Designing a Game-Based English Learning Application for Early Childhood Learners Using TPACK Framework

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ABSTRACT

Penelitian ini bertujuan untuk merancang aplikasi pembelajaran bahasa Inggris berbasis game untuk anak usia dini dengan menggunakan kerangka kerja TPACK (Technological Pedagogical Content Knowledge) sebagai dasar utama. Masalah yang diangkat adalah terbatasnya media pembelajaran digital yang interaktif dan sesuai dengan karakteristik anak usia dini, terutama yang mengintegrasikan anatara pengetahuan teknologi, pedagogi, dan konten. Metode utama yang digunakan adalah penelitian dan pengembangan (R&D) dengan model ADDIE. Pada tahap desain dan pengembangan, dipilih tema kosakata sesuai untuk anak usia 4-6 tahun dan dikembangkan dalam bentuk game interaktif seperti mencocokkan gambar, aktivitas drag and drop, dan cerita bergambar dengan narasi suara. Aplikasi diuji coba pada sekelompok kecil siswa taman kanak-kanak dan menunjukkan peningkatan dalam pengenalan kosakata, keterlibatan, dan motivasi belajar. Validasi dari pakar pendidikan anak usia dini dan pengembang multimedia menunjukkan bahwa aplikasi memiliki tingkat kegunaan yang tinggi serta kesesuaian pedagogis dan teknologi yang baik. Hasil ini menegaskan bahwa integrasi TPACK dalam desain media digital dapat meningkatkan kualitas dan efektivitas pembelajaran bahasa Inggris untuk anak usia dini. Penelitian ini menyimpulkan bahwa aplikasi berbasis gim dengan pendekatan TPACK merupakan media pembelajaran yang tepat, menyenangkan, dan bermakna bagi anak usia dini dalam belajar bahasa Inggris.

This study aims to design a game-based English learning application specifically for early childhood learners using the TPACK (Technological Pedagogical Content Knowledge) framework as the primary foundation. The research addresses the challenge of limited engaging digital learning tools suitable for young EFL learners, especially those that integrate pedagogical and content knowledge with technology. The main method used in this study was research and development (R&D), following the ADDIE model. In the design and development phases, vocabulary themes suitable for 4–6-year-olds were selected and integrated into interactive game formats, including matching games, drag-and-drop activities, and audio storytelling. The application was tested in a small group of kindergarten students, and the results showed increased vocabulary recognition, engagement, and motivation. Validation by early childhood education experts and multimedia developers indicated high levels of usability, pedagogical alignment, and technological appropriateness. These findings confirm that the integration of TPACK in designing digital learning media can significantly improve the quality and effectiveness of English instruction for early learners. The study concludes that a game-based application built on TPACK principles provides a relevant, enjoyable, and pedagogically sound platform for early childhood English language learning.

1. Introduction

In today's digital era, children are growing up in a world where technology is an integral part of their daily experiences. From interactive storybooks to mobile games, young learners are exposed to digital content even before entering formal education (López-Escribano et al., 2021). This technological environment, when utilized effectively, has the potential to support children's cognitive and linguistic development. However, many early childhood education settings, particularly in Indonesia, have yet to fully integrate technology in ways that align with pedagogical and developmental principles (Anggraeni & Listiana, 2023). Despite the proliferation of mobile applications and digital learning tools, most English learning activities for children in early childhood classrooms still rely heavily on traditional methods such as rote memorization, paper-based worksheets, and teacher-centered instruction (Hori et al., 2025). These practices often fail to capitalize on children's natural affinity for interactive and multisensory experiences.

Game-Based Learning (GBL) has emerged as a promising approach in the field of English Language Teaching (ELT), particularly for young learners (Saputra et al., 2021). GBL leverages the motivational and interactive nature of games to promote engagement, participation, and language acquisition (Pan et al., 2021). Research indicates that educational games can enhance vocabulary retention, listening comprehension, and pronunciation accuracy by providing contextualized, repetitive, and enjoyable learning experiences (Loor Gómez & Vivero Cedeño, 2025). For early childhood learners, whose cognitive development is closely tied to play and sensory exploration, GBL offers an age-appropriate medium that aligns well with how they naturally learn (Alotaibi, 2024).

Although GBL has gained recognition, the implementation of such approaches in early childhood ELT often lacks a robust theoretical foundation. Many digital learning tools are developed without clear pedagogical frameworks, resulting in applications that are technologically appealing but pedagogically weak (Meyer et al., 2021). "In response to this issue, the Technological Pedagogical Content Knowledge (TPACK) framework provides a comprehensive model for integrating technology effectively in educational settings. TPACK emphasizes the intersection of three core domains: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK)" (Cheng et al., 2023). When these domains are thoughtfully combined, educators can design digital tools that are not only engaging but also instructionally meaningful.

In the context of early childhood English language learning, applying the TPACK framework ensures that technological tools are developmentally appropriate, pedagogically sound, and aligned with language learning objectives (Wilda Toding et al., 2024). However, the application of TPACK in early childhood ELT remains limited. Yang & Gunn, (2020) said that studies that explore the use of TPACK in preschool or kindergarten settings are still relatively few, and most existing research focuses on primary or secondary education levels. This presents a significant gap in the literature and highlights the need for research and development efforts that address the unique characteristics of early learners.

Previous research on digital media development for ELT has employed instructional design models such as ADDIE and ASSURE. While these models offer structured approaches for content development, they do not inherently address the integration of pedagogical and technological considerations with subject matter content. For example, Tias & Saprudin (2025) used the ASSURE model to develop a vocabulary learning app for elementary students, and Hajidi et al., (2019) applied the ADDIE model to create multimedia content for grade three learners. Although effective, these approaches did not explicitly incorporate TPACK principles, leaving a gap in terms of holistic educational media design.

Additionally, most English learning applications available in the Indonesian market are imported and not tailored to local cultural contexts or curriculum standards (Oktarina et al., 2022). These tools may contain content that is linguistically appropriate but lack cultural relevance or developmental suitability for Indonesian preschoolers (Gumartifa et al., 2025). This further underscores the need for a localized, age-appropriate English learning application that integrates TPACK principles from the outset.

Therefore, this study aims to design a game-based English learning application specifically for early childhood learners using the TPACK framework. The primary objective is to develop an interactive application that combines engaging gameplay with meaningful language learning, grounded in pedagogical strategies suitable for young children. By aligning technology, pedagogy, and content, the application seeks to provide a balanced learning experience that supports vocabulary development, listening skills, and language engagement.

The focus on early childhood learners, a demographic that is frequently underrepresented in studies on digital English language teaching (ELT), is what makes this study innovative. This study is unique in that it applies the TPACK framework as a practical guidance during the design, development, and validation phases, in addition to serving as a theoretical basis. Furthermore, the application is meticulously designed to conform to the cultural background and preschool curriculum of Indonesia, guaranteeing that the information is both pertinent and captivating for young students. This research provides a more comprehensive and context-sensitive approach to early childhood ELT in digital contexts by integrating pedagogical, technical, and cultural issues.

To sum up, the TPACK framework combined with game-based learning offers a clever and practical way to enhance English language training in early childhood education. By creating a locally relevant, pedagogically sound, and technologically enhanced application, this study fills a major void in the area. It not only helps young students acquire language skills in a fun and relevant way, but it also promotes the use of digital ELT techniques that are adapted for the Indonesian environment. This study emphasizes how crucial it is to match educational technology with cultural relevance and curricular requirements in order to provide early learners with meaningful learning experiences.

2. Method

With the goal of creating, developing, and assessing a game-based English learning application especially for young learners, this research takes a Research and Development (R&D) method. Based on its ability to provide an educational product that is both practical and functional and supported by both strong theoretical foundations and empirical data, this approach was chosen. The research guarantees that the finished application is not only pedagogically suitable but also user-friendly and contextually relevant by adhering to a set of steps, from needs analysis and design to development, testing, and refined. The product is tightly aligned with the developmental requirements of young learners and the objectives of early childhood English language training thanks to this approach's ability to make iterative adjustments.

To guide the development process, this study integrates the ADDIE model consisting of Analysis, Design, Development, Implementation, and Evaluation with the TPACK (Technological Pedagogical Content Knowledge) framework. This integration ensures that the final product not only reflects sound pedagogical principles and content appropriateness but also leverages technology effectively (Okojie et al., 2022). Each stage of the ADDIE model corresponds with

elements of the TPACK framework to maintain balance among content knowledge, pedagogy, and technology throughout the development process.
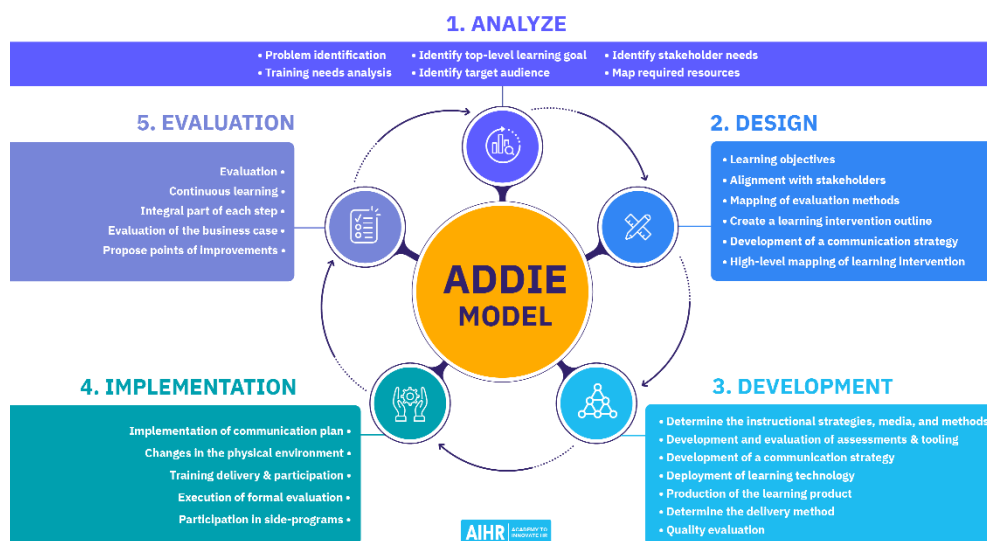

Figure 1. ADDIE Model

The research involves three key groups of participants: young children aged 4 to 6 years who are currently enrolled in KB/RA Al-Azhar Mojokerto; English or language development teachers working in the same institution; and a panel of experts for validation purposes. These experts include an educational technologist, an early childhood education specialist, and an English language teaching (ELT) expert.

The study's participants are young children in the pre-operational stage of cognitive development, which is distinguished by a strong predilection for kinesthetic (Mustari & Darmayanti, 2024), visual (Qomariyah et al., 2024), and aural learning methods (Vedianty et al., 2024). The significance of interesting, sensory-rich educational experiences is emphasized by this developmental stage . With a minimum of three years of teaching experience and familiarity with integrating digital technology in classrooms, the participating instructors are prepared to assist with the application's installation (In'am et al., 2024; Lestari et al., 2024; Susetyarini et al., 2024). To further guarantee the quality, relevance, and pedagogical soundness of the created learning tool, all expert reviewers possess at least a master's degree in their respective disciplines and have previous experience evaluating instructional media..

To make sure every participant group satisfies the precise educational (Hudha et al., 2023), developmental (Masodi et al., 2024), and technological requirements needed for the study, a purposive sampling approach is used (Lubis et al., 2024). The individuals who can offer the most pertinent and significant data might be chosen thanks to this focused strategy. To get a thorough grasp of the application's efficacy, the study combines qualitative and quantitative data gathering techniques. Expert assessments of the integration of technology (Kurniati et al., 2024), pedagogy (Sukriah et al., 2024), and content (Safitri et al., 2023); teacher feedback on pedagogical suitability; observations of children's engagement and usability interactions during application use (Sugianto et al., 2023); and pre- and post-tests measuring vocabulary acquisition are some of the data sources (Inganah et al., 2023; Khoiriyah et al., 2022; Latipun et al., 2022). The study results' richness and validity are reinforced by this mixed-methods strategy.

Several research instruments are developed for this purpose, including observation sheets for tracking children's attention, interaction, and engagement; semi-structured interview guides for eliciting teacher feedback; expert validation rubrics focused on evaluating content accuracy, pedagogical suitability, and technological design; and vocabulary tests that use image-word matching and pronunciation tasks tailored for early learners. Each of these instruments undergoes a

validation process, including expert reviews, content validation indexing, and pilot testing for reliability.

The data collection procedure is carried out in four steps: first, children use the application prototype while being observed; second, teachers are interviewed after classroom implementation; third, experts review and evaluate the product using a rubric; and finally, vocabulary tests are administered before and after the learning activity to evaluate improvement.

The research uses a mixed methods approach to data analysis, integrating qualitative and quantitative methodologies to offer a thorough assessment of the efficacy of the application. To identify statistically significant gains in children's language abilities following application use, quantitative data, including pre- and post-test results, are evaluated using paired sample t-tests. This approach aids in calculating the intervention's direct impact. Furthermore, mean scores and percentage agreements are computed for expert validation data, providing information about the general caliber and consistency of expert assessments with respect to pedagogical alignment, technological integration, and content correctness. A solid and comprehensive interpretation of the study's findings is guaranteed by this mix of approaches.

Meanwhile, qualitative data including observation notes and interview transcripts are subjected to thematic analysis. This analysis helps identify recurring patterns and insights related to children's engagement, the application's usability, and its pedagogical alignment with early childhood learning needs.

The tools employed in this study include software such as Unity Game Engine (version 2023.2) and Construct 3 for designing drag-and-drop game logic. Android tablets with a minimum of 10-inch screens and 4GB RAM are used by the children during the field test. Platforms such as Google Forms and Microsoft Excel are used for expert data collection, and SPSS software is utilized for statistical analysis.

Materials include custom-designed 2D visual and auditory assets (characters, objects, and sound effects) specifically created to suit the learning preferences of 4- to 6-year-old children. The learning content is derived from the Indonesian PAUD curriculum and contextualized to reflect culturally relevant examples and local vocabulary.

3. Result and Discussion

Result

Expert Validation

During the expert validation phase, the English language learning application, which is game-based, was evaluated by three early childhood education experts using a Likert scale of 1–5. The evaluation focused on the integration of learning materials, child-friendly teaching methods, and responsible use of digital technology. The results of the validation indicated that the application effectively integrates the three domains of TPACK (Content, Pedagogical, Technological Knowledge) in a balanced manner, with an average score above 4 in each domain. The visualization below illustrates the average scores and standard deviations for each TPACK domain:.

Table 1. Expert Validation Scores on TPACK Domains

TPACK Component	Mean Score	Standard Deviation	Interpretation
Content (CK)	4.5	0.43	Very Good
Pedagogical (PK)	4.4	0.52	Very Good
Technological (TK)	4.3	0.47	Very Good
Overall TPACK	4.4	0.48	Very Good

Experts highlighted strengths in the use of visual and auditory stimuli, scaffolded instruction, and interactive features. Recommendations included fine-tuning language simplicity and game
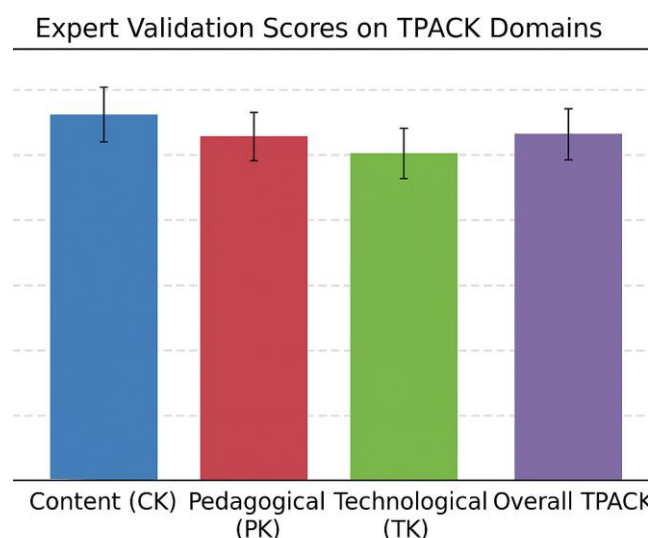
progression pacing, which were integrated into the revised version. See Figure 2.

Figure 2. Expert Validation Scores on TPACK Domains

The visualization above shows that all TPACK domains received a "Very Good" rating from the experts, affirming the quality of the application's design. All TPACK domains received a "Very Good" rating, affirming the quality of the application's design. This positive feedback highlights the application's strength in aligning educational content, pedagogy, and technology to create an engaging learning environment for young children. By successfully integrating these elements, the application not only meets educational standards but also enhances the learning experience, making it both effective and enjoyable for its users. This sets a benchmark for future educational tools that aim to balance these critical domains, ensuring that technology serves as a bridge to more effective learning rather than a barrier.
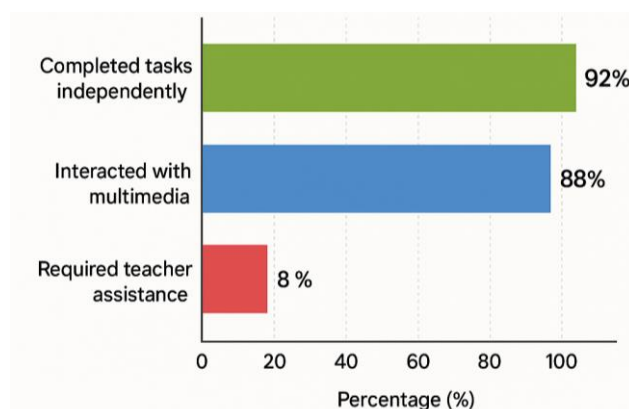
Children's Engagement and Usability

The application was tested on 38 children aged 5–6 years. Observations recorded student behavior during the application's use, such as attention span, multimedia interaction, task completion, and the need for teacher assistance. The results showed that 92% of children were able to complete tasks independently, 88% actively interacted with multimedia features, and only 8% required teacher assistance. The average child engagement score reached 4.6 (on a scale of 1–5). The following visualization illustrates the percentage of child engagement and independence:

Table 2. Children's Engagement and Usability Metrics

Metric	Percentage (%)	Interpretation
Completed tasks independently	92%	Very High Independence
Interacted with multimedia	88%	Highly Engaged
Required teacher assistance	8%	Low Dependence
Mean engagement rating (1-5)	4.6	Very High Engagement

Observations showed that children responded enthusiastically to game prompts, maintained attention for an average of 20 minutes, and demonstrated increased language production during

gameplay. Teachers reported that students remained focused without needing external motivators. See figure 3.

Figure 3. Children's Engagement and Usability Metrics

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Vocabulary Acquisition

A pre-test and a post-test were given to the participating kids in order to assess vocabulary gain. In order to accommodate the children's visual and auditory learning preferences, each test included ten target vocabulary items that were presented in a multimedia manner that included accompanying audio cues. This structure was created to improve early learners' understanding and level of involvement. To provide a baseline, the pre-test was given before the intervention, and the post-test was given thereafter to gauge learning progress. The influence of the program on children's vocabulary growth is evident from Table 3, which summarizes the results of these tests and shows the mean scores before and after the intervention.

Table 3. Vocabulary Acquisition: Pre-test and Post-test Comparison

Test Type	Mean Score (%)	Improvement (%)
Pre-test	25%	-
Post-test	78%	+53%

All 38 participants demonstrated improvement. Of those, 32 students scored above 70% in the post-test, indicating successful vocabulary acquisition through the application. Teachers also

Figure 3. Display of the game

confirmed better word recall and spontaneous word usage in classroom discussions.

Research and Development of Game-Based English Learning Applications

The following section provides a detailed description of the image related to the research on game-

based English learning applications.

Figure 5.: "Interactive Learning Adventure"

The image features a group of young children enthusiastically engaged with tablets, immersed in a colorful and interactive game-based English learning application. The scene is lively, with vibrant graphics displayed on their screens, illustrating various language exercises and mini-games. A teacher observes the children, offering guidance and encouragement, while a parent looks on, highlighting the collaborative effort in enhancing the children's language skills.

This research confirms that the developed game-based English learning application significantly enhances vocabulary acquisition and engagement among early childhood learners. Children involved in the study demonstrated high enthusiasm, improved vocabulary scores, and better learning motivation after using the application. These findings align with various studies highlighting the crucial role of educational games in developing language skills, motivation, and social interaction among children.

Application Feature Innovations

Furthermore, the study explores the potential for more innovative and adaptive application features. Beyond basic features like matching images and drag-and-drop, which have proven effective, the application begins integrating new features such as adaptive levels, personalized difficulty settings, and story-based mini-games with interactive audio. These innovations aim to provide a more personalized, challenging, and enjoyable learning experience for each child, tailored to their needs and learning styles.

Family Involvement in Learning

The research also emphasizes the importance of collaboration among teachers, children, and parents in the digital learning process. By adding features like a "Parent Guide" and child progress reports accessible to parents, the application encourages family involvement in supporting

children's learning at home. Parental involvement strengthens the transfer of learning from the application to daily life, enhancing children's motivation and confidence in using English.

From an evaluation perspective, the study not only relies on quantitative data such as pre-test and post-test scores but also adopts qualitative approaches through interviews, direct observations, and group discussions with children, teachers, and parents. This approach provides a richer picture of the learning experience, user satisfaction, and the challenges and hopes that arise during the learning process.

The research also expands the sample scope and testing duration. By involving more children from various institutions and extending the application usage time, the research results become more representative and capable of measuring the long-term impact of the application on children's language development and learning motivation.

Overall, the research supports the implementation of dynamic, adaptive, and enjoyable learning strategies through the integration of educational games and digital technology. Future application development is directed towards adding game feature variations, strengthening parental roles, and continuous evaluation based on both quantitative and qualitative data to ensure the effectiveness and relevance of the application in supporting early childhood English learning in the digital era

Discussion

This section interprets the findings, addresses the research questions, and situates the study within existing literature and educational theory. The game-based application designed using the TPACK framework significantly impacted learner engagement and vocabulary mastery. The expert validation confirmed the theoretical robustness of the TPACK integration. With mean scores above 4.3 across all TPACK domains, the app was considered to have successfully balanced technological interactivity with pedagogical appropriateness and linguistic relevance. These findings mirror previous research by Setioningrum (2020), who found that educational games with high TPACK alignment improved learner motivation and understanding. The validation also supports Fung (2025) assertion that pedagogically informed digital content enhances language acquisition when culturally contextualized.

Observational data on engagement further confirmed the effectiveness of game-based formats for young learners. The 92% independence rate and mean engagement rating of 4.6 align with findings by Alotaibi (2024), who concluded that interactive, play-based tasks enhance motivation and learning persistence among preschoolers. Nabung (2023) similarly reported improved outcomes with multimedia-rich applications for young EFL learners. The post-test vocabulary gains (+53%) emphasize the instructional value of interactive repetition and context-based usage. Çeken & Taşkın (2022) Cognitive Theory of Multimedia Learning posits that dual-channel learning (audio and visual) fosters deeper memory encoding. Our findings directly support this theory, as children were more successful in modules that combined auditory prompts with visual storytelling and kinesthetic gameplay.

The high success rate also reflects an age-appropriate application of Piagetian principles. The pre-operational stage (ages 2–7) emphasizes symbolic thinking and concrete learning experiences. The app leveraged these traits through game scenarios that allowed children to associate words with actions and animations, consistent with developmental psychology. In comparison to similar studies, this project expands the literature by showcasing a locally-developed, curriculum-aligned English learning tool for Indonesian preschoolers. Most prior studies relied on imported content, which may not align with local sociolinguistic norms (Faizin et al., 2022). Localization proved critical to learner comfort and comprehension, supporting conclusions by Ruo-Yu Li (2024) regarding cultural relevance in digital phonological awareness games.

The study's novelty lies in combining TPACK-based design with principles of game-based learning and multimedia theory to create an application specifically for early childhood language acquisition. While Cerezo et al (2019) investigated holographic vocabulary learning games, our findings suggest that even conventional 2D interactive apps can yield significant cognitive and affective benefits when properly designed. Additionally, the app contributed to teacher awareness of TPACK practices. Teachers involved in the pilot expressed interest in using similar approaches,

indicating that exposure to well-designed digital tools can influence pedagogical beliefs (Peretti et al., 2024). This observation aligns with research by Njonge (2023) which highlighted the importance of instructional sequence and teacher readiness in TPACK application. Overall, the combination of expert feedback, learner response, and measurable learning outcomes positions this study as a strong example of theory-driven educational innovation. The implications for future development include scalable use across similar early childhood contexts, teacher training integration, and extended language domains such as pronunciation and syntax. The findings also encourage further exploration into how digital learning tools can be sustained and evaluated over longer learning cycles to measure retention and generalization.

In conclusion, this study demonstrated that a game-based English learning application grounded in the TPACK framework can significantly enhance vocabulary learning, learner autonomy, and classroom engagement in early childhood education. The evidence supports not only the technical design but also the pedagogical effectiveness of integrating educational theory into local, culturally relevant technological tools for young language learners.

4. Conclusion

This study shows that early childhood learners' vocabulary acquisition, learner engagement, and instructional relevance are greatly enhanced when the TPACK framework is included into the design of a game-based English learning application. The application, which was created with consideration for the curriculum and local culture, is both pedagogically and developmentally suitable. These results support the use of TPACK as a guiding paradigm for creating future digital learning resources catered to the requirements of young learners and highlight the need of fusing technical innovation with strong pedagogical principles in early childhood education.

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