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TPACK-universal design for learning for Malaysian intellectual disability education: low-high tech integration

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ABSTRACT

The integration of technological pedagogical content knowledge (TPACK) and universal design for learning (UDL) in special education remains challenging, particularly for intellectual disabilities (ID) learners in East Malaysia. This study investigated how special education teachers utilize technology tools and integrate UDL principles with TPACK frameworks to support ID learners, addressing the need for inclusive education aligned with sustainable development goal 4 (SDG 4). Using a qualitative approach, data were collected through semi-structured interviews, classroom observations, and document analysis from four purposively selected special education teachers in two East Malaysian secondary schools offering special education integration programs (SEIP). Thematic analysis revealed three key findings: i) low technology supports for accessibility and engagement; ii) high technology integration for personalization and empowerment; and iii) integrating of TPACK and UDL principles challenges due to limited understanding and resource constraints. The study concluded that while teachers show commitment to technology use, there is a pressing need for targeted professional development to enhance TPACK and UDL competencies. These findings align with SDG 4's focus on quality education for all, emphasizing how enhanced teacher training and effective technology integration can significantly improve the quality and inclusivity of education for ID learners.

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1. INTRODUCTION

In recent years, the integration of technology into educational practices has created opportunities to support intellectual disabilities (ID) learners in inclusive environments. Frameworks such as technological pedagogical content knowledge (TPACK) and universal design for learning (UDL) have emerged as crucial paradigms for enhancing the educational experience of diverse learners, particularly those with ID [1], [2]. TPACK emphasizes the integration of technology, pedagogy, and content knowledge to optimize instructional strategies, while UDL supports the design of flexible learning environments to accommodate the needs of all learners [2]–[4].These frameworks align with sustainable development goal 4 (SDG 4): quality education, which aims to ensure inclusive and equitable quality education while promoting lifelong learning opportunities for all [5], [6].

Despite the recognized potential of TPACK and UDL frameworks, there is limited research on their effective implementation in special education contexts, particularly for ID learners. This gap is especially

critical as ID learners often require tailored educational approaches to meet their unique learning needs [7]. ID learners often require tailored educational approaches to meet their unique learning needs [7], [8]. Limited access to adequate resources and a lack of understanding of how to successfully integrate these frameworks contribute to the implementation gap. Previous studies have highlighted significant challenges faced by special education teachers, including the lack of resources and professional development opportunities necessary to support the creation of inclusive learning environments [9], [10]. Recent studies also have shown that these frameworks can significantly improve learning outcomes for students with disabilities when properly implemented [2], [11]. However, their application in Southeast Asian contexts, particularly in Malaysia, remains understudied [12]. This research explores how special education teachers in East Malaysia apply TPACK and UDL principles to enhance learning for students with ID in the special education integration program (SEIP).

The integration of low and high technology tools plays a crucial role in supporting ID learners through the application of TPACK and UDL principles. The application of UDL principles, which emphasize providing multiple means of representation, expression, and engagement, has shown promise in accommodating the diverse learning needs of students with ID [13]. Low technology supports refer to simple, readily available, and often non-electronic tools used to support learning, such as visual aids and graphic organizers, that have been shown to promote accessibility and engagement [14]. High technology, on the other hand, encompasses advanced electronic tools and digital resources, such as educational software, audiobooks, and interactive quizzes, which require some technical knowledge for setup and use [15]. Previous research indicates that using both low and high technology can significantly enhance learning for ID learners [16], [17]. However, there is limited research on how these technologies are used within the TPACK framework to support UDL principles in the Malaysian context, particularly in East Malaysia [9].

The importance of this study lies in its potential to bridge the existing gap in knowledge and practice by investigating how special education teachers in East Malaysia utilize TPACK and UDL frameworks. By exploring the current practices and challenges in both low and high technology integration, this study is addressed to inform the development of targeted professional development programs. This, in turn, can enhance teachers' ability to create inclusive and effective educational environments for ID learners, addressing the goals outlined in the Malaysian Education Blueprint for improving teacher quality and promoting inclusivity [18], [19]. By focusing on both low and high technology integration in the context of TPACK and UDL frameworks, this study contributes to the limited body of research on technology use in special education in Malaysia, particularly for ID learners.

This study aims to explore how special education teachers in East Malaysia utilize TPACK and UDL frameworks, focusing on both low and high technology tools to support ID learners in the SEIP. This study seeks to inform the development of targeted professional development programs, thereby enhancing teachers' ability to create inclusive and effective educational environments for ID learners. The study is guided by three primary objectives: i) to explore how special education teachers utilize low technology tools to support ID learners in SEIP classrooms; ii) to investigate the utilization of high technology tools in these classrooms; and iii) to explore how teachers integrate UDL principles with TPACK frameworks to enhance the learning experiences of ID learners. Using a qualitative approach, this study conducts semi-structured interviews, classroom observations, and document analysis to gather in-depth insights from four purposively selected special education teachers in two East Malaysian secondary schools offering SEIP. By addressing these objectives, this study aims to provide a comprehensive understanding of the current practices and challenges faced by special education teachers in utilizing technology within both frameworks, ultimately contributing to the improvement of inclusive environment for ID learners. The outcomes of this study have implications for educational policy, teacher training programs, the development of resources to support inclusive education practices in Malaysia and contributing to the broader goal of promoting inclusive and equitable quality education for all learners.

2. METHOD

This qualitative study used purposive sampling to choose four special education teachers from two secondary schools in East Malaysia that offer SEIP. These teachers were selected based on their experience with SEIP and their willingness to participate in an in-depth study, providing a focused sample for exploring TPACK and UDL implementation in this specific context. Data was gathered through semi-structured interviews, classroom observations, and document analysis. Thematic analysis was conducted as a method for identifying important patterns and themes in the data, following a six-stage process [20]. The analytical procedure involved becoming acquainted with the data, creating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing a report as the last stage, as shown in Figure 1.

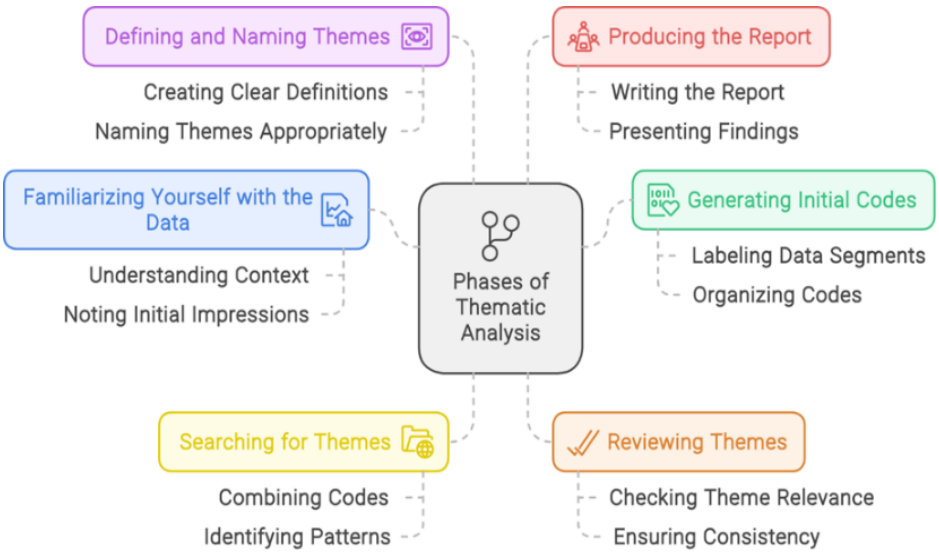

Figure 1. Thematic analysis [20]

2.1. The validity of the study instrument

Investigator triangulation is an approach used by researcher to acquire qualitative data via semi-structured interviews, observations, and document analysis [21]. Each data set obtained from numerous instruments will be examined for validity, and the findings from each evaluation will be compared to produce a wider and deeper understanding concerning the research [21], [22]. The triangulation process enhances data credibility through systematic cross-verification of findings from multiple sources [21]. This methodological approach strengthens the validity of research findings and helps identify consistent patterns across different data collection methods. Triangulation in qualitative research particularly benefits special education studies by providing comprehensive insights into complex educational phenomena [23].

2.2. The reliability of the study instrument

To ensure the study instrument's dependability, it was tested on a pilot sample equivalent to the main study sample. A pilot study is required to identify potential mistakes, avoid repetition, and initiate improvements before actual data collection [23], [24]. This process can increase the researcher's confidence to face possible situations and prepare more carefully before fieldwork [25]. The pilot study aims to gain insight into the phenomenon being studied, improve interview expertise, and enhance communication skills before actual data collection with study participants [26].

3. RESULTS AND DISCUSSION

Following the process of thematic analysis, several themes became evident in relation to the exploration of TPACK involving low and high technology that align with UDL principles for ID learners in the SEIP classroom. The analysis revealed how special education teachers incorporate different levels of technology in their teaching practices. Through thematic coding, patterns emerged showing various approaches to implementing both low and high technology tools. The examination of classroom practices demonstrated how special education teachers adapt TPACK frameworks and UDL principles to support learners with ID. Table 1 shows the findings based on observations.

The analysis explored how teachers utilize different technological approaches in their instructional practices. Each theme represents distinct aspects of how TPACK and UDL frameworks are implemented in special education settings. The findings show how classroom practices revealed varying levels of technology integration and implementation approaches. The analysis highlighted specific challenges teachers encounter in integrating these frameworks, particularly regarding resource constraints and framework. Thematic analysis of the data collected through semi-structured interviews, observations, and document analysis revealed three key themes related to the integration of TPACK and UDL principles in supporting learners with ID in SEIP classrooms in East Malaysia.

Table 1. Findings based on observation

Informant	TPACK integration	Low technology	High technology	UDL principles	Findings
Informant 1	Technology and pedagogy integration	Visual support materials, graphic organizers	Educational software, interactive quizzes	Multiple means of representation	Low technology supports for accessibility and engagement
Informant 2	Technology and content integration	Highlighted handouts, tactile materials	Digital flashcards, audiobooks	Multiple means of representation	Low technology supports for accessibility and engagement
Informant 3	Technology pedagogy, and content integration	Task analysis charts, choice boards	Word prediction apps, text-to-speech software	Multiple means of action and expression	High technology integration for personalization and empowerment
Informant 4	Comprehensive TPACK integration	Manipulatives, timers, fidget tools	Gamification elements, adaptive learning platforms	Multiple means of engagement	High technology integration for personalization and empowerment

3.1. Low technology supports for accessibility and engagement

All four informants demonstrated a strong commitment to using low technology supports to enhance accessibility and engagement for ID learners. As shown in Table 1, these included visual support materials, graphic organizers, highlighted handouts, and tactile materials. For instance, when asked about the use of visual aids in the classroom, one of informant provided a detailed response:

Interviewer : "*How do you use visual aids in your classroom?*"
Informant 1 : "*Visual aids are crucial for our ID learners. I use picture cards to teach vocabulary. It's amazing how much better students understand and remember when they can see and touch the materials.*"

This response exemplifies the strong commitment to using low technology supports to enhance accessibility and engagement for ID learners, as observed across all four informants. The use of picture cards for vocabulary instruction demonstrates a practical application of the UDL principle of multiple means of representation. Similarly, when discussing the use of organizational tools, another teacher shared their approach:

Interviewer : "*Can you give an example of how you use graphic organizers?*"
Informant 2 : "*I use graphic organizers to help students understand narrative structure when I teach comprehension. It helps them visualize the story elements and their relationships.*"

These interview responses corroborate with classroom observations, where Informant 1 actively uses picture cards in vocabulary lessons. Informant 2 implementing graphic organizers during comprehension exercises. Furthermore, document analysis of lesson plans also revealed consistent integration of these low-tech tools. These practices align with the UDL principle of providing multiple means of representation and engagement [4]. The effectiveness of such low-tech tools in enhancing learning for students with ID is supported by research, emphasizing their value [15].

3.2. High technology integration for personalization and empowerment

Observations and interviews indicated that all informants, particularly Informants 3 and 4, integrated high technology tools to personalize instruction and empowering students with ID. These included educational software, interactive quizzes, digital flashcards, word prediction apps, and audiobooks. For example:

Interviewer : "*How do you use high technology tools in your classroom?*"
Informant 3 : "*Using interactive quizzes like Kahoot has significantly improved student engagement and retention of the topics learned. The students are more excited to participate, and I can easily track their progress based on the responses given.*"
Informant 4 : "*The audiobooks and word prediction apps have been very helpful to my students who have difficulties with reading and writing. I can see these tools allow them to work with more complex texts and express their ideas more easily.*"

These responses align with our classroom observations, where we saw Informant 3 conducting an interactive quiz session using Kahoot, with students showing high levels of engagement. Informant 4 was observed assisting students with audiobooks and word prediction software during a writing exercise. Document analysis of lesson plans further confirmed the regular integration of these high-tech tools, with specific sections dedicated to technology-enhanced activities. The effective use of technology can empower students with disabilities, promoting independence and self-efficacy [13].

3.3. Integrating of TPACK and UDL principles

Despite the observed benefits, all informants reported challenges in fully integrating TPACK and UDL principles. Interviews and observations revealed issues related to limited understanding of the frameworks, resource constraints, and lack of institutional support. Limited teacher training and resource availability are identified as significant barriers in Malaysian special education, consistent with previous findings [19]. The importance of institutional support and adequate resources for the successful implementation of inclusive education practices is also emphasized in the literature.

Interviewer : "*What challenges do you face in integrating technology and inclusive design principles in your teaching?*"

Informant 1 : "*We want to do more with technology, but we lack the training and sometimes limited resources to implement these ideas effectively. It's challenging to keep up with new technologies and understand how to best integrate them into our teaching.*"

Informant 4 : "*Sometimes, we face technical issues or don't have enough devices for all students. It can be frustrating when you plan a lesson using technology and then can't implement it due to these constraints.*"

These findings underscore the need for targeted professional development to enhance teachers' competencies in TPACK and UDL, as well as improved resource allocation to support the effective integration of these frameworks in special education settings. Overall, the informants' views demonstrated how high technology and low technology resources can complement one another well in the context of special education. The findings of the study are consistent with previous research indicating that low and high technologies are interrelated to facilitate classroom teaching [3], [11].

Additionally, special education teachers emphasized the value of incorporating technology into instructional methods while endorsing less technologically complex, more adaptable, and more affordable options [16]. Through the integration of both TPACK and UDL principles, special education teachers developed comprehensive learning experiences tailored to the individual needs of ID learners [27], [28]. The implementation of these frameworks enabled teachers to create more inclusive learning environments that accommodate diverse learning needs [29]. These adaptations demonstrate how technology integration can support differentiated instruction in special education settings while considering practical resource constraints.

The exploration of TPACK and UDL within special education for ID learners reveals crucial insights regarding challenges and opportunities in low and high technology integration. Based on the findings, special education teachers had difficulties due to their limited familiarity with and knowledge of the application of UDL principles alongside TPACK frameworks. Addressing challenges through comprehensive professional development, equitable resource allocation, and robust institutional support is crucial for enhancing TPACK and UDL competencies among special education teachers. This approach is essential for creating an inclusive educational environment that optimizes low and high technology integration, ultimately ensuring inclusive and equitable learning experiences for ID learners.

4. CONCLUSION

Integrating TPACK and UDL principles enriches the educational experience for ID learners. By incorporating teaching expertise with technology and knowledge of the subject, the special education teachers can adapt instruction to individual ID learner besides create meaningful learning experiences. Future studies could explore the long-term impact of integrating TPACK and UDL principles on ID learners' academic outcomes. Additionally, developing targeted professional development programs based on these findings could enhance teachers' competencies in creating inclusive learning environments.

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AUTHOR CONTRIBUTIONS STATEMENT

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

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study. Participating teachers were informed about the purpose of the research and their right to withdraw at any time.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the Universiti Malaysia Sarawak Ethics Committee.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [ZSN], upon reasonable request. The data are not publicly available due to privacy and ethical restrictions as they contain information that could compromise the privacy of research participants.

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