers as professionals who do more than deliver content. They design learning experiences that are engaging and meaningful. This supports the broader educational shift toward design-based pedagogy, where teachers are creators of knowledge environments rather than passive transmitters of information.

Technological Competence and Innovation Culture

Building on the foundation of thoughtful design, the second theme—Technological Competence and Innovation Culture—highlights the essential role of digital skills and adaptability in education. Many participants in the study consistently referred to digital literacy as a "basic requirement" for teachers, underscoring that it is a fundamental skill rather than a supplementary one. They recognised that true innovation in education hinges on the confident and strategic use of digital tools, a sentiment echoed in the literature, which emphasises the necessity of supportive ecosystems for effective ICT integration in educational settings [56]. Participants also stressed the importance of ongoing professional learning, stating that "teachers should always upgrade themselves with new digital tools and methods because innovation happens when teachers keep learning." This perspective aligns with research by Moet and Kálmán, which illustrates how professional learning communities can significantly enhance educators' development and promote student achievement through continuous engagement [57].

However, the study also revealed barriers to innovation, such as time constraints, limited infrastructure, and unequal access to training opportunities. These concerns emphasize that fostering a culture of sustainable innovation is not solely the responsibility of individual educators; it also requires robust , institutional support systems to ensure that teachers are adequately prepared and resourced [58]. The importance of this theme is

further underscored by well-established frameworks such as Rogers' Diffusion of Innovation Theory, which delineates how innovations proliferate through early adopters who can influence their peers, and the DigCompEdu framework, which advocates for the ongoing professional development of educators that is reflective of their digital practices [59]. Together, these frameworks support the idea that effective technology integration necessitates not just competence but also a mindset of experimentation and lifelong learning.

The findings also resonate with the work of Jacobsen, et al. [60], who argue for a continued focus on developing innovative educational practices within professional learning communities, nurturing an environment that promotes collaboration and knowledge sharing, and enabling educators to become more adept at using technology to enhance their students' learning experiences. Moreover, recognising professional learning as an ongoing process is crucial, as emphasised by Kairat and Nurmukhanova [61]the need for sustained training, practice, and feedback to empower teachers. Thus, embracing a culture of innovation that values continuous improvement and adaptive learning can significantly influence the educational landscape.

Collaboration and Knowledge Sharing

Complementing the individual aspects of innovation, the third theme, Collaboration and Knowledge Sharing, highlights how collective effort can fuel significant educational transformation. Many participants believed that teachers should collaborate through peer networks and professional communities to sustain innovation. One participant remarked, “When teachers share ideas and resources, innovation spreads faster—everyone benefits when knowledge is shared.” This emphasis on collaboration reflects the established understanding that knowledge sharing among educators enhances both individual and collective growth, as noted by Shadle, et al. [62], who found that faculty interested in improving their teaching reported higher levels of engagement in collaborative activities.

Moreover, collaboration was perceived not just as helpful but as essential for effective teaching practices. It enables educators to co-create, test, and refine digital strategies, facilitating a learning environment where they can learn from each other's successes and challenges. The findings resonate with the principles of Professional Learning Communities (PLCs), which emphasise reflective dialogue and shared responsibility, ultimately enhancing the quality of instruction, as noted by Affandi, et al. [63] those who suggest that effective PLCs improve teachers' abilities to create supportive learning environments.

Through this lens, innovation is not solely an act of individual creativity but a social process driven by ongoing conversation, shared objectives, and collective problem-solving. This perspective aligns with the existing literature, which highlights that transformative change in education is best achieved through collaborative efforts [64]. Furthermore, a systematic review Henderson, et al. [65] emphasises the need to build supportive networks among educators to facilitate the dissemination of innovative practices in STEM education, underscoring the effectiveness of collaborative approaches.

In essence, fostering a culture of collaboration and knowledge sharing among teachers not only accelerates the diffusion of innovation but also helps establish a supportive community where educators can thrive. Encouraging such collaborative dynamics enhances the overall educational landscape, leading to increased student success through enriched learning experiences, as noted in Affandi, et al. [63] findings, which highlight the positive impact of professional learning communities on student achievement.

Integrated Perspective

Across all three themes, participants conceptualized teachers as active contributors to digital transformation, rather than passive users of educational technology. This perspective is crucial, as it underscores the belief that educators must proactively integrate technology into their practice. The themes collectively suggest an interdependent model: technological competence provides the foundation, pedagogical creativity forms the core, and collaboration ensures sustainability and scalability (Fig. 1). Research supports this assertion; for example, Ata and Alpaslan [66] it was found that teachers' digital teaching competencies significantly empower students in developing essential 21st-century skills through a collaborative approach.

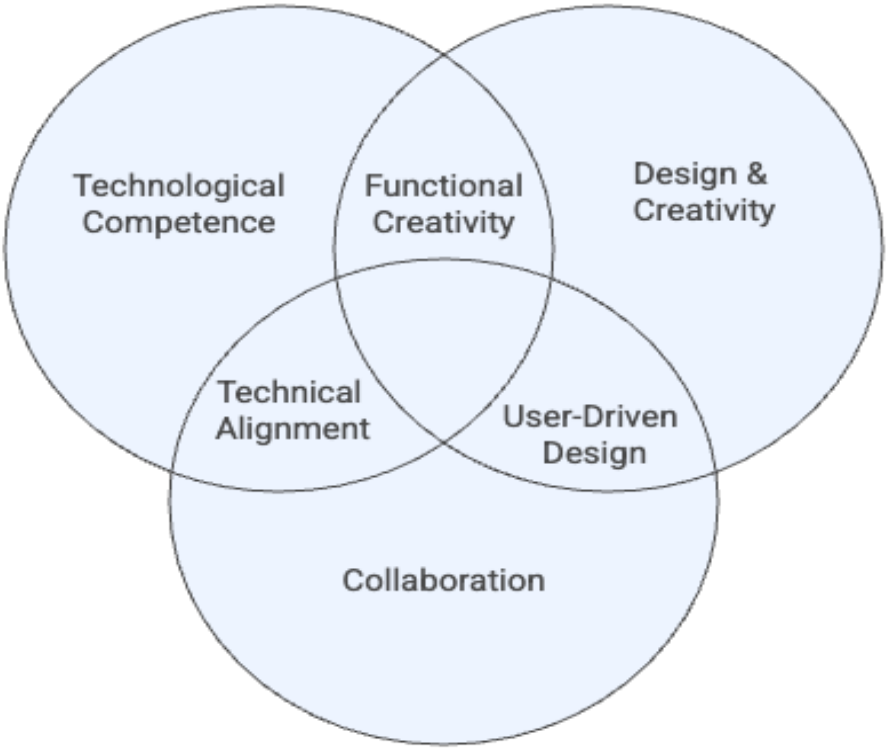

Fig. 1 Conceptual framework illustrating the relationship between design competence, technological competence, and collaborative practice in shaping teacher innovation in digital learning.

This model reflects an evolving teacher identity—one that embraces design thinking, digital fluency, and community engagement as integral components of effective teaching in the 21st century. By positioning themselves as creative designers, tech-savvy practitioners, and collaborative learners, pre-service teachers demonstrate a holistic vision of innovation in education. Esteve-Mon, et al. [67] discuss the importance of developing digital competencies among teachers, with a focus primarily on computational thinking and its application in the classroom, which may indirectly enhance educators' innovative capacity.

The overlapping region of the three circles—technological competence, design and creativity, and collaboration—represents a synergistic space where innovation, functionality, and human-centred values converge. At this intersection, individuals or teams demonstrate functional creativity, which integrates technical expertise with imaginative design thinking to produce solutions that are both original and practical. This synthesis moves beyond mere artistic creativity by embedding utility, feasibility, and performance within the creative process. As noted by Hidayat [68], effective utilisation of digital tools enables teachers to facilitate engaging and innovative learning experiences, emphasising their role as facilitators in this context.

The convergence of technological competence and collaboration leads to technical alignment, emphasizing the importance of shared digital literacy and coordinated understanding among collaborators. This ensures interoperability and efficient collective problem-solving, facilitating communication in a common technological language and the co-development of integrated systems or products. Özer and Kuloğlu [69] found that teachers' perceptions of 21st-century skills significantly predict their reflective practices, which are crucial for effective collaboration in educational settings. Similarly, the overlap between collaboration and creativity underpins user-driven design, in which solutions are shaped through participatory engagement and responsiveness to user needs.

At the core of all three domains lies the highest level of integrative practice—a space where technological knowledge, creative insight, and collaborative engagement operate in harmony, as emphasised by Yakubov, who argues that teachers' collaborative endeavours enhance the learning environment [70]. This central point symbolizes a mature form of professional competence marked by adaptability, interdisciplinary fluency, and reflective innovation. It is within this equilibrium that purposeful, functional, and user-responsive ideas are

transformed into sustainable innovations, bridging the gap between what is technically possible, what is creatively desirable, and what is socially meaningful.

While the discussion of findings draws primarily on the TPACK and SAMR frameworks, the themes also resonate with broader theoretical perspectives. From the lens of Activity Theory, teachers' innovation is understood as emerging from social interaction and collective meaning-making within institutional systems. Similarly, Rogers' Diffusion of Innovation Theory highlights the role of early adopters in shaping innovation culture through collaboration and modelling. Integrating these perspectives provides a richer account of how technological, pedagogical, and socio-cultural factors converge to influence teachers' creative agency in digital learning environments.

In the context of Malaysian teacher education, these findings hold significant implications. The perspectives shared by pre-service teachers align with national priorities outlined in Malaysia's Digital Education Policy (2021–2030), which emphasizes developing teachers who can effectively integrate technology into their teaching practices. However, while these teachers express strong awareness of innovation, many still lack structured opportunities to practice digital content design, peer collaboration, or classroom-based experimentation. Strengthening these components within teacher training programs could better prepare them to meet the demands of digital education. The findings indicate that pre-service teachers are ready to embrace their roles as designers and innovators but require supportive ecosystems that include mentoring, collaboration, and access to appropriate tools.

CONCLUSION

This study explored how pre-service teachers conceptualise the teacher's role in digital innovation, particularly in designing digital learning materials. The thematic analysis of 42 reflections revealed three interrelated themes: teachers as creative designers of digital learning materials, technological competence and innovation culture, and collaboration and knowledge sharing. Collectively, these findings show that pre-service teachers perceive teachers as active agents of change who integrate technology with pedagogy to create meaningful and engaging learning experiences. Practical digital innovation, in their view, depends on teachers' capacity to design purposeful resources, maintain reflective technological competence, and participate in collaborative communities that sustain professional growth. These dimensions are mutually reinforcing and together shape a forward-looking teacher identity grounded in creativity, adaptability, and collective learning. The study underscores the need for teacher education programmes to cultivate these attributes through authentic design practice, continuous professional development, and institutional cultures that value experimentation and collaboration. Strengthening these elements within teacher education programmes will not only enhance digital competence but also cultivate reflective and ethically aware educators capable of navigating emerging technologies such as generative AI. The study contributes a conceptual framework that links creative design, technological adaptability, and collaborative practice as interdependent dimensions of teacher innovation by offering a foundation for future pedagogical and policy development in digitally mediated education.

Limitation And Future Direction

This study was limited to a single institutional site and relied solely on written reflections as the data source. Although this approach provided valuable insights into participants' self-perceptions, the absence of triangulated evidence such as interviews, digital artefacts, or classroom observations constrains the depth of interpretation. Future research could adopt a longitudinal design to trace changes in pre-service teachers' digital innovation practices over time, or expand the scope to include multiple institutions for comparative analysis. Incorporating mixed methods and multimodal data sources would enrich the understanding of how teachers' digital competence and innovation evolve across professional contexts.

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