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NAVIGATING THE INTERSECTION OF EARLY CHILDHOOD SPECIAL EDUCATION, MOBILE LEARNING, AND CLIMATE CHANGE IN POST-PANDEMIC MALAYSIA AND BEYOND

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ABSTRACT

The post-pandemic era has highlighted the urgent need to adapt educational practices to emerging global challenges. Early Childhood Education (ECE) and Special Education (SPED) face unique demands in addressing the needs of diverse learners, especially amid climate change and the digital transformation of learning. This article examines the evolving landscape of ECE and SPED in Malaysia and other countries, focusing on integrating mobile learning technologies to enhance educational equity and quality. By addressing the dual challenges of climate change and the pandemic, the study explores innovative strategies to create sustainable and inclusive educational frameworks. Comparative analyses, case studies, and actionable recommendations provide insights into how educational systems can respond to global trends and local realities.

Keywords: *Early Childhood Education, Special Education, Mobile Learning, Post-Pandemic Education, Climate Change and Education, Malaysia Education System, Global Education Trends, Technology Integration in Education, Comparative Education Studies.*

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INTRODUCTION

The COVID-19 pandemic has fundamentally transformed the educational landscape worldwide, amplifying existing inequalities and exposing systemic vulnerabilities. For Early Childhood Education (ECE) and Special Education (SPED), these challenges are particularly acute. These fields cater to young and diverse learners whose developmental needs are highly sensitive to disruptions. The pandemic also intersected with the growing impacts of climate change, presenting a dual crisis that affects educational infrastructure, resource availability, and curriculum relevance.

In Malaysia, the confluence of these factors demands urgent attention. The country's geographic location makes it vulnerable to climate change, with increasing instances of flooding, heatwaves, and resource scarcity (World Bank, 2022). These challenges affect access to education, particularly for marginalized and rural communities. Furthermore, the rapid adoption of mobile learning technologies during the pandemic demonstrated the potential of digital tools to bridge educational gaps, though their integration into SPED and ECE systems remains inconsistent. This article explores these interconnected themes and proposes strategies to create resilient, inclusive, and effective educational frameworks in Malaysia and beyond (UNESCO, 2021; OECD, 2021).

METHODOLOGY

This study employs a systematic literature review (SLR) approach to comprehensively analyze the intersection of Early Childhood Education (ECE), Special Education (SPED), mobile learning, and climate change in a post-pandemic context. The methodology is designed to ensure a robust and transparent synthesis of existing knowledge by adhering to established SLR protocols, particularly PRISMA guidelines (Moher et al., 2009).

The systematic review focused on peer-reviewed journals, policy documents, and official reports to identify global and regional trends in ECE and SPED, with a particular focus on Malaysia and comparable nations such as Singapore, Japan, and Australia. Research published between 2010 and 2023 was included, addressing themes such as mobile learning, climate resilience, and their application in ECE and SPED. Literature was sourced exclusively from online databases, including Web of Science, Scopus, and JSTOR. Inclusion criteria emphasized high-quality, peer-reviewed studies in English, while articles unrelated to education or not addressing Malaysia or comparable regions were excluded. This method ensured the comprehensiveness and reliability of the data (Higgins et al., 2019).

Case studies from Malaysia and three benchmark countries—Singapore, Japan, and Australia—were included to provide contextual depth. These countries were chosen for their advanced practices in climate resilience, mobile learning, and the integration of educational technology. Singapore's SkillsFuture framework highlights lifelong learning and education technology, Japan's disaster-resilient education programs emphasize adaptation to natural disasters, and Australia's comprehensive climate change education embedded in the curriculum offers valuable lessons (Ministry of Education Singapore, 2023; UNESCO, 2021).

Quantitative data were collected from secondary sources, including World Bank and OECD reports, focusing on indicators such as mobile learning adoption rates, teacher training hours, internet connectivity, and climate resilience of educational infrastructure. Comparative tables and descriptive statistics were used to identify gaps and levels of readiness within Malaysia's education system relative to benchmark countries. Tools such as SPSS and Microsoft Excel facilitated data analysis and visualization (World Bank, 2022; OECD, 2021).

Theoretical frameworks underpinning the study included Bronfenbrenner's Ecological Systems Theory, which explores the multifaceted influences on children's learning environments, and the SAMR (Substitution, Augmentation, Modification, Redefinition) model, used to assess the transformative potential of mobile learning technologies. Design

Thinking and Ecopedagogy frameworks were also integrated to further bridge theory with practical innovation, ensuring recommendations are both learner-centered and sustainable (Penuel & Gallagher, 2017).

Impact of Climate Change on Early Childhood and Special Education

Climate change poses significant challenges to educational systems, particularly for vulnerable populations. In Malaysia, recurring floods disrupt schooling in rural areas, while heatwaves strain the infrastructure of poorly ventilated classrooms. For children in ECE and SPED programs, these disruptions are especially detrimental due to their reliance on stable environments for learning and development (World Bank, 2022).

To humanize this narrative, consider the story of a rural teacher in Sarawak who struggled to continue lessons during floods, often using mobile phones and community halls to maintain student engagement. Such real-life accounts underline the urgent need for climate-resilient policies and infrastructure (UNESCO, 2021).

By comparison, countries like Japan and the Netherlands have implemented climate-resilient educational policies that offer valuable lessons. Japan's school safety programs integrate disaster preparedness into early childhood curricula (UNESCO, 2021), while the Netherlands' flood-resistant infrastructure ensures uninterrupted education during extreme weather events (OECD, 2021). Adapting such strategies to Malaysia's context could mitigate the adverse effects of climate change on education.

Mobile Learning: A Pathway to Resilient Education

Mobile learning emerged as a critical tool during the pandemic, enabling educators and students to maintain continuity of learning. For ECE and SPED, mobile platforms offer unique opportunities to personalize learning experiences, cater to diverse needs, and provide accessible resources. However, challenges such as digital divides, lack of specialized content, and insufficient teacher training hinder its full potential (OECD, 2021).

Innovative solutions from global contexts highlight the way forward. For instance, in South Africa, mobile apps designed for low-bandwidth areas have empowered teachers to reach students in remote communities (Isaacs, 2020). Similarly, in rural areas of India, gamified apps have been instrumental in teaching numeracy and literacy. Drawing from these practices can enhance Malaysia's efforts (Banerjee et al., 2021).

In Malaysia, mobile learning initiatives such as the Digital Educational Learning Initiative Malaysia (DELIMa) show promise but require greater alignment with ECE and SPED objectives. Singapore's EdTech ecosystem and Finland's use of gamified learning apps provide useful benchmarks for integrating mobile learning into early childhood and special education systems (Ministry of Education Singapore, 2023).

Mobile learning has emerged as a key strategy to enhance educational resilience, particularly in the wake of the COVID-19 pandemic. The integration of mobile technologies in learning environments has facilitated accessibility, flexibility, and personalization of learning experiences. Studies indicate that mobile learning has played a transformative role in early childhood education (ECE) and special education (SPED), particularly in low-resource settings (Isaacs, 2020).

Several global case studies highlight successful implementations of mobile learning. For instance, in sub-Saharan Africa, the usage of offline mobile applications has enabled students in remote areas to continue their education despite infrastructural limitations (Banerjee et al., 2021). Similarly, Singapore's Digital Educational Learning Initiative Malaysia (DELIMa) serves as a model for integrating mobile learning in mainstream education, though its effectiveness in ECE and SPED requires further assessment (Ministry of Education Singapore, 2023). AI-driven personalized learning tools, such as adaptive learning applications in South Korea, demonstrate promising outcomes in addressing diverse learning needs (UNESCO, 2021). However, barriers such as the digital divide, teacher preparedness, and curriculum integration remain key challenges (OECD, 2021).

Post-Pandemic Shifts in Educational Practices

The COVID-19 pandemic accelerated the adoption of hybrid learning models, integrating both in-person and digital instruction across various educational levels. In early childhood education (ECE) and special education (SPED), hybrid models offer flexibility but also present challenges in maintaining student engagement, ensuring accessibility, and accurately assessing learning outcomes. Systematic literature reviews highlight the necessity of collaborative frameworks involving educators, parents, and policymakers to develop effective hybrid learning environments (Hattie, 2015; Bond et al., 2020).

For instance, the United States has implemented Individualized Education Programs (IEPs) tailored to hybrid settings in SPED, ensuring that students' unique needs are met through personalized learning plans and assistive technologies. Systematic reviews of SPED hybrid models indicate that successful implementations rely on structured teacher training, parental involvement, and robust digital infrastructure (Penuel & Gallagher, 2017; Carter & Wheldall, 2021). Malaysia could adopt similar strategies by integrating culturally relevant, inclusive hybrid models that address both urban and rural disparities (Darling-Hammond, 2020; UNESCO, 2021).

Globally, hybrid education models have evolved to meet contextual needs. In the United States, post-pandemic policies continue to emphasize IEPs for students with disabilities, ensuring continuity of support in hybrid settings. Meanwhile, Australia has embedded climate change resilience into its educational frameworks, ensuring that schools remain operational despite environmental disruptions (OECD, 2021). SLR findings suggest that resilient educational systems incorporate flexible infrastructure, digital preparedness, and adaptive pedagogical approaches (Graham et al., 2022). Malaysia, currently in transition, requires a comprehensive hybrid learning strategy that accounts for both technological readiness and socio-economic factors to effectively bridge urban-rural educational gaps (World Bank, 2022; Ministry of Education Malaysia, 2023).

Comparative Perspectives on Global Trends

The integration of technology, climate change adaptation, and post-pandemic resilience in education has been approached differently across countries, reflecting diverse policy priorities and socio-economic contexts. Australia has embedded climate change education into its national curriculum from an early age, fostering environmental awareness and sustainability literacy among young learners (Darling-Hammond, 2020; UNESCO, 2022). South Korea, on the other hand, has leveraged AI-driven mobile learning platforms to support special education (SPED) students by providing personalized and adaptive learning experiences (Banerjee et al., 2021; Kim & Jung, 2023). Meanwhile, Kenya's community-driven digital education initiatives illustrate how grassroots solutions can align with global innovations to drive systemic change and increase educational accessibility in underprivileged areas (Isaacs, 2020; Wanjala & Omondi, 2023).

Malaysia's education system could benefit from adapting and localizing these global best practices by adopting a holistic approach that integrates climate education, digital tools, and inclusive pedagogies. Systematic literature reviews emphasize that multidimensional education strategies combining digital learning, sustainability, and adaptive pedagogies can equip students with the skills and knowledge to navigate future uncertainties (UNESCO, 2021; OECD, 2022).

Comparative analyses of global education trends highlight the effectiveness of gamification techniques in digital learning environments. For instance, Finland's mobile learning platforms incorporate gamification elements, enhancing student engagement, motivation, and retention (UNESCO, 2021; Järvinen & Väättäjä, 2022). Similarly, Kenya's grassroots digital initiatives emphasize community-based education models, reinforcing localized digital learning strategies to bridge socioeconomic and rural-urban disparities (Isaacs, 2020; Wanjala & Omondi, 2023). These models offer valuable insights for Malaysia as it seeks to expand and refine its digital education landscape.

Additionally, public-private partnerships (PPPs) have been instrumental in scaling mobile learning initiatives worldwide. South Korea's government-led digital education policies, developed in collaboration with technology companies, have established sustainable digital learning ecosystems that promote equal access to quality education (Banerjee et al., 2021; Kim & Jung, 2023). Systematic reviews highlight that well-structured PPPs enhance financial sustainability, technological advancement, and long-term scalability in digital learning (OECD, 2022). Malaysia's education policies could leverage similar collaborative frameworks to enhance the accessibility, inclusivity, and effectiveness of its mobile learning solutions (Ministry of Education Singapore, 2023; World Bank, 2023).

RECOMMENDATIONS

To address the pressing challenges in Early Childhood and Special Education, a multifaceted approach is required. Firstly, developing climate-resilient educational policies is imperative. Integrating disaster preparedness training into ECE and SPED curricula would equip young learners and educators with the skills needed to respond to environmental challenges (UNESCO, 2021). Furthermore, investing in climate-resilient infrastructure, especially in flood-prone and rural areas, would ensure educational continuity during extreme weather events (World Bank, 2022).

Secondly, enhancing the integration of mobile learning is crucial. This involves developing specialized mobile learning content tailored to the unique needs of SPED and ECE students (OECD, 2021). Comprehensive training programs should be provided to educators to maximize the potential of these technologies (Ministry of Education, Singapore, 2023). Additionally, expanding internet connectivity in underserved areas to ensure equitable access to digital tools would help bridge the digital divide (Isaacs, 2020).

Fostering collaborative frameworks is another critical step. Stakeholders, including parents, educators, and policymakers, must actively co-design hybrid learning models to ensure they are both inclusive and effective (Hattie, 2015). Establishing partnerships with international organizations would enable Malaysia to adopt best practices and access additional resources (Darling-Hammond, 2020).

Embedding climate change education into early childhood and special education curricula is equally important. Age-appropriate climate education programs should be developed to raise awareness among young learners (UNESCO, 2021). Practical activities, such as community gardening, can provide hands-on experiences that instill sustainability concepts (OECD, 2021).

Lastly, strengthening research and data-driven decision-making is essential for continuous improvement. Longitudinal studies on the effectiveness of hybrid and mobile learning in ECE and SPED should be conducted to identify best practices and areas requiring intervention (Ministry of Education Singapore, 2023). Utilizing data analytics would further aid in tailoring educational strategies to meet the diverse needs of learners (World Bank, 2022).

Short-Term Goals: Expand internet connectivity and conduct localized teacher training sessions.

Medium-Term Goals: Develop mobile apps tailored to SPED learners and conduct nationwide pilot programs for hybrid learning models.

Long-Term Goals: Institutionalize climate-resilient infrastructure policies and position Malaysia as a leader in inclusive, tech-driven education across Southeast Asia.

Data and Tables

Table 1:

Key Indicators of Educational Resilience in Malaysia and Selected Countries

Indicator	Malaysia	Singapore	Japan	Netherlands
Mobile Learning Access	65%	95%	90%	85%
Teacher Training Hours	20	40	35	30
Climate Resilience Programs	Limited	Moderate	High	High
Internet Connectivity (%)	80%	98%	96%	94%

Source: Data adapted from World Bank (2022), OECD (2021), and Ministry of Education Singapore (2023).

Table 1 presents the key indicators of educational resilience, highlighting disparities in mobile learning access, teacher training, climate resilience, and internet connectivity across Malaysia, Singapore, Japan, and the Netherlands. Singapore leads in mobile learning adoption (95%) and teacher training hours (40 per year), demonstrating strong governmental investment in digital education. Japan and the Netherlands also show high levels of internet connectivity (96% and 94%, respectively) and robust climate resilience programs, ensuring minimal disruptions in education due to environmental factors. Malaysia, however, lags in mobile learning access (65%) and climate resilience programs, which remain limited. While its internet connectivity (80%) is relatively high, inconsistent access in rural areas remains a barrier. To enhance resilience, Malaysia must expand digital learning infrastructure, improve teacher training in mobile education, and implement policies for climate-adaptive education systems.

Table 2:
Comparative Frameworks for SPED and ECE Integration

Framework	Malaysia	United States	Australia
Individualized Learning	Developing	Established	Established
Climate Education	Minimal	Emerging	Comprehensive
Mobile Technology Use	Moderate	High	High

Source: Compiled from UNESCO (2021), Darling-Hammond (2020), and Hattie (2015).

This table compares the integration of Special Education (SPED) and Early Childhood Education (ECE) frameworks in Malaysia, the United States, and Australia. Malaysia's individualized learning approach for SPED students is still in its early stages, whereas the United States and Australia have well-established programs that provide tailored educational support. Similarly, climate education remains minimal in Malaysia, while Australia has taken a comprehensive approach by embedding sustainability and climate resilience in early education curricula. In terms of mobile technology use, Malaysia is at a moderate level, while the U.S. and Australia have already integrated high-level digital tools to enhance inclusive and adaptive learning experiences. To close the gap, Malaysia must strengthen policies for individualized learning in SPED, integrate climate education into early learning frameworks, and increase adoption of mobile technology for personalized and inclusive education.

Table 3:
Mobile Learning and Education Resilience Indicators in Malaysia and Benchmark Countries

Indicator	Malaysia	Singapore	Japan	Australia
Mobile Learning Adoption Rate	65%	95%	90%	85%
Teacher Training on Mobile Learning (Avg. Hours Per Year)	20	40	35	30
Integration of Climate Education in Curriculum	Low	Moderate	High	High
Internet Connectivity in Schools (%)	80%	98%	96%	94%
Availability of SPED Mobile Learning Tools	Limited	High	High	Moderate
Government Support for Digital Learning	Moderate	High	High	High
Public-Private Partnerships in Education Tech	Limited	Extensive	Strong	Strong

Source: Adapted from UNESCO (2021), World Bank (2022), Ministry of Education Singapore (2023), OECD (2021).

The table highlights key indicators of mobile learning adoption and education resilience across Malaysia, Singapore, Japan, and Australia. Singapore leads with a 95% mobile learning adoption rate, extensive teacher training programs, and strong government support for digital learning. Malaysia lags in integrating climate education and leveraging public-private partnerships, which limits its capacity to scale mobile learning solutions effectively. While Japan and Australia have high climate resilience in education, Malaysia still faces infrastructure and internet connectivity gaps, particularly in rural areas. Expanding government initiatives and industry collaboration could significantly enhance Malaysia’s mobile learning ecosystem.

Table 4:
Comparative Analysis of SPED and ECE Integration in Mobile Learning

Framework	Malaysia	United States	Australia
Use of Individualized Learning Plans (ILPs) in SPED	Developing	Established	Established
Mobile Learning Accessibility for ECE & SPED	Moderate	High	High
Integration of Gamification in Early Learning	Minimal	High	High
Climate Change Education in Early Learning	Low	Emerging	Comprehensive
Policy Support for Digital Inclusion	Moderate	High	High

Source: Compiled from UNESCO (2021), Darling-Hammond (2020), Hattie (2015), Penuel & Gallagher (2017).

This comparative framework illustrates how the integration of mobile learning in Malaysia’s early childhood education (ECE) and special education (SPED) compares with that in the United States and Australia. While Malaysia is developing individualized learning plans (ILPs) for SPED students, countries like the U.S. and Australia have well-established programs that support hybrid learning environments. The use of gamification in early learning remains low in Malaysia, which contrasts with Australia’s and the U.S.’s highly engaging mobile platforms. Additionally, climate change education remains in its early stages, underscoring the need for Malaysia to embed sustainability learning into digital education tools.

Table 5:
Barriers and Opportunities for Mobile Learning in ECE & SPED

Challenge	Impact on Malaysia	Potential Solutions
Digital Divide (Unequal access to devices & internet)	High	Investment in low-cost internet access & school-provided tablets
Lack of Specialized SPED Content	Moderate	Development of adaptive AI-driven learning apps
Teacher Preparedness & Training	Moderate	Comprehensive digital training programs for educators
Parental Engagement in Mobile Learning	Low	Parent-focused mobile learning workshops
Government and Industry Collaboration	Limited	Expansion of public-private partnerships (PPPs) to scale up mobile education

Source: Isaacs (2020), Banerjee et al. (2021), Ministry of Education Singapore (2023), OECD (2021).

Despite Malaysia’s progress in digital education, several barriers hinder the full adoption of mobile learning in ECE and SPED. The digital divide remains a significant challenge, with rural students having limited access to the internet and insufficient digital devices. There is also a lack of specialized SPED content tailored for mobile platforms, which could be addressed by developing AI-driven adaptive learning tools. Additionally, low parental engagement in digital learning suggests a need for parent-focused training programs to support home-based learning. Expanding public-private

partnerships (PPPs) and teacher training programs will be key to overcoming these barriers and ensuring greater accessibility and effectiveness of mobile education in Malaysia.

Table 4: Key Success Factors from Global Case Studies

Country	Key Mobile Learning Initiative	Lessons for Malaysia
South Korea	AI-driven SPED learning tools	AI-based personalization can enhance accessibility
Singapore	Digital Educational Learning Initiative (DELIMa)	Structured digital ecosystem improves effectiveness
Kenya	Community-based mobile learning	Localized, low-cost solutions are viable for rural Malaysia
Finland	Gamified mobile learning for ECE	Gamification enhances engagement & retention
Japan	Climate-resilient school infrastructure	Early integration of climate education is crucial

Source: UNESCO (2021), OECD (2021), World Bank (2022), Wanjala & Omondi (2023).

By analyzing successful mobile learning initiatives from South Korea, Singapore, Kenya, Finland, and Japan, Malaysia can adapt proven strategies to improve its education system. South Korea’s AI-driven SPED tools demonstrate how personalized learning technologies can benefit students with diverse needs. Singapore’s structured EdTech ecosystem (DELIMa) offers insights into how a well-regulated national digital education initiative can drive success. Kenya’s grassroots mobile learning solutions prove that localized, low-cost innovations can significantly enhance access to education, especially in underserved communities. Additionally, Finland’s use of gamification in ECE shows how interactive mobile apps can boost engagement and learning retention. Malaysia can leverage these lessons to strengthen mobile learning policies, infrastructure, and content development for early childhood and special education programs.

CONCLUSION

The intersection of climate change, mobile learning, and post-pandemic shifts presents both challenges and opportunities for Early Childhood and Special Education in Malaysia and globally. By leveraging technology, fostering collaboration, and prioritizing sustainability, educational systems can adapt to emerging needs and create a more inclusive future. Malaysia, with its unique context and growing commitment to educational reform, has the potential to become a regional leader in integrating these critical dimensions into its education system.

To maximize global impact, educational reforms in Malaysia should emphasize cross-border collaborations, draw on international best practices, and actively contribute to global research initiatives. These efforts will not only bolster Malaysia’s education sector but also set an example for other nations grappling with similar challenges (OECD, 2021; UNESCO, 2021; Isaacs, 2020).

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article. All views expressed in this study are solely those of the authors and do not represent the positions or policies of any affiliated institutions or organizations.

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CONFLICT OF INTEREST

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

AUTHOR CONTRIBUTION STATEMENT

Author 1 contributed to the conceptualization, research design, and writing of the original draft.
Author 2 was responsible for data collection, analysis, and validation of the results.
Author 3 provided supervision, critical review, and editing of the final manuscript.
All authors have read and approved the final version of the manuscript.

ETHICS STATEMENT

This research was conducted in accordance with the ethical standards of UPTM and adhered to the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the **Review Board** under reference number [**Approval Number, if applicable**]. All participants were informed about the purpose of the study and provided written informed consent prior to participation. Participants' privacy and confidentiality were strictly maintained, and data collected were used solely for academic purposes.

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