Research Article:

# Nurturing Sustainable Learning: Implementing an Interactive Mobile Multimedia Applications (IMMAS) Training Program for Special Education Teachers to Enhance Inclusive Pedagogical Innovation

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## ABSTRACT

Globally, inclusive teacher training is a cornerstone of equitable education, yet many low- and middle-income countries (LMICs) face challenges in preparing teachers to integrate technology into diverse classrooms. This study examines the impact of the Interactive Mobile Multimedia Applications (IMMAS) training program, an eight-week blended professional development initiative for 10 Malaysian special education teachers. Designed around Technological Pedagogical Content Knowledge (TPACK) and Universal Design for Learning (UDL) principles, IMMAS aimed to build teachers' digital capacity, transform professional identity, and promote sustainable instructional innovation. Data were collected through semi-structured interviews, weekly reflective journals, and multimedia lesson portfolios, and analysed using Braun and Clarke's (2006) thematic analysis. Three themes emerged: (1) a pedagogical shift toward learner-centred, multimodal lesson design; (2) transformation of teacher identity, with participants increasingly viewing themselves as content creators and mentors; and (3) sustainability through reusability of digital resources and grassroots peer collaboration. Findings demonstrate that mobile multimedia training can operationalise UDL principles, foster teacher self-efficacy, and establish school-based ecosystems of innovation. This study contributes new evidence from Southeast Asia to global discussions on inclusive education and educational technology, complementing top-down models in OECD countries with a cost-effective, grassroots-driven approach. IMMAS aligns with Sustainable Development Goal 4, emphasising equity and quality in education, and offers a scalable model for teacher development in resource-constrained settings. Future research should explore long-term sustainability and integration with national policies to scale this innovation.

**Keywords:** Special education teachers, mobile learning, inclusive pedagogy, multimedia applications, sustainable education

## INTRODUCTION

The integration of mobile and multimedia technologies into teaching and learning has become a defining feature of 21st-century pedagogy. For special education, this integration is not merely an enhancement; it is a necessity. Learners with disabilities often face systemic barriers, including inflexible instructional formats, communication challenges, and limited access to adapted materials (UNESCO, 2021). In this context, mobile technologies offer unprecedented opportunities to provide differentiated, accessible, and culturally responsive instruction.

In Malaysia, efforts to advance inclusive education are guided by frameworks such as the Malaysia Education Blueprint 2013–2025 and the Special Education Transformation Plan 2019–2025. These policies emphasise technology as a key enabler for inclusive pedagogy. However, despite policy aspirations, ground-level implementation is uneven, particularly among special education teachers in primary schools, who often lack the training and support to create accessible multimedia resources (Jelas & Majzub, 2015; Saini et al., 2024).

Globally, countries such as Finland, South Korea, and Australia have made progress in embedding digital pedagogical training in their teacher education systems. Notably, these models prioritise teacher-led innovation, inclusive design, and mobile content creation for diverse learners (Schleicher, 2022). Drawing from these global precedents and grounded in Malaysia's local needs, the Interactive Mobile Multimedia Applications (IMMAS) program was conceptualised to train special education teachers in designing inclusive digital content using mobile tools. IMMAS does not merely introduce new technologies; it repositions teachers as creators, not just users, of instructional innovation.

However, while OECD and Southeast Asian initiatives demonstrate progress, Malaysia continues to face unique challenges. Primary-level special education teachers often lack localised digital tools in Bahasa Malaysia or BIM, receive minimal context-sensitive training, and have few peer-driven support systems. IMMAS directly addresses this gap by offering a grassroots, teacher-centred model that empowers educators as digital content creators, translating policy aspirations into practical classroom transformation.

This study examines the impact of the IMMAS program on Malaysian special education teachers by investigating three dimensions:

1. Shifts in pedagogical practice.

2. Transformation in teacher identity and digital agency.

3. Emergence of sustainable instructional ecosystems.

By doing so, it contributes to a growing discourse on how mobile pedagogical capacity-building can support inclusive and sustainable education, particularly in low- and middle-income countries.

Given the pressing need to operationalise inclusive pedagogy through context-responsive, technology-driven teacher development, this study explores the implementation of the IMMAS training program among Malaysian special education teachers. While existing policies emphasise inclusive access and ICT integration, a gap remains in understanding how digital pedagogical training translates into actual classroom transformation, particularly in special education settings.

Globally, inclusive education is increasingly supported by mobile learning technologies that enable personalised instruction and reduce barriers for learners with disabilities (Navas-Bonilla et al., 2025). Countries such as Sweden, Finland, and the United States have implemented national programs that train teachers to utilise digital tools in meeting the diverse needs of students (Organization for Economic Co-operation and Development [OECD], 2023). In Southeast Asia, initiatives such as community radio for inclusive learning in the Philippines and Malaysia's Digital Education Policy 2023 highlight the growing recognition of EdTech's role in promoting equitable access (UNESCO, 2020; EdTech Hub, 2024). Despite these advances, many LMICs face challenges in providing teachers with sustained training and accessible resources (Hennessy et al., 2022). Against this backdrop, the IMMAS program was designed to address gaps in inclusive instructional design and mobile technology integration for special educators.

To address this gap, the study investigates the transformative potential of IMMAS as both a professional development tool and a mechanism for grassroots innovation. Specifically, it aims to examine not only pedagogical changes but also shifts in teacher identity and sustainability of practice.

The following research questions guide this study:

1. How does the IMMAS training program influence the pedagogical practices of special education teachers?

2. In what ways does the program impact teachers' digital agency and professional identity?

3. What elements contribute to the sustainability of instructional innovation post-training?

## LITERATURE REVIEW

### Technology Integration in Special Education

Mobile technology has been widely recognised for its transformative role in enhancing personalised and inclusive education. For students with hearing impairments, autism spectrum disorder, or learning disabilities, multimedia content can support language development, attention, and cognitive processing through visual reinforcement and interactive elements (Smith et al., 2019; Fernandes & Myers, 2009). In Malaysia, however, meaningful technology integration in special education remains inconsistent despite national ICT policies and the availability of devices in many schools.

Saini et al. (2024), and Nordin and Abu Bakar (2024) found that while special education teachers demonstrate positive attitudes toward technology, many lack confidence in using it effectively due to insufficient training and a lack of context-relevant applications. Moreover, special education software and mobile applications available in Bahasa Malaysia or local sign languages (e.g., BIM) are limited, making it challenging for teachers to develop inclusive materials independently. This signals a critical need for training that not only introduces digital tools but also aligns them with pedagogical goals for diverse learners.

### Teacher Professional Development and the TPACK Framework

Professional development is only effective when it addresses the complex interplay between technology, pedagogy, and content knowledge, as articulated in the TPACK model (Mishra & Koehler, 2006). In special education contexts, this intersection is even more complex, as teachers must also navigate Individualised Education Plans (IEPs), communication disorders, and curriculum modifications.

While national efforts like *Transformasi Sekolah 2025* (TS25) promote higher-order thinking and student-centred practices, these programs often overlook how teachers can practically integrate mobile technology into inclusive lesson planning (Tan et al., 2022; Asadullah et al., 2023). IMMAS fills this void by operationalising TPACK for special education, supporting teachers in developing lessons that are not only content-aligned but also technologically feasible and pedagogically sound.

### Inclusive Design: From UDL Theory to Practice

The Universal Design for Learning (UDL) framework provides a theoretical foundation for making learning accessible and flexible (CAST, 2018). UDL encourages educators to provide multiple means of engagement, representation, and expression, significant for students with sensory or cognitive impairments. However, as noted by Jelas and

Majzub (2015), UDL is rarely applied in Malaysian classrooms beyond theory due to a lack of training in design-based thinking and multimedia tools.

However, as noted by Jelas and Majzub (2015), UDL is rarely applied in Malaysian classrooms beyond theory due to a lack of training in design-based thinking and multimedia tools. Globally, the importance of UDL in advancing inclusive education through digital innovation has been increasingly recognised. A content analysis by Al-Azawei et al. (2016) of peer-reviewed UDL studies between 2012 and 2015 revealed that UDL principles are most effective when supported by technology-based instructional design, especially in higher education and special needs contexts. This underscores the need for localised professional development initiatives that translate UDL principles into tangible practices using digital tools.

Programs like IMMAS are significant because they bridge this theory-practice gap. Rather than passively introducing the UDL framework, IMMAS trains teachers to design and implement multimedia resources that reflect UDL principles: Captioned videos, sign-integrated instructions, and scaffolded visuals. These practices position teachers as active agents in adapting instruction to learner variability, moving UDL from abstract policy to daily teaching praxis.

**Theoretical Framework Integrating TPACK and UDL**

Teacher professional development that merges Technological Pedagogical Content Knowledge (TPACK) and UDL frameworks is emerging as a powerful approach to inclusive pedagogy (Wang & Sitthiworachart, 2025). Studies emphasise that TPACK equips teachers with the knowledge to integrate technology effectively, while UDL provides a flexible structure to design content accessible for all learners (CAST, 2018; Mishra & Koehler, 2006). For example, Lambert et al. (2023) found that UDL-focused training programs shifted teacher beliefs from seeing UDL as a checklist to embracing it as "a way of thinking" that adapts instruction moment-to-moment. Integrating these frameworks in training helps educators create content that is both technologically innovative and sensitive to learner diversity (Alhabahbe & Alhadidi, 2022). IMMAS builds on this evidence by positioning teachers as content designers, empowering them to align digital media with inclusive strategies.

**Sociocultural Perspectives and Teacher Identity in Learning**

Teaching is not merely a technical act but a social and identity-constructing process (Wenger, 1998). According to Vygotsky's sociocultural theory, learning occurs through mediated activity, especially in communities of practice where knowledge is co-constructed (Vygotsky, 1978). In the Malaysian context, many special education teachers work in isolation with limited access to peer collaboration or digital networks

(Ahmed et al., 2022; Cramer et al., 2022). This limits not only skill acquisition but also professional growth.

IMMAS addresses this by fostering collaborative learning spaces where teachers engage in peer feedback, co-design of lessons, and reflective dialogue, key mechanisms for identity transformation. Teachers move from seeing themselves as implementers of curriculum to innovators and mentors within their communities. This shift is supported by research on teacher self-efficacy (Bandura, 1997), which suggests that belief in one's capacity to effect change is essential for long-term practice improvement.

### Sustainability and Grassroots Innovation

Sustainability in digital pedagogy requires more than infrastructure; it demands teacher ownership, adaptability, and low-cost innovation (Sterling, 2001). Global evidence shows that when teachers are empowered to develop reusable and scalable digital content, the impact extends beyond individual classrooms to system-wide change (Schleicher, 2022). In Malaysia, however, sustainability efforts often centre on top-down initiatives with limited teacher agency.

By equipping teachers with open-source tools and promoting design thinking, IMMAS supports bottom-up innovation. Teachers create modular content banks and shareable resources, forming the foundation for school-based innovation ecosystems. Such grassroots efforts align with Sustainable Development Goal 4, particularly its emphasis on inclusive and equitable quality education for all, including those with disabilities (UNESCO, 2020).

### Conceptual Framework of the IMMAS Training Model

Figure 1 presents the conceptual framework underpinning this study, illustrating the transformative pathway of the IMMAS training program for special education teachers. The framework is grounded in established theoretical constructs, including the TPACK model (Mishra & Koehler, 2006), UDL principles (CAST, 2018), sociocultural learning theory (Vygotsky, 1978), and self-efficacy theory (Bandura, 1997). It visually synthesises how the IMMAS program fosters pedagogical innovation, professional identity transformation, and sustainable instructional ecosystems in inclusive education.
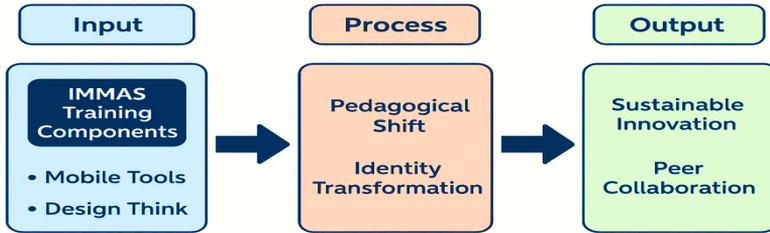
**Figure 1.** Conceptual model

*Input: IMMAS training components*

The input phase comprises two core elements:

1. Mobile Tools (e.g., Canva, Cap Cut, Quizzes): These applications enable teachers to create accessible, multimedia-rich teaching content aligned with diverse learning needs.

2. Design Thinking Pedagogy: Teachers are guided through iterative, user-centred design processes that prioritise adaptability and inclusivity, directly linking to UDL principles.

These training components are intentionally structured to build teachers' technological competence while embedding a design mindset that centres learner variability and equity.

*Process: Pedagogical shift and identity transformation*

As teachers engage with IMMAS, they experience two interrelated processes:

1. Pedagogical Shift: Instructional approaches move from traditional, teacher-centred methods to multimodal, learner-centred design, emphasising differentiated instruction, accessibility, and engagement hallmarks of inclusive pedagogy.

2. Identity Transformation: Teachers reframe their professional roles from passive users to active creators and digital mentors, bolstered by growing confidence and mastery experiences. This aligns with Bandura's concept of self-efficacy and Wenger's communities of practice.

This process responds directly to Research Questions 1 and 2:

RQ1: How does the IMMAS training program influence the pedagogical practices of special education teachers?

RQ2: In what ways does the program impact teachers' digital agency and professional identity?

***Output: Sustainable innovation and peer collaboration***

The outcome reflects the long-term goals of IMMAS:

1. Sustainable Innovation: Teachers develop reusable digital content libraries, adapt lessons across subjects and levels, and maintain inclusive instructional practices beyond the training period.

2. Peer Collaboration: Informal mentoring circles, WhatsApp feedback groups, and shared digital resource banks emerge, forming micro-communities of practice within schools.

This aligns with Research Question 3:

RQ3: What elements contribute to the sustainability of instructional innovation post-training?

This conceptual framework captures the IMMAS model as an integrative, theory-driven professional development approach. It operates the research objectives by showing how carefully designed training inputs catalyse shifts in pedagogy and teacher identity, ultimately leading to enduring instructional transformation and collaborative innovation. It reinforces the notion that sustainable change in inclusive education is not technology-driven alone but emerges from empowered, connected educators equipped with both tools and agency.

Table 1 summarises recent studies illustrating global trends in inclusive education technology, teacher professional development, and grassroots innovation. These findings emphasise the urgent need for scalable, context-sensitive training models like IMMAS.

**Table 1.** Recent studies on inclusive EdTech and teacher professional development

| Author(s) and year | Context and participants | Focus of study | Key findings | Relevance to IMMAS |
|---|---|---|---|---|
| Navas-Bonilla et al. (2025) | Systematic review of 100+ studies (global) | Inclusive EdTech for learners with disabilities | Mobile and multimedia tools personalise learning, reduce barriers, and improve access for diverse learners. | Supports mobile multimedia approach for inclusive classrooms. |
| Hennessy et al. (2022) | LMICs, multiple countries | Technology-mediated teacher PD | Tech-based PD is effective if context-specific and peer-supported. | Justifies IMMAS's blended, localised teacher training model. |
| Esmat & Amasha (2025) | Egypt, 80 teachers | Mobile PD application for continuous learning | Teachers using the app showed significantly higher teaching performance and confidence. | Demonstrates the potential of mobile apps for scalable PD in LMICs. |
| Lambert et al. (2023) | U.S., inclusive classrooms | UDL-focused PD | PD shifted teacher mindset: UDL is viewed as a dynamic, reflective process. | Reinforces IMMAS's emphasis on flexible design thinking. |
| Wang & Sitthiworachart (2025) | Jordan, teacher training program | Integration of TPACK and UDL | Embedding UDL in TPACK-based PD improves inclusive tech integration skills. | Validates IMMAS's theoretical foundation. |
| UNICEF (2018) | North Macedonia | Grassroots innovation | A teacher-designed e-tool for IEP management improved collaboration and inclusion. | It shows the feasibility of teacher-led, low-cost innovations. |
| OECD (2023) | Sweden, Belgium, OECD countries | National-level inclusive tech policies | System-wide training and tools enhance teacher confidence and inclusion practices. | Positions IMMAS as a complementary bottom-up approach. |
| Zhao et al. (2024) | Southeast Asia | Regional review of inclusive EdTech | Regional initiatives emphasise affordable solutions and teacher capacity-building. | Highlights IMMAS's relevance in Southeast Asia's education landscape. |

## METHODOLOGY

### Research Design

This study employed a qualitative single-case study design (Yin, 2018) to explore the implementation and pedagogical impact of the IMMAS training program within authentic school contexts. The case study design was chosen to provide a rich, contextually grounded understanding of how mobile multimedia training influenced teaching practices, digital agency, and sustainable pedagogical innovation among special education teachers.

The "bounded system" in this case was the delivery and implementation of the IMMAS training program to a single cohort of teachers over an eight-week intervention. This design enabled triangulation and provided deeper insights into teachers' lived experiences, essential for inclusive education research.

### Participants and Sampling

Participants were selected using purposive sampling based on clearly defined inclusion criteria:

1.  Full-time special education teachers.

2.  A minimum of three years' experience working with students with hearing, cognitive, or communication impairments.

3.  Basic ICT literacy.

4.  No prior formal training in multimedia content development using mobile tools.

Ten teachers (7 female, 3 male) from three government primary schools in Penang and Perak were recruited. Their teaching experience ranged from 3 to 15 years. The participant cohort was diverse in terms of age, school context, and technological confidence, which enhanced the transferability of findings across settings.

### IMMAS Training Intervention

The IMMAS training program was delivered over eight weeks using a blended learning model. Weekly modules were structured around specific multimedia design competencies and included asynchronous video tutorials, app-based walkthroughs (e.g., Canva, Cap Cut), hands-on assignments, and synchronous peer feedback sessions.

Each module focused on inclusive instructional design principles, multimedia adaptation strategies, and reusability of content. By the end of each week, participants submitted a multimedia artefact (e.g., lesson video, digital visual aid) aligned with their classroom curriculum, completed a reflective journal detailing its implementation, and student response. Topics included captioning, audio integration, sign language overlays, animation, and interactive content creation.

## Data Collection Methods

To ensure comprehensive data coverage and methodological triangulation, the following data sources were employed:

1. Semi-Structured Interviews: Conducted pre- and post-intervention, each lasting approximately 45–60 minutes. Interview questions explored participants' instructional practices, digital confidence, pedagogical beliefs, and perceptions of IMMAS's impact.

2. Reflective Journals: Participants submitted structured weekly reflections via Google Forms. Prompts encouraged critical examination of design decisions, student engagement, challenges encountered, and perceived pedagogical shifts.

3. Document Analysis: Participant portfolios were analysed, including multimedia lesson plans, edited teaching videos, classroom screenshots, and content reusability logs. These artefacts provided insight into how theoretical principles were operationalised in practice.

To enhance transparency and replicability, summaries of the methodological instruments are integrated here (full versions remain in Appendices A–E):

1. Interview Protocol (Appendix A): Questions explored teachers' instructional practices, digital confidence, pedagogical beliefs, and IMMAS's impact. Example: *Can you share an example of how students responded to a multimedia activity?*'

2. Reflective Journal Template (Appendix B): Structured weekly reflections on lesson title, multimedia tools, student responses, challenges, and next steps.

3. Observation Checklist (Appendix C): Indicators included use of multimedia for objectives, UDL principles, captions/sign language, and evidence of peer collaboration.

4. Multimedia Lesson Artefact (Appendix D): Screenshots of anonymised multimedia lessons showing captioned videos, interactive images, and sign-language clips.

5. Training Module Outline (Appendix E): Weekly IMMAS modules covering UDL principles, multimedia design, classroom implementation, and sustainability strategies.

**Data Analysis Procedures**

Data was analysed using Braun and Clarke's (2006) six-phase thematic analysis method:

1. Familiarisation: The research team read all interview transcripts, journal entries, and artefacts multiple times for immersion.

2. Initial Coding: Inductive codes were generated in NVivo 14, capturing recurrent concepts and significant experiences.

3. Theme Development: Related codes were clustered to form preliminary themes based on shared patterns and meanings.

4. Theme Review: Themes were refined through iterative comparisons with raw data to ensure internal coherence and external distinction.

5. Theme Naming and Definition: Final themes were clearly defined and aligned with the study's research questions and theoretical framework.

i. Coding Framework and Intercoder Reliability

To enhance transparency, a coding framework was developed collaboratively. Initial codes were generated inductively in NVivo 14, then clustered into subthemes and themes aligned with the research questions. Table 2 illustrates sample codes, their definitions, and representative extracts.

Intercoder reliability was established through dual coding of 25% of the dataset by two independent researchers. Cohen's Kappa was calculated at 0.82, indicating strong agreement. Discrepancies were discussed and resolved through consensus, and the refined codebook was then applied to the full dataset. This process ensured that the analysis was systematic, replicable, and trustworthy.

**Table 2.** Coding framework

| Theme | Sub-code | Definition | Example extract |
|---|---|---|---|
| Pedagogical shift | Multimodal delivery | Use of captions, sign overlays, videos | Now, I show videos I made with sign language, colors, and movement. My students are more alert. (P2, Interview) |
| Teacher identity | Digital confidence | Growth in self-perception as digital content creator | I never thought I could make a full lesson video. Now I feel like an instructional designer. (P3, Interview) |
| Sustainability | Peer collaboration | Sharing resources, mentoring, and group innovation | We've created a folder of all our digital lessons so everyone can use and modify. (P10, Reflective Journal) |

6.  Report Production: Findings were synthesised into narrative accounts with illustrative quotes and analytical interpretation.

To enhance reliability, dual coding was conducted by two independent researchers. The coding framework was co-developed and peer-reviewed, and interpretative discrepancies were resolved through consensus. An audit trail, including codebooks, reflexive memos, and analytic decisions, was maintained to support dependability.

**Ethical Considerations**

Rigorous qualitative standards were applied using Lincoln and Guba's (1985) trustworthiness criteria:

1.  Credibility was enhanced through triangulation of three data sources and prolonged engagement over the eight-week training.

2.  Transferability was supported by providing thick descriptions of participants, contexts, and instructional designs.

3.  Dependability was addressed via detailed records of coding procedures, software outputs, and training documentation.

4.  Confirmability was reinforced through researcher reflexivity, audit trails, and peer debriefing.

Ethical approval was obtained from the university's research ethics committee. Participants were briefed on their rights, including confidentiality and voluntary withdrawal. Written informed consent was secured. All identifying data were anonymised during transcription, analysis, and dissemination to protect participants' privacy.

## FINDINGS

Thematic analysis of the qualitative data revealed three major themes that encapsulate the experiences and transformations of participants following their engagement with the IMMAS training program, as shown in Table 2.

**Table 2.** Thematic analysis

| Theme | Sub-themes/ Patterns | Representative quotes | Interpretive insights |
|---|---|---|---|
| Pedagogical shift toward learner-centred multimedia design | Use of videos, captions, and sign overlays. Shift from teacher-centred to multimodal delivery | Now, I show videos I made with sign language, colours, and movement. My students are more alert. (P2, Interview) | Teachers redesigned instruction to support diverse learning needs through multimodal strategies. |
| Emergence of digital agency and creative identity | Increased confidence with digital tools, Professional identity as content creators Peer and admin recognition | I never thought I could make a full lesson video. Now I feel like an instructional designer. (P3, Interview) | Teachers developed digital self-efficacy, creative agency, and redefined their professional roles. |
| Sustainability through reusability and peer collaboration | Content reusability across subjects Peer mentoring and digital sharing groups School-based micro-communities | I never thought I could make a full lesson video. Now I feel like an instructional designer. (P3, Interview) | Grassroots innovation fostered long-term sustainability through collaborative practices and digital ecosystems. |

These themes include: (1) Pedagogical shift toward learner-centred multimedia design, (2) Emergence of digital agency and creative identity, and (3) Sustainability through reusability and peer collaboration. Each theme is presented with representative quotes and analytical interpretations.

### Pedagogical Shift toward Learner-Centred Multimedia Design

Before the IMMAS intervention, most participants described their pedagogical approaches as primarily teacher-centred, relying heavily on verbal explanations, worksheets, and traditional visuals.

Post-intervention, all teachers reported a transformation in how they designed and delivered instruction. They began employing mobile tools to create multimodal teaching content that incorporated videos, animated icons, voiceovers, captions, and gesture-based cues.

> I used to just talk and write on the board. Now, I show videos I made with sign language, colours, and movement; my students are more alert and enjoy learning."(P2, Interview)

> Some of my students don't read well, so now I make sure there's always a visual and a voiceover. The difference is big; they follow better and remember more."(P9, Reflective Journal)

Across cases, teachers consistently reported replacing text-heavy explanations with multimodal designs that combined visuals, captions, and sign overlays. This convergence demonstrates how IMMAS encouraged teachers to move beyond experimentation toward internalising UDL principles, particularly multiple means of representation and engagement. Rather than anecdotal improvements, the evidence reflects a cohort-wide pedagogical shift from teacher-centred delivery to inclusive design thinking.

**Emergence of Digital Agency and Creative Identity**

The second theme highlights how teachers' engagement with multimedia design tools contributed to the development of digital self-efficacy and a redefinition of their professional identities. Initially hesitant and uncertain, participants evolved into confident creators and facilitators of digital content.

> I never thought I could make a full lesson video. Now I feel like an instructional designer, not just a teacher. It's a good feeling. (P3, Interview)

> My headmistress asked me to train others in our school after seeing my videos. That has never happened before. (P1, Journal Entry)

Taken together, these reflections reveal a broader transformation: teachers began to redefine their professional identity from curriculum implementers to digital innovators. This pattern echoes Bandura's (1997) concept of mastery experiences driving self-efficacy and Wenger's (1998) idea of communities of practice, where recognition by peers and leaders strengthens identity. The convergence across cases shows that IMMAS facilitated not isolated boosts in confidence but a collective re-positioning of teachers as content creators and peer mentors.

**Sustainability through Reusability and Peer Collaboration**

The third theme centres on the sustainability of pedagogical innovation introduced by IMMAS. Teachers consistently reused and adapted their multimedia resources across different subjects and year levels. Many developed their own personal "digital libraries" and began contributing to school-wide resource banks.

> I used one video for both science and civic lessons. I just changed the voiceover. It saves me time and still fits the topic. (P6, Interview)

> We've created a folder of all our digital lessons so everyone can use and modify. It's become our shared toolkit. (P10, Reflective Journal)

Across schools, participants consistently reused, adapted, and shared multimedia content, signalling not only efficiency but also grassroots collaboration. These practices reflect Vygotsky's (1978) sociocultural theory of learning through mediated community activity and Sterling's (2001) call for sustainability via adaptability and teacher ownership. Rather than isolated anecdotes, the evidence points to the formation of micro-communities of practice that sustained innovation beyond the training period.

## DISCUSSION

The findings from this study demonstrate that a structured, practice-oriented training program like IMMAS can significantly influence special education teachers' pedagogical approaches, professional identity, and sustainability of innovation. This section discusses these findings through the lens of relevant theoretical frameworks, including TPACK, UDL, sociocultural learning theory, and self-efficacy theory.

**Integrating TPACK for Inclusive Pedagogical Practice**

The IMMAS program facilitated the intersection of TPACK, equipping teachers with the tools and mindset necessary to integrate technology meaningfully into their instructional design (Mishra & Koehler, 2006). Participants did not merely learn to use multimedia apps; they contextualised these tools within their teaching goals, student needs, and content standards. Their outputs reflected the synergy of digital proficiency, content alignment, and inclusive teaching strategies.

This aligns with studies showing that teacher development programs must go beyond technical training to address the dynamic interplay of technology, pedagogy, and content (Niess, 2011). In the Malaysian special education context, where formal digital training

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opportunities are limited, IMMAS offers a replicable model for operationalising TPACK in low-resource and inclusive environments.

Across cases, the consistent pattern was that teachers not only experimented with multimedia tools but embedded them into pedagogical routines, signalling a systemic shift in practice. This synthesis demonstrates that IMMAS functioned less as a technical workshop and more as a catalyst for rethinking pedagogy in line with TPACK.

## Operationalising UDL Principles through Teacher-Created Multimedia

The design of lesson materials that featured captioning, sign language, audio support, and visual cues illustrates how teachers internalised the principles of UDL (CAST, 2018). Although UDL was not explicitly taught in the IMMAS curriculum, its core tenets emerged organically in the teachers' practices, reflecting an intuitive alignment with the framework's emphasis on learner variability.

This finding reinforces the importance of hands-on, reflective design experiences in bridging the gap between UDL theory and practice. Rather than depending on pre-packaged content, teachers became empowered creators of adaptive learning resources, making UDL not just a policy directive but a daily instructional reality.

Synthesising across participants, the evidence shows that teachers applied UDL principles intuitively and consistently. Rather than isolated anecdotes, the cohort-wide pattern indicates that inclusive design became a shared pedagogical habit, reinforcing that IMMAS successfully bridged the theory–practice gap.

## Sociocultural Learning and Collaborative Innovation

Teachers' participation in peer feedback, informal mentoring, and collaborative design reflects Vygotsky's (1978) sociocultural theory, which posits that learning is a socially mediated process. Through community interaction and dialogue, teachers expanded their zone of proximal development, moving from novice digital users to confident co-designers.

The emergence of micro-communities of practice within schools is particularly noteworthy. Teachers did not wait for institutional directives; they initiated organic sharing platforms, review circles, and content exchanges. This bottom-up innovation process mirrors successful professional learning models in Finland and Estonia, where collaborative design is embedded into school culture (Schleicher, 2022).

Taken together, teachers' accounts of peer mentoring, feedback circles, and collaborative lesson design reflect not anecdotal variation but a structural move toward

micro-communities of practice. This cross-case synthesis affirms Vygotsky's claim that innovation in learning is mediated through social interaction.

## Professional Identity Transformation and Self-Efficacy

Participants described a deep transformation in how they viewed themselves professionally, from implementers of curriculum to digital content designers and mentors. This change aligns with Bandura's (1997) theory of self-efficacy, which suggests that mastery experiences and social recognition are key to building confidence and autonomy.

Recognition from school leaders, peer mentoring roles, and student engagement served as reinforcing feedback loops that strengthened teachers' sense of competence. Such shifts in identity are foundational for sustained innovation. When teachers see themselves as capable, creative professionals, they are more likely to continue experimenting, iterating, and leading change.

Across the cohort, participants consistently described a redefinition of professional identity, from passive implementers to confident digital innovators. This collective transformation aligns with Bandura's theory of self-efficacy, showing that the IMMAS model catalysed not isolated identity shifts but a shared trajectory of professional empowerment and sustainability.

## Sustainability through Reusability and Local Innovation

Sustainability in educational innovation is often associated with institutional support and policy frameworks. While these are important, this study shows that teacher-led content development and peer collaboration are equally critical. Participants demonstrated how sustainability can be achieved through the reusability of content, the sharing of templates, and informal peer coaching.

This reflects a grassroots model of innovation that does not rely heavily on expensive infrastructure. Instead, it leverages the creativity, agency, and relational networks of teachers to build lasting change. In contexts where educational equity is a challenge, such as rural or underfunded schools, the IMMAS model provides a scalable, cost-effective strategy to improve inclusive teaching.

Synthesising across cases, sustainability was not simply a by-product of individual teacher efficiency but a collective process where peer mentoring, content sharing, and iterative adaptation created durable micro-ecosystems of practice. This convergence shows that IMMAS enabled teachers to move beyond short-term innovations toward structural, community-driven sustainability. The pattern aligns with Vygotsky's (1978)

sociocultural view of learning as mediated by collaboration, and with Sterling's (2001) notion that lasting educational transformation depends on adaptability and teacher ownership. In this way, sustainability in IMMAS was not anecdotal but systemic, transcending individual classrooms and pointing toward scalable grassroots innovation.

**Global and Regional Context**

The IMMAS outcomes parallel international best practices. In Sweden, national agencies provide targeted teacher training to integrate accessibility features into classrooms, resulting in widespread confidence among educators (OECD, 2023). Similarly, teachers in North Macedonia created a grassroots e-tool to manage individualised education plans (IEPs), demonstrating that empowering teachers drives innovation even in low-resource contexts (UNICEF, 2018). Unlike these top-down or grassroots-only approaches, IMMAS represents a hybrid model, offering structured training while fostering teacher-led content creation. This aligns with Hennessy et al.'s (2022) findings that mobile professional development in LMICs succeeds when it balances formal instruction and peer-driven support networks.

Table 3 contrasts inclusive EdTech strategies across Malaysia, OECD nations, and Southeast Asia, illustrating how IMMAS offers a grassroots-driven, scalable approach that complements policy-heavy and resource-intensive models.

**Table 3.** Comparison of inclusive EdTech approaches in different contexts

| Factor | Malaysia (IMMAS Study) | OECD example (Sweden, Belgium, U.S.) | Southeast Asia example (Philippines, Thailand) |
|---|---|---|---|
| Training Model | Blended, practice-based, teacher-led multimedia design training | National-level programs and webinars focus on accessibility and differentiation (OECD, 2023) | Community-driven approaches, e.g., radio-based lessons and affordable e-platforms (UNESCO, 2020) |
| Teacher Role | Teachers as content creators, peer mentors, and innovators | Teachers trained with standardised resources and top-down support | Teachers often lead creative, low-tech inclusion solutions |
| Infrastructure | Moderate resources; uses open-source, mobile-friendly tools | High-level investment in accessibility tech and national PD programs | Mixed: Some high-tech investments, but many rely on low-cost tools |
| Innovation Approach | Grassroots-driven, scalable, low-cost content sharing | System-driven innovation, policy-led resource deployment | Hybrid: Policy support plus local adaptation |

**Table 3:** (Continued)

| Factor | Malaysia (IMMAS Study) | OECD example (Sweden, Belgium, U.S.) | Southeast Asia example (Philippines, Thailand) |
|---|---|---|---|
| Key Outcome Evidence | Increased teacher self-efficacy, sustainable multimedia lesson libraries | Higher confidence and integration of accessibility features | Equity in access through creative solutions during school closures |
| Relevance to SDG 4 | Bridges policy aspirations with classroom realities | Institutionalised equity measures and universal design integration | Regional solutions highlight adaptability and resourcefulness |

## Critical Reflections and Tensions

Despite its successes, the study also highlights several challenges. Time constraints were a common issue, as teachers struggled to balance multimedia creation with their teaching load. Additionally, while participants gained digital fluency, not all received formal institutional recognition for their efforts, potentially limiting long-term motivation.

There is also a risk that, when scaled, IMMAS could lose its contextual sensitivity. Any future expansion must retain the adaptive, teacher-centred ethos of the program, allowing for flexibility based on classroom realities. Ongoing support, incentives, and reflective spaces will be essential to maintain impact at scale.

In sum, the discussion confirms that mobile multimedia training, when rooted in pedagogical purpose and supported by community practice, can lead to transformational outcomes in inclusive education. IMMAS empowered teachers not only to teach differently but to see themselves differently, sparking a shift toward innovation, ownership, and sustainability in special education.

## IMPLICATIONS FOR POLICY AND PRACTICE

The IMMAS model presents a promising, scalable professional development framework that aligns closely with the goals of the Malaysia Education Blueprint (2013–2025) and the Special Education Transformation Plan (2019–2025). The findings demonstrate that inclusive digital pedagogy can be effectively nurtured not through top-down mandates alone, but through teacher-driven innovation, supported by context-sensitive training in mobile content creation.

At the policy level, ministries of education and curriculum developers should consider embedding mobile multimedia design-based training as a core component of national

in-service teacher professional development programs. Such training should be aligned with UDL principles and localised to accommodate language, cultural, and disability-specific needs.

At the school level, institutional supports such as peer mentoring structures, collaborative digital content libraries, and leadership recognition mechanisms are crucial for sustaining innovation. Headteachers and school leaders play a key role in enabling a professional culture where special education teachers are viewed not only as implementers of policy but also as instructional designers and changemakers.

Additionally, the IMMAS model holds high potential for adaptation across other LMICs where systemic barriers to inclusion persist, and where mobile technologies are more accessible than expensive hardware or fixed infrastructure. Its grassroots orientation, cost-effectiveness, and teacher agency emphasis make it an attractive model for equity-driven educational reforms globally.

## LIMITATIONS AND FUTURE DIRECTIONS

While this study provides meaningful insights into the pedagogical and identity transformation of special education teachers through the IMMAS training program, several limitations must be acknowledged. First, the relatively small sample size of ten teachers (7 female, 3 male) constrains the generalisability of the findings beyond the immediate study context. While the qualitative case study design allowed rich, in-depth exploration, the restricted number of participants means results should be interpreted as context-specific rather than representative of all Malaysian special education teachers. Replication with larger and more diverse cohorts is needed to strengthen external validity.

Second, participants were drawn exclusively from government primary schools in two Malaysian states, Penang, and Perak. This geographical and institutional scope may not fully capture the cultural, administrative, and infrastructural diversity across Malaysia or in other low- and middle-income country contexts. Therefore, replication of this study across multiple regions or educational systems would be valuable to explore how local contexts mediate the effectiveness of digital training interventions.

Third, the study focused on short-term impacts immediately following the eight-week intervention. While evidence of professional identity shift and peer collaboration was promising, the long-term sustainability of these changes remains unverified. Future research should adopt longitudinal designs to trace how teacher practices, peer networks, and content reusability evolve, particularly after institutional supports diminish.

Finally, while the IMMAS program emphasised user-centred design and localised content creation, further exploration is needed on how these teacher-generated innovations interface with national curriculum mandates, assessment systems, and school leadership structures. Investigating these systemic enablers and constraints would enhance understanding of how grassroots innovation can scale within formal education systems.

By addressing these limitations, future research can contribute to a more robust, comparative, and policy-relevant knowledge base for inclusive digital pedagogy in special education.

## CONCLUSION

This study examined the pedagogical, professional, and sustainable impacts of the Interactive Mobile Multimedia Applications (IMMAS) training program among Malaysian special education teachers. The program demonstrated that mobile multimedia tools, when embedded within a carefully designed, context-responsive training model, can significantly enhance teacher capacity and instructional innovation. Teachers shifted from traditional, worksheet-driven instruction to multimodal, learner-centred lesson design, integrating accessibility features such as captions, sign language overlays, and scaffolded visuals.

More importantly, IMMAS contributed to teacher identity transformation, positioning participants as instructional designers and peer mentors rather than passive implementers of curriculum. These findings affirm Bandura's (1997) assertion that mastery experiences and social recognition fuel professional confidence and agency. The emergence of school-level micro-communities of practice aligns with Vygotsky's (1978) sociocultural learning theory, demonstrating that sustainable innovation often stems from teacher collaboration and grassroots initiatives.

Nonetheless, studying carries important limitations. The small sample size of ten teachers constrains the generalisability of findings beyond the immediate cohort, and the absence of quantitative triangulation means that results should be interpreted as exploratory rather than conclusive. In addition, the short intervention period captures only immediate transformations, without evidence of long-term sustainability. These constraints underline the need for larger, mixed-methods, and longitudinal studies to validate and extend the present findings.

Globally, this study extends the literature on integrating TPACK and Universal Design for Learning (UDL) frameworks in teacher professional development. Consistent with Lambert et al. (2023) and Wang and Sitthiworachart (2025), IMMAS illustrates how design-based training can translate UDL principles into practical classroom strategies,

especially in LMICs where accessibility-focused PD remains limited. The study also highlights parallels with OECD models, where structured, top-down training is common (OECD, 2023), while positioning IMMAS as a complementary bottom-up approach tailored to Malaysia's education landscape and broader Southeast Asian contexts (EdTech Hub, 2024).

This research contributes to Sustainable Development Goal 4 (SDG 4) by demonstrating that inclusive, equitable education can be advanced not only through infrastructure investment but also through empowering teachers as innovators. By emphasising reusable digital resources, mobile learning tools, and peer mentoring, IMMAS offers a scalable, cost-effective model for teacher professional development that bridges policy aspirations and classroom realities.

Future research should adopt longitudinal designs to evaluate long-term sustainability, institutional recognition, and integration with national education policies, such as Malaysia's Digital Education Policy (2023). Comparative studies across other Southeast Asian and OECD contexts would further illuminate how IMMAS can inform global strategies for inclusive, technology-driven teacher training. Ultimately, this work underscores that sustainable educational transformation is most powerful when educators are equipped with the tools, confidence, and agency to design inclusive learning experiences for every child.


## CONFLICT OF INTEREST

The authors have no conflict of interest in reporting.


## DATA AVAILABILITY

The datasets generated and analysed during the current study are not publicly available due to ethical restrictions and participant confidentiality but are available from the corresponding author on reasonable request.


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## AUTHORS' CONTRIBUTIONS

Murugesu Supermaniam: Conceptualisation, methodology, writing – original draft preparation.

Nur Amalina Samsudin: Data collection, formal analysis, writing – review and editing.

Ersin Ates: Supervision and project administration

## STATEMENT OF ARTIFICIAL INTELLIGENCE (AI) USE

AI tools (ChatGPT, OpenAI) were used during the writing process to generate outlines, summarise relevant literature, and provide language support. The authors critically reviewed, validated, and revised all AI-generated text to ensure accuracy and academic integrity**.**

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## APPENDICES

### Appendix A: Interview Protocol for Teacher Participants

This semi-structured interview protocol was used to explore teachers' perceptions of the IMMAS training program and its classroom impact.

Questions:

1. Can you describe your initial experience with the IMMAS training program?

2. What challenges did you face in integrating multimedia resources into your teaching?

3. How has your confidence in using mobile technology for inclusive lessons changed?

4. Can you share an example of how students responded to a multimedia activity?

5. How do you see IMMAS impacting your lesson planning over the next year?

6. What further support or training would enhance your teaching practice?

**Appendix B: Reflective Journal Template**

| Week | Lesson title | Multimedia tools used | Observed student responses | Challenges faced | Next steps |
|---|---|---|---|---|---|
| Example: Week 2 | Science of Sound | IMMAS app, captioned video, sign language overlay | Students were highly engaged; deaf students followed captions easily | Limited time for editing | Plan shorter videos for next week |

**Appendix C: Observation Checklist**

| Observation item | Yes/No | Notes |
|---|---|---|
| Multimedia content is used to support lesson objectives | | |
| UDL principles (multiple means of engagement) evident | | |
| Captions or sign language included | | |
| Students actively engaged | | |
| Teacher demonstrates confidence using mobile tools | | |
| Peer collaboration or group activities observed | | |

**Appendix D: Multimedia Lesson Artifact**

This screenshot shows a multimedia lesson created using IMMAS, featuring:

- A captioned introduction video explaining vocabulary.

- An interactive image hotspot for science concepts.

- A sign-language demonstration clip embedded for deaf learners (Insert anonymised screenshot with a clear caption).

**Appendix E: Training Module Outline (IMMAS Program)**

| Module | Title | Key focus areas | Duration | Activities |
|---|---|---|---|---|
| 1 | Introduction to Inclusive Multimedia | Overview of UDL, TPACK, and inclusion strategies | 2 hours | Group discussion, case studies |
| 2 | Mobile Tools for Accessibility | Training on IMMAS app features, captioning tools | 3 hours | Hands-on workshop |
| 3 | Lesson Design Studio | Guided design of inclusive multimedia lessons | 4 hours | Peer review of lesson drafts |
| 4 | Classroom Implementation | Strategies for adapting content for diverse learners | 3 hours | Simulated teaching |
| 5 | Reflection & Sustainability | Content sharing, peer mentoring, scaling ideas | 2 hours | Reflection journals, group sharing |