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Development of Digital Technology-Based Educational Play Tools for Early Childhood Learning: A Literature Review on Design, Interactivity, and Learning Effectiveness

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ABSTRACT

The rapid integration of digital technology into early childhood education has encouraged the development of educational play tools that combine play, interactivity, multimedia, and structured learning objectives. However, the effectiveness of these tools depends not only on technological sophistication but also on the quality of design, meaningful interaction, and developmental appropriateness. This literature review aimed to analyze the development of digital technology-based educational play tools in early childhood learning, with particular emphasis on design characteristics, interactivity, and learning effectiveness. A systematic-integrative literature review was conducted by searching Scopus, Web of Science, ScienceDirect, ERIC, Google Scholar, and SINTA/GARUDA for peer-reviewed studies published mainly between 2016 and 2026. Following identification, screening, eligibility assessment, and quality evaluation based on PRISMA 2020 principles, 15 articles were included in the final synthesis. The findings showed that effective digital educational play tools generally incorporated child-centered interfaces, multimodal representations, scaffolded feedback, progressive difficulty, meaningful touchscreen interaction, and adult mediation. Empirically, touchscreen-based learning produced an overall effect size of d = 0.46, while electronic storybooks demonstrated effects of g = 0.25 for language and literacy, g = 0.40 for vocabulary, and g = 0.54 for expressive vocabulary. Augmented reality interventions also improved attention, motivation, conceptual understanding, and early literacy, including letter-naming gains of 6.28% compared with 3.35% in a two-dimensional condition. The review concludes that digital educational play is most effective when technological features are aligned with pedagogical goals and children's developmental needs. These findings support a Design Interactivity Learning Effectiveness (DILE) framework as a conceptual basis for future development and evaluation.

KEYWORDS: Digital Educational Play; Early Childhood Education; Educational Technology; Interactivity; Learning Effectiveness.

INTRODUCTION

The rapid expansion of digital technology has transformed the learning environment of young children, changing not only how educational content is delivered but also how children interact, explore, communicate, and construct knowledge. In early childhood education (ECE), digital technology is increasingly incorporated into educational games, touchscreen applications, interactive multimedia, augmented reality, electronic storybooks, and other technology-supported play resources. Such developments have generated considerable interest in digital technology-based educational play tools, which may be understood as developmentally oriented learning resources that combine play, educational objectives, multimedia representations, and interactive digital functions. Research indicates that touchscreen devices can facilitate learning among children aged zero to five, although the magnitude of their effects varies according to age, learning domain,

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instructional setting, and the nature of the comparison condition (Huang et al., 2019). A systematic review by Herodotou (2018) similarly found beneficial outcomes in literacy, mathematics, science, problem solving, and self-efficacy, while emphasizing that design characteristics and adult involvement strongly influence outcomes. The central problem, therefore, is not whether digital technology should simply be introduced into early childhood classrooms, but how educational digital play tools should be designed and used so that technological features genuinely contribute to developmentally appropriate learning. Children in early childhood require concrete, meaningful, playful, and socially mediated experiences. Consequently, technological sophistication alone cannot guarantee educational value. Mak and Nathan-Roberts (2017) argue that applications for young children must reflect their cognitive, physical, and emotional developmental characteristics. Likewise, contemporary evidence suggests that labeling an application as "educational" provides little assurance that it possesses appropriate pedagogical or child computer interaction quality.

This issue is particularly relevant in Indonesia, where the development of digital media for ECE is increasing. Studies have produced interactive multimedia games for language development (Dewi & Agung, 2021), digital media for early learning (Jumiati et al., 2022), augmented-reality learning resources (Nasution et al., 2022; Irmade et al., 2022), and digital media for stimulating literacy among children aged five to six years (Satriana et al., 2022). These initiatives demonstrate substantial innovation, but they also indicate a need to examine systematically the relationships among design quality, interactivity, and learning effectiveness rather than evaluating technological products primarily through feasibility or user responses. Contemporary scholarship has progressively shifted from asking whether young children can learn from digital media toward identifying the conditions under which digital experiences produce meaningful learning. Chu et al. (2024), through a systematic review of 118 empirical studies, characterized digital play as situated, interactive, enjoyable, meaningful, and potentially supportive of learning and development, although concerns remain regarding inappropriate or excessive technology use. Undheim (2022) further conceptualizes technology-supported learning as a pedagogical process in which children and teachers engage jointly with digital resources, emphasizing teacher knowledge, pedagogical judgment, creative participation, and the recognition of digital play as genuine play.

Research on specific digital environments reinforces this position. Schenke et al. (2020) experimentally demonstrated that a carefully designed iPad application could support preschool children's understanding of measurement concepts. Sheehan et al. (2019), examining preschool children's interaction with the ScratchJr coding application, showed that the quality and task relevance of parent–child interaction were related to learning. Macrides et al. (2022) similarly identified generally positive outcomes from early programming interventions. These results indicate that learning is produced by the interaction between technology, task structure, learner activity, and social mediation rather than by digital devices themselves.

Interactivity, however, requires careful conceptualization. Interactivity should not be reduced to tapping, swiping, animation, sound effects, or numerous clickable elements. Xu et al. (2021) demonstrated that interactive hotspots in electronic books may increase engagement, yet their educational contribution depends on whether the interactive feature supports rather than distracts from story comprehension. Savva et al. (2022), in a meta-analysis of electronic storybooks, likewise highlighted variations in literacy and language outcomes according to the characteristics of digital enhancements and instructional conditions. Recent experimental evidence also suggests that touchscreen gestures are most meaningful when the physical interaction is congruent with the learning content. From a design perspective, Barrocas et al. (2023) demonstrated the importance of connecting interaction design with theories of numerical development when developing multitouch mathematics applications, although their intervention did not automatically produce significant mathematical gains. This finding is theoretically important because it challenges technological determinism: a well-functioning digital product is not necessarily an effective educational product. Similarly, the review of touchscreen research by Xie and colleagues shows that the effectiveness of mobile devices is conditioned by learning context and technology-enhanced learning mechanisms.

More recent reviews strengthen this developmental-pedagogical orientation. Utami and Crescenzi-Lanna (2025) highlight growing research on digital play and digital game-based learning for children aged zero to six, while Kyaw and Li (2026) emphasize that effective literacy applications require alignment between design principles and pedagogical practices. Research on immersive technologies also suggests that augmented and virtual environments can increase engagement and attention when accompanied by appropriate teacher mediation and safeguards.

Despite this growing evidence base, at least three significant gaps remain. First, existing studies are fragmented across particular technologies or developmental outcomes. Reviews frequently concentrate separately on tablets, digital play, electronic books, programming, creativity, augmented reality, or particular academic domains rather than integrating the relationships among design, interactivity, and effectiveness within a single analytical framework (Chu et al., 2024; Eliasson et al., 2023; Macrides et al., 2022). Second, technological interactivity is frequently discussed as a desirable feature without adequately distinguishing meaningful pedagogical interaction from decorative, distracting, or cognitively excessive interaction. The mixed findings reported across touchscreen, e-book, and game-based studies demonstrate that more interaction does not necessarily produce more learning (Barrocas et al., 2023; Xu et al., 2021). Third, a contextual gap remains between international findings and the rapidly expanding Indonesian literature. Indonesian research has successfully developed various digital learning products, yet many studies focus on product feasibility, validation, attractiveness, or specific learning outcomes. A broader synthesis is therefore needed to determine which design principles and interactive mechanisms consistently contribute to effective early childhood learning. Roza and Dwiningrum (2025) similarly identify technological limitations, weaknesses in game design, and insufficient curriculum integration as continuing challenges in educational games for young children. Ibrahim and Suminar (2026) further demonstrate that the effectiveness of digital learning media depends on curriculum integration, teacher readiness, and developmental appropriateness.

Against this background, this literature review aims to analyze the development of digital technology-based educational play tools in early childhood learning by synthesizing evidence concerning three interconnected dimensions: design characteristics, forms and quality of interactivity, and learning effectiveness. Rather than merely cataloguing technologies, the review examines how child-centered visual and interface design, multimodality, feedback, game mechanics, touchscreen interaction, adaptive responses, social mediation, and developmentally appropriate content contribute to cognitive, language, literacy, numeracy, creativity, engagement, and related learning outcomes. The principal novelty of this review lies in its proposed Design–Interactivity–Learning Effectiveness framework, which positions educational effectiveness as the result of alignment among technological design, meaningful child interaction, pedagogical objectives, developmental characteristics, and adult mediation. This integrative perspective extends previous technology-specific reviews by connecting product-development principles with empirical evidence about how children actually interact with and learn through digital educational play tools.

Overall, current evidence indicates that digital technology offers substantial possibilities for enriching early childhood learning, but educational benefits cannot be attributed to technology alone. Effective digital educational play emerges when technological affordances are deliberately transformed into developmentally appropriate, pedagogically meaningful, interactive play experiences. Consequently, examining design, interactivity, and effectiveness as an integrated system is essential for identifying evidence-based principles that can guide researchers, teachers, curriculum developers, and educational-technology designers in developing digital educational play tools that are not merely attractive or innovative, but genuinely capable of supporting meaningful early childhood learning.

METHOD

This study employed a systematic-integrative literature review to examine the development of digital technology-based educational play tools in early childhood education, particularly in relation to their design characteristics, forms of interactivity, and effectiveness in supporting learning. A literature review was selected because it enables researchers to systematically consolidate fragmented empirical findings, identify conceptual patterns, compare methodological approaches, and construct an evidence-based understanding of an emerging field (Snyder, 2019). The integrative orientation was also appropriate because research on digital play and educational technology involves heterogeneous designs, including experiments, quasi-experiments, developmental studies, qualitative investigations, and mixed-method studies. Torraco (2016) emphasizes that an integrative review should move beyond descriptive summarization by critically comparing previous findings and producing new conceptual interpretations.

The review procedure was organized according to the principles of PRISMA 2020, particularly transparency in identification, screening, eligibility assessment, and final study inclusion (Page et al., 2021).

Similar systematic procedures have been used successfully in recent reviews of digital play and educational applications for young children, demonstrating the importance of explicit search strategies and quality-based selection in this rapidly developing research area (Chu et al., 2024; Papadakis et al., 2021).

The literature search was conducted across major academic databases and scholarly indexing platforms, including Scopus, Web of Science, ScienceDirect, ERIC, Google Scholar, and SINTA/GARUDA. The search focused primarily on peer-reviewed publications from 2016 to 2026, thereby representing the most recent decade of research. Search strings combined Boolean operators and keywords such as "early childhood education," "young children," "educational play tools," "digital educational games," "digital play," "educational applications," "interactive learning media," "touchscreen," "digital technology," "interactivity," "learning effectiveness," and "educational technology." Multiple keyword combinations were applied to increase sensitivity because terminology surrounding digital play varies across disciplines. This approach is consistent with contemporary systematic reviews that use combinations of population, technological medium, play, and educational-context terms to capture relevant research comprehensively (Chu et al., 2024).

Studies were included when they: (1) were published in peer-reviewed journals indexed in Scopus, Web of Science, SINTA, or other recognized scholarly databases; (2) were published mainly between 2016 and 2026; (3) focused on children approximately 2–8 years of age or formal early childhood educational settings; (4) investigated digital educational games, applications, touchscreen media, augmented reality, interactive multimedia, or related technology-based educational play resources; (5) reported evidence concerning design, interactivity, learning processes, or learning outcomes; and (6) provided sufficient methodological and empirical information for analysis. Studies were excluded when they focused exclusively on adolescents or adults, discussed technology without an educational-play component, constituted editorials or non-peer-reviewed publications, or lacked sufficient empirical relevance.

After duplicate removal, title and abstract screening, and full-text eligibility assessment, 15 articles were retained as the final analytical corpus. This deliberately focused sample enabled an in-depth comparison of relevant empirical studies rather than a superficial aggregation of a larger but highly heterogeneous literature. Such quality-focused selection is important because research on touchscreen learning has shown that outcomes vary substantially according to children's age, learning domain, experimental context, and comparison conditions (Huang et al., 2019).

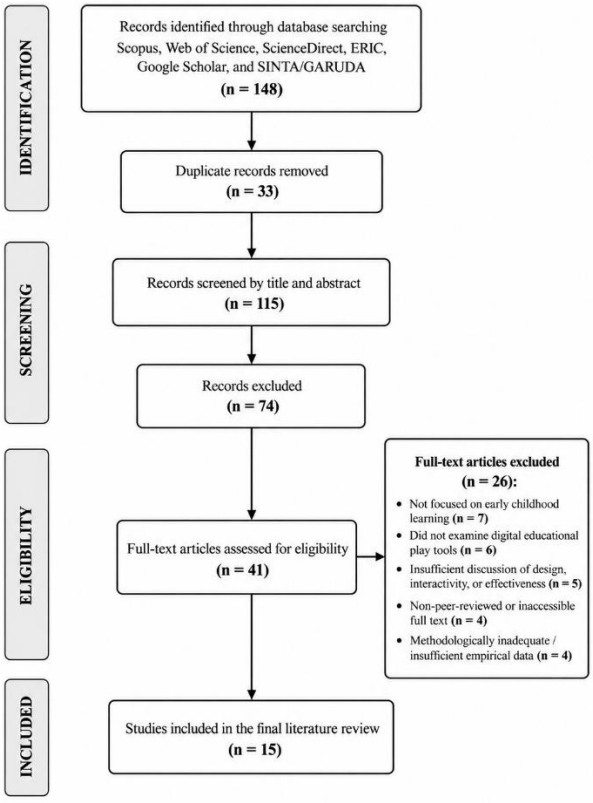


Figure 1. Prisma 2020 Flow Diagram of study selection

Data from the 15 articles were extracted into a review matrix containing authors and publication year, country, participants, research design, type of digital educational tool, learning domain, design characteristics, interactive features, pedagogical strategy, outcome measures, major findings, and study limitations. Methodological credibility was evaluated by considering clarity of research objectives, appropriateness of study design, transparency of sampling and instruments, adequacy of data analysis, and correspondence between findings and conclusions. This process follows the principle that systematic synthesis should incorporate methodological quality rather than treating all studies as equally persuasive.

Finally, the data were synthesized through thematic and comparative analysis. Initial coding focused deductively on three predetermined domains design, interactivity, and learning effectiveness while additional themes were generated inductively from recurring findings across the selected studies. This analytical approach allowed relationships among visual/interface design, multimodal features, feedback, game mechanics, child–technology interaction, teacher or parent mediation, engagement, and cognitive or developmental outcomes to be identified. The final synthesis therefore sought not only to determine whether digital educational play was effective, but also to explain which design and interactive characteristics were associated with meaningful early childhood learning and under what pedagogical conditions those effects were most likely to emerge.

RESEARCH RESULTS AND DISCUSSION

Research Results

Characteristics of the Selected Studies

The systematic selection procedure resulted in 15 articles that met the predetermined inclusion criteria and were subsequently subjected to thematic and comparative synthesis. The selected studies were published between 2018 and 2024, reflecting the relatively recent expansion of research concerning touchscreen applications, digital games, interactive multimedia, augmented reality (AR), electronic storybooks, coding applications, and other technology-mediated play environments for young children.

The included literature represented diverse methodological traditions, comprising experimental and quasi-experimental research, research and development studies, app-evaluation studies, systematic reviews, and meta-analyses. Despite methodological heterogeneity, the studies converged around three analytical dimensions: (1) educational design, including interface simplicity, multimedia representation, scaffolding, feedback, adaptive challenge, and developmental appropriateness; (2) interactivity, referring to children's active manipulation of digital content, touchscreen actions, feedback loops, AR experiences, and socially mediated interaction; and (3) learning effectiveness, reflected in literacy, language, mathematics, coding, conceptual development, attention, motivation, engagement, and related learning outcomes.

Table 1. Characteristics and Major Findings of the 15 Studies Included in the Review

Study	Digital Technology / Focus	Design and Interactivity Characteristics	Main Empirical Findings
Herodotou (2018)	Tablets/mobile applications	Touch-based apps, multimedia presentation, adult mediation	Review of 19 studies involving children aged 2–5 years showed predominantly positive outcomes for literacy, mathematics, science, problem solving, and self-efficacy. Design quality, adult participation, and similarity between the app and transfer context influenced outcomes.
Xie et al. (2018)	Touchscreen learning	Physical touchscreen manipulation and interactive learning	Meta-analysis of 36 studies, 79 effect sizes, and 4,206 participants produced a significant overall learning effect of $d = 0.46$, $p < .001$. Age, learning domain, comparison condition, and experimental context moderated effectiveness.
Sheehan et al. (2019)	ScratchJr coding application	Child–parent interaction, questions,	Among children aged approximately 4.5–5 years, task-relevant parent–child interaction predicted coding learning, indicating that social interaction surrounding

		spatial talk, task-focused interaction	digital play is an important part of educational effectiveness.
Schenke et al. (2020)	*Measure Up!* iPad mathematics app	Game-based measurement tasks and parent companion application	RCT involving 99 children aged 4–5 years found significantly better measurement-learning outcomes for app users; treatment produced approximately two additional correct answers, particularly for pan-balance concepts.
Griffith et al. (2020)	Interactive educational applications	Active app interaction across academic domains	Systematic review of 35 studies identified evidence that interactive apps can promote early academic skills, with particularly consistent evidence for early mathematics; findings were more limited in some social-communication domains.
Taylor et al. (2021)	Educational preschool apps	Evaluation of pedagogical goal, interface and educational features	Assessment of 19 free and 24 paid apps indicated that price was not a reliable indicator of pedagogical quality. Educational value depended more strongly on the presence and quality of developmentally grounded design features.
Callaghan and Reich (2021)	Mobile vocabulary application	Verbal hints, feedback and progressive difficulty	Experiment with 240 children aged 4–5 years demonstrated that scaffolded verbal feedback was especially beneficial during initial learning ($p < .01$), while gradual increases in difficulty produced faster and more accurate responses than randomly ordered challenges ($p < .001$).
Pan et al. (2021)	Augmented reality literacy	3D letters, animation and interactive AR learning centre	Rapid letter-naming performance increased by 6.28% in the AR condition versus 3.35% in the 2D condition. Motivation increased by 11.5% and 10.9%, respectively, suggesting stronger academic advantages for AR than motivational differentiation.
Dewi and Agung (2021)	Interactive multimedia educational game	Integration of games, multimedia and language-oriented activities	ADDIE-based development research demonstrated that digital educational games could be designed as feasible multimedia resources for supporting early-childhood language development, although evidence was primarily based on expert validation and limited individual trials.
Savva et al. (2022)	Electronic storybooks	Animation, audio, hotspots, dictionary functions and adult scaffolding	Meta-analysis of 29 studies, 44 comparisons, $n = 2,317$ showed a small overall advantage of e-books for language/literacy ($g = 0.25$), a larger effect for vocabulary ($g = 0.40$) and expressive vocabulary ($g = 0.54$), but no significant superiority for story comprehension.
Macrides et al. (2022)	Early programming/coding tools	Interactive coding environments and developmentally appropriate programming tasks	The systematic review found generally positive pedagogical benefits from introducing programming to children aged 3–8 years, although outcomes depended on the educational tool and instructional approach.
Aydoğdu (2022)	Augmented reality	AR-based interactive representations compared with traditional instruction	Quasi-experimental study of 26 children aged 4–5 years found significantly greater increases in motivation, attention, and conceptual skills in the AR group compared with the control group.
Irmade et al. (2022)	Augmented reality learning media	Interactive 3D objects accompanied by audio explanations	Expert evaluation indicated that the developed AR product was suitable for learning, while children responded positively and showed a preference for 3D representations accompanied by audio explanations.
Barrocas et al. (2023)	Multitouch mathematics game	Theory-based multitouch and	Despite theoretically grounded design and active touchscreen interaction, the intervention did not significantly improve mathematical skills,

		embodied numerical interaction	demonstrating that interactive technological sophistication does not automatically produce measurable learning gains.
Chu et al. (2024)	Digital play	Touchscreen apps and broader digital play experiences	Systematic review of 118 empirical studies identified learning and development, interaction, meaningfulness, enjoyment, situatedness, and entertainment as major characteristics of digital play, while also identifying concerns regarding inappropriate or excessive technology use.

Design Characteristics of Effective Digital Educational Play Tools

The synthesis revealed that design quality was more important than technological novelty alone. Across the studies, effective digital educational play tools generally demonstrated five interrelated design principles: developmentally appropriate interfaces, alignment between digital actions and learning objectives, scaffolding and feedback, multimodal representation, and progressively structured levels of challenge. The importance of scaffolding was most clearly demonstrated by Callaghan and Reich (2021). Their experiment showed that scaffolded verbal hints were particularly beneficial during children's initial interaction with an application, while gradual progression in difficulty produced significantly faster and more accurate learning responses than randomly sequenced challenge levels. These findings indicate that feedback should perform a pedagogical function by helping children understand errors and determine the next appropriate action instead of merely providing praise, sounds, animations, or rewards. Similarly, evaluation research shows that visually attractive applications cannot automatically be classified as educationally strong. Taylor et al. found that even highly rated preschool apps showed considerable limitations in pedagogical quality, while app cost did not reliably distinguish superior educational value. This suggests that the development of digital APE (*Alat Permainan Edukatif*) should begin with developmental and learning objectives and only subsequently determine the technological features required to achieve those objectives. Multimodality was another recurrent characteristic. Combining visual representations, spoken explanations, movement, sound, animation, and tactile manipulation can provide multiple pathways through which young children process information. However, multimedia effectiveness depends upon relevance. The e-book meta-analysis showed that digital enhancements can support vocabulary and code-related learning, yet excessive or poorly aligned interactive features may fail to improve story comprehension.

Interactivity as a Mechanism of Learning

The findings also indicate that interactivity should be conceptualized as meaningful cognitive and physical engagement rather than simply the number of clickable elements available on a screen. Touchscreen technology produced a moderate overall learning advantage in Xie et al.'s meta-analysis ($d = 0.46$), but the highly heterogeneous results demonstrated that touching a screen alone was insufficient to explain learning performance. Three forms of interactivity emerged from the synthesis. First, physical interactivity occurred when children tapped, dragged, manipulated, matched, constructed, or moved digital objects. Second, cognitive interactivity occurred when children received meaningful feedback, solved problems, predicted outcomes, selected alternatives, coded sequences, or progressed through adaptive challenges. Third, social interactivity involved teachers or parents participating in children's digital experiences.

The importance of social interaction was particularly visible in the ScratchJr study. Sheehan et al. found that task-relevant interaction between parents and preschool children predicted coding learning, demonstrating that adult participation is valuable when it focuses children's attention on the conceptual demands of the task rather than merely increasing the amount of conversation. AR additionally expanded interaction from two-dimensional screen manipulation into an integration of physical and virtual environments. Pan et al. reported that rapid letter naming increased more strongly in the AR condition (6.28%) than in the corresponding 2D condition (3.35%). Aydoğdu similarly reported significantly greater improvements in children's attention, motivation, and conceptual skills following an AR-based intervention.

Learning Effectiveness

Overall, the evidence indicates a predominantly positive but conditional relationship between digital educational play and early learning outcomes. The strongest quantitative evidence was found in touchscreen

learning and digital literacy studies. Xie et al. reported a medium overall touchscreen effect of d = 0.46, while Savva et al. identified positive effects of electronic storybooks on overall language and literacy (g = 0.25) and particularly vocabulary (g = 0.40). Effectiveness, however, differed considerably across outcome domains. The reviewed studies provided positive evidence for early mathematics, vocabulary, language, literacy, coding, conceptual skills, attention, and motivation. Griffith et al.'s review of 35 studies found especially consistent evidence supporting early academic learning through interactive applications, particularly mathematics. Schenke et al. provided experimental support for mathematics learning, whereas Callaghan and Reich demonstrated improvements in novel-word learning when feedback and challenge were carefully scaffolded.

Nevertheless, the synthesis does not support an interpretation that digital technology is inherently superior to non-digital learning. Savva et al. found no significant advantage of e-books over print books for story comprehension, and Barrocas et al. reported no significant improvement in mathematics despite a theoretically informed multitouch application. These findings are important because they demonstrate that educational outcomes depend upon alignment among content, design, interactivity, developmental level, instructional strategy, and learning assessment.

Table 2. Integrated Synthesis of Design, Interactivity, and Learning Effectiveness

Dimension	Major Findings Across the Review	Educational Interpretation
Child-centred design	Simple interfaces, age-appropriate instructions and clear learning goals repeatedly emerged as desirable features.	Technology must accommodate children's cognitive, language and motor-development characteristics.
Multimedia integration	3D objects, animation, audio narration, visual cues and digital representations can strengthen attention and representation of abstract concepts.	Multimedia is most useful when each element directly supports the learning objective rather than functioning as decoration.
Feedback and scaffolding	Scaffolded hints and progressive difficulty were associated with stronger and more accurate learning responses.	Digital feedback should guide thinking, correct misconceptions and progressively support independent learning.
Physical interactivity	Touchscreen manipulation showed an overall positive learning effect (d = 0.46).	Touch actions are valuable when they correspond meaningfully to the concept being learned.
Social interactivity	Adult–child task-relevant interaction contributed to coding and digital learning.	Digital APE should complement rather than eliminate teacher/parent mediation.
Language and literacy	E-books yielded g = 0.25 overall and g = 0.40 for vocabulary; expressive vocabulary reached g = 0.54.	Multimedia and interactive features are particularly promising for vocabulary when cognitive load is appropriately controlled.
Mathematical learning	Positive findings occurred in measurement and early mathematics, although not every app produced significant gains.	Effectiveness depends more on pedagogical architecture than on digitization itself.
AR learning	AR supported conceptual learning, attention and selected literacy outcomes; Pan et al. found letter-naming gains of 6.28% versus 3.35%.	AR is potentially valuable for connecting concrete experience with virtual representations.
Motivation and engagement	Digital play was frequently described as enjoyable and engaging; AR was particularly associated with attention and motivation.	Engagement functions as a learning facilitator but should not be treated as equivalent to learning achievement.
Adult mediation	Parent/teacher involvement affected learning in several studies, although additional adult-support technology did not always produce incremental effects.	Mediation quality and task relevance appear more important than the mere presence of an adult.
Limitations	Null and mixed results were found when digital features were poorly aligned with outcomes or when novelty exceeded pedagogical value.	More features, animation, and interactivity do not necessarily mean more effective learning.

Cross-Study Pattern

A particularly important result of the review is the distinction between technological attractiveness and pedagogical effectiveness. Attractive graphics, animation, audio, touchscreen functions, and AR may increase

children's willingness to engage with an educational activity, but engagement represents an intermediate process rather than the final learning outcome. The Barrocas et al. study is especially instructive: despite theory-informed multitouch design, measurable mathematics improvement was not significant. Conversely, relatively focused design elements such as scaffolded hints and progressive difficulty produced measurable benefits in Callaghan and Reich's experiment. The evidence therefore supports a proposed Design–Interactivity–Learning Effectiveness (DILE) relationship: Developmentally Appropriate Design → Meaningful Interactivity → Cognitive/Emotional Engagement → Learning Effectiveness. This relationship is not strictly linear. Adult mediation, children's age, learning domain, prior knowledge, task difficulty, and implementation context function as moderating conditions. This interpretation is supported by the meta-analysis of touchscreen learning, in which age, domain, experimental environment, and comparison conditions significantly altered observed effects.

Summary of Findings

In summary, the review of 15 selected articles demonstrates that digital technology-based educational play tools have considerable potential for early childhood learning, but their effectiveness is conditional rather than automatic. The strongest designs integrate clear educational objectives, developmentally appropriate interfaces, multimodal representation, meaningful touch or embodied interaction, instructional feedback, progressive challenge, and opportunities for social mediation. Empirical findings demonstrate meaningful improvements across several domains. Touchscreen learning produced an overall effect of $d = 0.46$; electronic storybooks produced $g = 0.25$ for overall language/literacy and $g = 0.40$ for vocabulary; AR literacy activities produced rapid letter-naming gains of 6.28% compared with 3.35% for a 2D condition; and AR interventions significantly improved preschool children's motivation, attention, and conceptual skills. However, null and mixed findings confirm that technological innovation cannot replace sound pedagogy. The central finding of this literature review is therefore that the most effective digital educational play tool is not the tool with the greatest number of technological features, but the one in which design and interactivity are deliberately aligned with children's developmental characteristics and clearly specified learning objectives.

Discussion

The findings of this literature review demonstrate that digital technology-based educational play tools have substantial potential to support early childhood learning, but their educational effectiveness is determined less by the presence of technology itself than by the quality of the relationship among design, interactivity, developmental appropriateness, and pedagogical purpose. This interpretation is consistent with Xie et al. (2018), whose meta-analysis of 36 studies involving 4,206 young children demonstrated a moderate overall touchscreen learning effect ($d = 0.46$), while simultaneously showing that age, learning domain, comparison condition, and experimental environment significantly moderated outcomes. Similarly, Herodotou (2018), Griffith et al. (2020), Lawrence and Choe (2021), and Chu et al. (2024) emphasize that interactive digital technology can facilitate learning when children's actions are meaningfully connected to learning content rather than functioning merely as screen-based entertainment.

The first major finding concerns design quality. The reviewed evidence suggests that effective digital educational play tools require clear instructional objectives, simple interfaces, developmentally appropriate visual representations, meaningful multimedia, immediate feedback, and progressively structured challenges. Papadakis et al. (2017, 2018) argue that educational applications should be evaluated not only according to visual attractiveness but also according to content, functionality, usability, and technical-pedagogical quality. More recent evidence reinforces this argument. Taylor et al. (2022) found that even highly rated preschool applications achieved relatively modest educational-quality scores, while Vaiopoulou et al. (2023) demonstrated that learning suitability, usability, security, and parental control constitute distinct dimensions of app quality. Strataki et al. (2022) likewise showed considerable variability in the educational characteristics of applications marketed to preschool children. These findings challenge the assumption that a commercial label such as “educational app” necessarily indicates pedagogical quality.

The results also demonstrate that scaffolding represents a critical design mechanism. Callaghan and Reich (2021) found that scaffolded verbal hints significantly supported children's initial word learning and that gradually increasing difficulty produced faster and more accurate responses than randomly ordered challenges. Schenke et al. (2020) similarly demonstrated that an appropriately designed mathematics

application improved preschoolers' measurement knowledge, with children in the intervention groups answering approximately two additional post-test questions correctly. These findings indicate that digital educational play should operate as an adaptive learning environment in which feedback explains, guides, redirects, and progressively transfers responsibility to the child.

A second major finding concerns the meaning of interactivity. The evidence suggests that interactivity should not be equated with tapping, swiping, animation, sound, or numerous clickable objects. Rather, educationally meaningful interactivity occurs when children's physical actions activate cognitive processes such as prediction, classification, problem solving, sequencing, comparison, and reflection. Huber et al. (2016) demonstrated that young children could transfer knowledge acquired through touchscreen interaction to physical-world problem solving, supporting the potential connection between digital manipulation and embodied understanding. Marsh et al. (2018) similarly found that app-design characteristics may either support or inhibit children's play and creativity. Barrocas et al. (2023), however, showed that a theoretically grounded multitouch mathematics application did not automatically produce significant mathematical gains. Thus, greater technological interactivity does not necessarily mean greater educational effectiveness.

This interpretation is particularly important for augmented reality and other immersive technologies. Aydoğdu (2022) reported improvements in motivation, attention, and conceptual skills following AR-supported preschool learning, while Irmade et al. (2022) found positive responses toward three-dimensional objects accompanied by audio explanations in an Indonesian early childhood setting. However, AR should be considered pedagogically valuable only when virtual representations make otherwise difficult concepts more concrete, observable, or manipulable. Kewalramani et al. (2020) similarly demonstrate that emerging technologies such as the Internet of Toys can create multilayered interactions among children, educators, digital objects, and physical environments.

The third major finding relates to learning effectiveness across developmental domains. Digital technology appears particularly promising for early literacy, vocabulary, mathematics, coding, conceptual understanding, motivation, and engagement. Savva et al. (2022) reported positive effects of electronic storybooks on language and literacy ($g = 0.25$), vocabulary ($g = 0.40$), and expressive vocabulary ($g = 0.54$). Nevertheless, e-books were not significantly superior to print books for story comprehension, confirming that multimedia enhancement does not automatically strengthen deep understanding. Similar conclusions emerge from research on digital reading and personalization (Kucirkova, 2017, 2018; Kucirkova et al., 2021), digital storytelling (Wu & Chen, 2020), and Indonesian early childhood digital storytelling (Purnama et al., 2022). These studies suggest that digital media become educationally valuable when personalization, narrative, interaction, and multimedia are pedagogically coherent rather than cognitively distracting.

The reviewed evidence further supports the role of game-based learning. Behnamnia et al. (2022) identified digital games as potentially beneficial for preschool learning when game mechanics are linked to explicit educational objectives, while recent meta-analytic evidence indicates positive effects on cognitive development, social outcomes, emotional development, motivation, and engagement. Programming-based activities similarly appear capable of supporting computational thinking and interdisciplinary learning when integrated with storytelling, mathematics, movement, science, and literacy (Macrides et al., 2022; Ongoro & Fanjiang, 2023). Inclusive game design is also important because digital educational tools must accommodate children with different abilities and learning needs (Zolkipli et al., 2023).

Finally, the findings demonstrate that adult mediation remains central rather than becoming obsolete in digitally mediated learning. Undheim (2022) conceptualizes effective technology use as joint engagement among children, teachers, and digital resources, whereas Luo et al. (2021) show that positive teacher attitudes alone are insufficient when technological-pedagogical competence remains limited. Evidence on co-use similarly indicates that adult involvement is most valuable when it directs attention, stimulates dialogue, asks meaningful questions, and links digital experiences with children's everyday knowledge. Importantly, greater screen exposure should not be confused with better learning: systematic evidence shows that higher quantities of screen use are associated with weaker language outcomes, whereas higher-quality educational content and caregiver co-use are positively associated with language development.

Collectively, these findings support the proposed Design–Interactivity–Learning Effectiveness (DILE) framework. Within this framework, developmentally appropriate design generates meaningful interaction; meaningful interaction promotes cognitive, emotional, and social engagement; and engagement facilitates learning

when supported by appropriate pedagogical mediation. The framework extends previous technology-centred perspectives by demonstrating that effectiveness emerges from the alignment of the child, technology, learning objective, interaction mechanism, and social environment. Consequently, the development of digital Alat Permainan Edukatif for early childhood education should not pursue technological novelty as an end in itself. Instead, future products should prioritize developmental appropriateness, pedagogical coherence, meaningful play, adaptive scaffolding, multimodal simplicity, inclusive accessibility, adult mediation, and empirically measurable learning outcomes. This orientation provides a stronger foundation for transforming digital technology from an attractive instructional accessory into an evidence-based educational play environment.

CONCLUSION

This literature review concludes that digital technology-based educational play tools have significant potential to enhance early childhood learning when their technological features are systematically aligned with developmental and pedagogical principles. Across the 15 selected studies, three interrelated dimensions consistently emerged as determinants of effectiveness: design quality, meaningful interactivity, and learning outcomes. Effective tools were characterized by developmentally appropriate interfaces, clear instructional objectives, multimodal representations, scaffolded feedback, progressive levels of difficulty, and opportunities for adult-supported interaction. Empirically, the reviewed evidence demonstrated positive effects across several learning domains. Touchscreen-based learning produced an overall effect size of d = 0.46, while electronic storybooks generated effects of g = 0.25 for language and literacy, g = 0.40 for vocabulary, and g = 0.54 for expressive vocabulary. Augmented reality interventions also showed positive effects on attention, motivation, conceptual understanding, and early literacy, including rapid letter-naming gains of 6.28% compared with 3.35% in a two-dimensional condition. However, several studies reported mixed or non-significant outcomes, indicating that digital sophistication alone does not guarantee learning effectiveness. Conceptually, the findings support a Design–Interactivity–Learning Effectiveness (DILE) framework, in which developmentally appropriate design promotes meaningful interaction, which in turn facilitates engagement and learning. Therefore, future development of digital educational play tools should prioritize pedagogical coherence, child-centered usability, adaptive scaffolding, inclusive access, and empirical evaluation of learning outcomes.

REFERENCE

Aydoğdu, F. (2022). Augmented reality for preschool children: An experience with educational contents. British Journal of Educational Technology, 53(2), 326–348. https://doi.org/10.1111/bjet.13168

Barrocas, R., Bahnmueller, J., Roesch, S., Lachmair, M., & Moeller, K. (2023). Design and empirical evaluation of a multitouch interaction game-like app for fostering early embodied math learning. International Journal of Human-Computer Studies, 175, 103030. https://doi.org/10.1016/j.ijhcs.2023.103030

Behnamnia, N., Kamsin, A., Ismail, M. A. B., & Hayati, S. A. (2022). A review of using digital game-based learning for preschoolers. Journal of Computers in Education. https://doi.org/10.1007/s40692-022-00240-0

Callaghan, M. N., & Reich, S. M. (2021). Mobile app features that scaffold pre-school learning: Verbal feedback and leveling designs. British Journal of Educational Technology, 52(2), 785–806. https://doi.org/10.1111/bjet.13055

Chu, C., Paatsch, L., Kervin, L., & Edwards, S. (2024). Digital play in the early years: A systematic review. International Journal of Child-Computer Interaction, 40, 100652. https://doi.org/10.1016/j.ijcci.2024.100652

Dewi, N. P. A. P., & Agung, A. A. G. (2021). Game education berbasis multimedia interaktif pada aspek bahasa anak usia dini. Jurnal Pendidikan Anak Usia Dini Undiksha, 9(2), 149–157. https://doi.org/10.23887/paud.v9i2.35439

Eliasson, S., Peterson, L., & Lantz-Andersson, A. (2023). A systematic literature review of empirical research on technology education in early childhood education. International Journal of Technology and Design Education, 33, 793–818. https://doi.org/10.1007/s10798-022-09764-z

Griffith, S. F., Hagan, M. B., Heymann, P., Heflin, B. H., & Bagner, D. M. (2020). Apps as learning tools: A systematic review. Pediatrics, 145(1), e20191579. https://doi.org/10.1542/peds.2019-1579

Herodotou, C. (2018). Young children and tablets: A systematic review of effects on learning and development. Journal of Computer Assisted Learning, 34(1), 1–9. https://doi.org/10.1111/jcal.12220

Huber, B., Tarasuik, J., Antoniou, M. N., Garrett, C., Bowe, S. J., Kaufman, J., & Team, B. (2016). Young children's transfer of learning from a touchscreen device. Computers in Human Behavior, 56, 56–64. https://doi.org/10.1016/j.chb.2015.11.010

Ibrahim, F. S., & Suminar, T. (2026). The role of digital learning media in supporting curriculum development in early childhood education: A systematic literature review. Innovative Journal of Curriculum and Educational Technology, 15(1). https://doi.org/10.15294/ujet.v15i1.48438

Irmade, O., Widjanarko, P., & Andaryani, E. T. (2022). Augmented reality as early childhood learning media: Environment theme. Edukasi, 16(1). https://doi.org/10.15294/edukasi.v16i1.36655

Jumiati, J., Rahakabauw, H., & Budiarti, E. (2022). Pengembangan media pembelajaran digital untuk anak usia dini. JIIP - Jurnal Ilmiah Ilmu Pendidikan, 5(6), 1757–1760. https://doi.org/10.54371/jiip.v5i6.630

Kewalramani, S., Palaiologou, I., Arnott, L., & Dardanou, M. (2020). The integration of the Internet of Toys in early childhood education: A platform for multi-layered interactions. European Early Childhood Education Research Journal, 28(2), 197–213. https://doi.org/10.1080/1350293X.2020.1735738

Konca, A. S., & Tantekin Erden, F. (2021). Digital technology (DT) usage of preschool teachers in early childhood classrooms. Journal of Education and Future, 19, 1–12. https://doi.org/10.30786/jef.627809

Kucirkova, N. (2018). How and why to read and create children's digital books: A guide for primary practitioners. UCL Press. https://doi.org/10.14324/111.9781787353473

Kucirkova, N. (2019). Children's reading with digital books: Past moving quickly to the future. Child Development Perspectives, 13(4), 208–214. https://doi.org/10.1111/cdep.12339

Kucirkova, N., & Cremin, T. (2018). Personalised reading for pleasure with digital libraries: Towards a pedagogy of practice and design. Cambridge Journal of Education, 48(5), 571–589. https://doi.org/10.1080/0305764X.2017.1375458

Kumpulainen, K., Sairanen, H., & Nordström, A. (2020). Young children's digital literacy practices in the sociocultural contexts of their homes. Journal of Early Childhood Literacy, 20(3), 472–499. https://doi.org/10.1177/1468798420925116

Kyaw, H. M. M., & Li, Y. (2026). Design principles and pedagogical practices in literacy apps for young children: Insights from a synthesis of experimental research. Early Childhood Education Journal. Advance online publication. https://doi.org/10.1007/s10643-026-02326-1

Lauricella, A. R., Herdzina, J., & Robb, M. (2020). Early childhood educators' teaching of digital citizenship competencies. Computers & Education, 158, 103989. https://doi.org/10.1016/j.compedu.2020.103989

Lawrence, A., & Choe, D. E. (2021). Mobile media and young children's cognitive skills: A review. Academic Pediatrics, 21(6), 996–1000. https://doi.org/10.1016/j.acap.2021.01.007

Luo, W., Berson, I. R., Berson, M. J., & Li, H. (2021). Are early childhood teachers ready for digital transformation of instruction in Mainland China? A systematic literature review. Children and Youth Services Review, 120, 105718. https://doi.org/10.1016/j.childyouth.2020.105718

Macrides, E., Miliou, O., & Angeli, C. (2022). Programming in early childhood education: A systematic review. International Journal of Child-Computer Interaction, 32, 100396. https://doi.org/10.1016/j.ijcci.2021.100396

Madigan, S., McArthur, B. A., Anhorn, C., Eirich, R., & Christakis, D. A. (2020). Associations between screen use and child language skills: A systematic review and meta-analysis. JAMA Pediatrics, 174(7), 665–675. https://doi.org/10.1001/jamapediatrics.2020.0327

Mak, D., & Nathan-Roberts, D. (2017). Design considerations for educational mobile apps for young children. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 61(1). https://doi.org/10.1177/1541931213601773

Marsh, J., Plowman, L., Yamada-Rice, D., Bishop, J., Lahmar, J., & Scott, F. (2018). Play and creativity in young children's use of apps. British Journal of Educational Technology, 49(5), 870–882. https://doi.org/10.1111/bjet.12622

Nasution, N., Darmayunata, Y., & Wahyuni, S. (2022). Pengembangan media pembelajaran anak usia dini berbasis augmented reality. Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini, 6(6), 6462–6468. https://doi.org/10.31004/obsesi.v6i6.3408

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Palaiologou, I., Kewalramani, S., & Dardanou, M. (2021). Make-believe play with the Internet of Toys: A case for multimodal playscapes. British Journal of Educational Technology, 52. https://doi.org/10.1111/bjet.13110

Pan, Z., López, M. F., Li, C., & Liu, M. (2021). Introducing augmented reality in early childhood literacy learning. Research in Learning Technology, 29, 1–21. https://doi.org/10.25304/rlt.v29.2539

Papadakis, S. (2021). Tools for evaluating educational apps for young children: A systematic review of the literature. Interactive Technology and Smart Education, 18(1), 18–49. https://doi.org/10.1108/ITSE-08-2020-0127

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2017). Designing and creating an educational app rubric for preschool teachers. Education and Information Technologies, 22(6), 3147–3165. https://doi.org/10.1007/s10639-017-9579-0

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2018). Educational apps from the Android Google Play for Greek preschoolers: A systematic review. Computers & Education, 116, 139–160. https://doi.org/10.1016/j.compedu.2017.09.007

Piotrowski, J. T., & Krcmar, M. (2017). Reading with hotspots: Young children's responses to touchscreen stories. Computers in Human Behavior, 70, 328–334. https://doi.org/10.1016/j.chb.2017.01.010

Purnama, S., Ulfah, M., Ramadani, L., Rahmatullah, B., & Ahmad, I. F. (2022). Digital storytelling trends in early childhood education in Indonesia: A systematic literature review. JPUD – Jurnal Pendidikan Usia Dini, 16(1), 17–31. https://doi.org/10.21009/JPUD.161.02

Roza, R. N., & Dwiningrum, S. I. A. (2025). A critical review of recent papers in educational games for early childhood: Challenges and future prospects. JPUD – Jurnal Pendidikan Usia Dini, 19(2), 274–281. https://doi.org/10.21009/jpud.v19i2.46605

Satriana, M., Haryani, W., Jafar, F. S., Maghfirah, F., Sagita, A. D. N., Sopia, & Septiani, F. A. (2022). Media pembelajaran digital dalam menstimulasi keterampilan literasi anak usia 5–6 tahun. Jurnal Pendidikan Anak Usia Dini Undiksha, 10(3), 408–414. https://doi.org/10.23887/paud.v10i3.51579

Savva, M., Higgins, S. E., & Beckmann, N. (2022). Meta-analysis examining the effects of electronic storybooks on language and literacy outcomes for children in grades Pre-K to grade 2. Journal of Computer Assisted Learning, 38(2), 526–564. https://doi.org/10.1111/jcal.12623

Schenke, K., Redman, E. J. K. H., Chung, G. K. W. K., Chang, S. M., Feng, T., Parks, C. B., & Roberts, J. D. (2020). Does “Measure Up!” measure up? Evaluation of an iPad app to teach preschoolers measurement concepts. Computers & Education, 146, 103749. https://doi.org/10.1016/j.compedu.2019.103749

Sheehan, K. J., Pila, S., Lauricella, A. R., & Wartella, E. A. (2019). Parent-child interaction and children's learning from a coding application. Computers & Education, 140, 103601. https://doi.org/10.1016/j.compedu.2019.103601

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Strataki, A. (2022). An evaluation of educational apps for preschool-age children in Android and iOS. Advances in Mobile Learning Educational Research, 2(1), 278–288. https://doi.org/10.25082/amler.2022.01.012

Taylor, G., Monaghan, P., & Westermann, G. (2022). Selecting educational apps for preschool children: How useful are website app rating systems? British Journal of Educational Technology, 53(5), 1262–1282. https://doi.org/10.1111/bjet.13199

Torraco, R. J. (2016). Writing integrative literature reviews: Using the past and present to explore the future. Human Resource Development Review, 15(4), 404–428. https://doi.org/10.1177/1534484316671606

Undheim, M. (2022). Children and teachers engaging together with digital technology in early childhood education and care institutions: A literature review. European Early Childhood Education Research Journal. https://doi.org/10.1080/1350293X.2021.1971730

Utami, A., & Crescenzi-Lanna, L. (2025). Research design and implementation of digital play and digital games-based learning in early development (0 to 6 years): A systematic review. Education 3–13. Advance online publication. https://doi.org/10.1080/03004279.2025.2537102

Vaiopoulou, J., Papadakis, S., Sifaki, E., Kalogiannakis, M., & Stamovlasis, D. (2023). Classification and evaluation of educational apps for early childhood: Security matters. Education and Information Technologies, 28(3), 2547–2578. https://doi.org/10.1007/s10639-022-11289-w

Wu, J., & Chen, D.-T. V. (2020). A systematic review of educational digital storytelling. Computers & Education, 147, 103786. https://doi.org/10.1016/j.compedu.2019.103786

Xu, Y., Yau, J. C., & Reich, S. M. (2021). Press, swipe and read: Do interactive features facilitate engagement and learning with e-books? Journal of Computer Assisted Learning, 37(1), 212–225. https://doi.org/10.1111/jcal.12480

Xie, H., Peng, J., Qin, M., Huang, X., Tian, F., & Zhou, Z. (2018). Can touchscreen devices be used to facilitate young children's learning? A meta-analysis of touchscreen learning effect. Frontiers in Psychology, 9, 2580. https://doi.org/10.3389/fpsyg.2018.02580

Yang, W., Su, J., & Li, H. (2024). Demystifying early childhood computational thinking: An umbrella review to upgrade the field. Future in Educational Research. https://doi.org/10.1002/fer3.38

Zolkipli, N. Z., Rahmatullah, B., Mohamad Samuri, S., Árva, V., & Sugiyo Pranoto, Y. K. (2023). 'Leave no one behind': A systematic literature review on game-based learning courseware for preschool children with learning disabilities. Southeast Asia Early Childhood Journal, 12(1), 85–105. https://doi.org/10.37134/saecj.vol12.1.7.2023