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Article

Development of an Augmented Reality-Based Application to Support Reading Skills in Children with Learning Disabilities

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Abstract: This study presents the development and evaluation of augmented reality (AR)- based application designed to enhance reading skills among children with learning disabilities in inclusive classrooms. The application incorporates speech recognition, visual aids and interactive multimedia tailored to the phonetic complexity of the Thai language. By leveraging AR, the tool provides a multi-sensory learning environment that supports individualized instruction and promotes student engagement. The research utilizes a structured research and development (R&D) methodology, focusing on the design, implementation, and expert evaluation of the learning module. Findings suggest that the AR-based innovation can improve literacy outcomes and promote equitable access to education for students with special needs. This approach supports inclusive education by providing meaningful learning opportunities aligned with each learner's needs.

Keywords: Augmented reality (AR), Educational technology, Human-computer interaction, Learning disabilities, Inclusive education

1. INTRODUCTION

The 21st century has brought about rapid transformations across technology, society and education sectors, with a greater emphasis being placed on skills related to innovation, communication and adaptability (González-Pérez & Ramírez-Montoya, 2022). In this aspect, education plays an integral role in fostering equity and progress, particularly for children with special educational needs who face persistent barriers to access and achievement. Inclusive education, which emphasizes equal rights and shared learning environments has become a key principle in contemporary education reform, both globally and in Thailand.

Across primary schools, children with learning disabilities often struggle with core skills such as reading, writing, and basic mathematics, despite having average intellectual potential. Among the 402,897 special needs students in Thailand, over 88% are classified to have learning disabilities. This growing population continues to face difficulties in regards to being present in inclusive classrooms as conventional teaching approaches frequently rely on rote memorization and text-heavy instruction (Haymon & Wilson, 2020; Kormos & Smith, 2023). These methods do not effectively support diverse cognitive needs, resulting in low comprehension, disengagement, and reduced confidence among students (Thomas & Uthaman, 2019; Kamran et al., 2023).

To address these issues, educational strategies must be adapted to meet the individual needs of students with learning disabilities while promoting equitable learning environments. One promising direction is the use of augmented reality (AR), a technology that combines digital content with real-world settings to provide multi-sensory and interactive learning experiences. Furthermore, international studies have found that ART can enhance motivation,

comprehension and engagement for students with special needs (Quintero et al., 2019; Baccaq Acosta et al., 2014). In Thailand, however, the application of an AR in inclusive classrooms remains underexplored.

This study focuses on the development and evaluation of an AR-based application designed to improve Thai language reading skills in children with learning disabilities. The proposed tool integrates speech recognition, visual prompts and 3D multimedia content aligned with Thai phonetics and vocabulary. By using AR's visually-engaging qualities, the application seeks to support inclusive learning, create opportunities for literacy development and create accessible pathways for children with special needs to succeed in mainstream educational settings.

2. LITERATURE REVIEW

Current State of Education in the 21st century

Today, the world is undergoing several rapid changes across multiple sectors such as economics, social, technological and even lifestyle. These transformations have positioned 21st-century skills as being essential not only in learning and innovation, but also across areas related to information processing and knowledge-based development (González-Pérez & Ramírez-Montoya, 2022). Education plays a key role in strengthening national progress, particularly across developing countries. It also acts as a fundamental component in achieving equity and opportunity for all learners, including those with special needs.

Current educational policy in Thailand places a strong emphasis on the requirement to improve the quality of education for children who face disadvantages in accessing equal learning opportunities. However, several challenges persisted, especially following the COVID-19 pandemic, which led to the disruption of normal classroom learning occurring while also deepening literacy-related issues. A survey of Thai schools has revealed a growing number of children who face significant difficulties in reading, particularly in the Thai language. This is especially true for children with learning disabilities, who continue to encounter instructional barriers that hinder their academic success. Those challenges have also exposed the shortcomings associated with traditional teaching approaches and highlight the requirement for change.

Furthermore, this change is based on the fact that conventional methods rely heavily on note memorization and textbook-based instruction which often fails to meet the learning requirements of children with learning disabilities. This misalignment between teaching and learning styles can cause slow academic progress, low engagement, and increased frustration (Hayom & Wilson, 2020). In Thailand, children with learning disabilities now represent the majority of those with special educational needs with many of them being in primary schools, and struggling greatly with basic skills like reading, writing and foundational mathematics despite having cognitive abilities that are within normal range.

As per the Ministry of Education, out of 402,897 children with special needs, 350,535 are classified to have learning difficulties. This figure represents 88.24 percent of the total, based on the 2014 national report. These statistics emphasize the urgent need to adapt educational methods and develop inclusive learning environments. These refer to environments in which all learners' needs are accommodated through the use of flexible teaching practices, the incorporation of tailored instructional materials and various support technologies. The ultimate objective is to not only include these students in the classroom but also to help them achieve meaningful learning outcomes.

To solve these challenges, one promising solution stands out which is the integration of educational technology. There have been several advancements in information and communication technology which has led to the emergence of tools that support diverse learning styles and increase accessibility. Educational innovations such as augmented reality (AR) can help content be delivered in a way that is visual, auditory and even interactive thus ensuring this aligns with the ways in which children with learning disabilities process information. These tools allow students to explore materials in a more engaging and personalized manner, enhancing both comprehension and retention.

The incorporation of technology into education and its advantages is especially relevant for students with special needs. By offering customized learning experiences, these tools can provide multitude of opportunities for

students to build foundational skills at their own pace. Furthermore, this individualized approach can also encourage active participation and bolster student's confidence levels. As noted by Niyomyart et al. (2013), the use of digital media in classrooms supports the transition to a knowledge-based society and promotes lifelong learning. Additionally, a study by Ainscow (2020) also emphasized that when children with special needs are given adequate and right tools along with support, the more likely they will feel better prepared to actively engage in everyday life and contribute to their communities.

This is also further explored by Reimers (2020) who contends that enhancing educational quality not only benefits individual learners but also strengthens community resilience. Educational systems that are inclusive and equitable contribute to the long-term development of disadvantaged groups, including students with disabilities. Aligned with these values is the advocacy of rights for all children by the United Nations Educational, Scientific and Cultural Organization (UNESCO) that believes that said children have the right to receive an education that respects their identity, ability and potential. This is also supported by The Declaration on the Rights of the Child which details access to inclusive education for children of all backgrounds, including those with physical or cognitive disabilities (UNESCO, 1999).

Despite these global commitments, classroom practices in many schools still emphasize standardization over personalization. In these contexts, instruction focuses more on memorization and mechanical repetition, as opposed to being adapted to individual needs. As noted by Kormos and Smith (2023), children with learning disabilities frequently face barriers in reading instruction that do not respond to their cognitive profiles. This results in recurring problems like difficulty with spelling, decoding, sentence comprehension, and vocabulary retention. When students are not supported through targeted interventions, these difficulties can lead to frustration, behavioral problems, and loss of self-confidence (Thomas & Uthaman, 2019; Kamran, Siddiqui, & Adil, 2023; Johnson & Walmsley, 2003).

These consequences not only affect academic performance but also a child's emotional and social development. Without timely and adequate help, children may fall behind their peers, ultimately experiencing disappointment and frustration regarding their academic success. Educators play a crucial role in disrupting this pattern. They must understand the distinct learning obstacles encountered by each student and adapt their approaches accordingly. Technology and inclusive instructional approaches provide effective strategies to facilitate varied learning and enhance academic equity.

Technology for Children with Special Needs

Children with special needs are taught across a wide variety of academic subjects, based on the principle that every child can learn and develop when given suitable support. Children with learning difficulties frequently face significant challenges in traditional school environments. Standard teaching methods, especially in literacy education, largely rely on text-based, repetitious, and auditory memorizing strategies. These methodologies hardly correspond with the cognitive profiles and learning preferences of children with learning difficulties, hence making comprehension and retention extremely difficult and challenging (Thomas & Uthaman, 2019).

The consequences of misaligned instruction are well-established.. Students may display signs of dissatisfaction, disengagement, and behavioral issues due to continuous academic failure. Over time, these experiences can affect self-confidence and lead to a reduction in enthusiasm to engage in class (Kamran, Siddiqui, & Adil, 2023; Johnson & Walmsley, 2003). In the lack of prompt intervention and tailored training, learners may fall farther behind, leading to ongoing learning gaps and a sense of academic despair. These results highlight the necessity for instructional practices that are customized to meet the diverse requirements of learners in inclusive classrooms.

Effective management of inclusive education needs more than the just physical integration of learners into shared classrooms. Educators must develop a comprehensive understanding of the unique challenges faced by children with learning disabilities and implement tailored educational strategies. Inclusive education frameworks, such Universal Design for Learning (UDL), highlight the need of providing a diverse approach of representation,

interaction, and expression. This ensures that content is available in many formats, which is important for students who process information differently than their peers (CAST, 2018).

In this context, educational technologies like augmented reality (AR) have emerged as promising tools for supporting students with sith special needs. Augmented Reality allows learners to interact with digital objects and environments layered on the real world, fostering a multisensory and interactive experience that improves cognitive processing. This approach helps enhance attention, increase language development, and builds active learning in children with learning disabilities. Augmented reality apps can integrate pictures, auditory cues, animations, and interactive tasks, appealing to diverse sensory channels and making abstract concepts more concrete and memorable.

In the Thai educational system, where inclusive education is still evolving and traditional literacy approaches are more common, the use of augmented reality (AR) gives a chance to transform the learning experience for students with learning challenges. Ongoing research in this field reveals substantial evidence that AR-based solutions can enhance and improve educational practices. These technologies possess the ability to create more accessible, engaging, and equitable learning environments, thereby advancing the ultimate objective of inclusive education.

Development of Augmented Reality (AR) Applications

Despite the global increase in research on augmented reality (AR) in education, its use in Thai classrooms, particularly for students with learning disabilities, is still limited. International research has highlighted augmented reality benefits for children with special educational requirements. Quintero et al. (2019) and Bacca Acosta et al. (2014) noted that augmented reality technology can provide accessible and engaging educational environments for children with learning disabilities. These apps frequently utilize multimedia content, such as animations, 3D models, and interactive features, to enhance understanding and maintain engagement.

Augmented Reality (AR) allows for children to be directly engaged with educational content as abstract concepts are transformed into concrete visual representations. This method goes beyond static text and repeated verbal instruction, offering hands-on learning possibilities. Pyae et al. (2023)'s research asserts that augmented reality learning environments can reduce the cognitive burden associated with decoding novel terminology, hence fostering children's engagement with the material For children with learning disabilities, who frequently encounter difficulties with traditional reading activities, the ability to conceptualize, auditory process, and modify educational content can effectively close essential gaps in understanding.

Tobar-Muñoz, Baldiris, and Fabregat (2017) noted that augmented reality promotes exploratory learning by stimulating g many senses simultaneously. Children are not only passive recipients of information but are active participants in a dynamic educational process. An augmented reality (AR) reading activity could enable students to scan a physical flashcard, thereby activating a three-dimensional animation that illustrates the word's definition, pronunciation, and contextual use. These features help children develop stronger cognitive associations and improve their long-term retention.

In Thailand, augmented reality educational use is still relatively underdeveloped. Although educational institutions are progressively acknowledging the significance of digital innovation, augmented reality has not yet been widely incorporated into traditional or inclusive classrooms. This gap is a challenge and an opportunity. Limited exposure to AR technologies indicates that several children with learning difficulties may not be receiving the benefits of tools found to be helpful in other countries. Moreover, The growing interest in educational technology among Thai educators and policymakers provides a promising opportunity for the development of innovative, culturally relevant AR applications.

A substantial body of evidence supports the notion that augmented reality can improve academic performance and affect engagement. Ebadi and Ashrafabadi (2022) found that augmented reality applications enhanced student motivation, interest, and reading comprehension, especially in language learning dimensions. This is extremely relevant in Thai language instruction, as children with learning disabilities frequently face unique challenges associated with tonal variation, intricate vowel patterns, and word segmentation. Traditional phonics-based

approaches, although necessary, may not effectively meet the requirements of these learners. Augmented reality can provide compensation by giving students many access points to identical content via audio-visual reinforcement.

This study focuses on developing an augmented reality application to enhance Thai reading skills among children with learning disabilities. The objective is to design a learning tool that facilitates basic vocabulary development while fostering a positive emotional connection to reading. The application aims to enhance student engagement and offer a secure environment for experiential learning through gamified components, interactive activities, and contextually relevant examples. The platform incorporates immediate feedback, integrated pronunciation guides, and animated situations to enhance reading fluency and comprehension in an engaging manner.

A core benefit of augmented reality is its flexibility in accommodating various learning styles. Students who have visual strengths may benefit from vibrant animations, whilst auditory learners can use spoken prompts and voice commands. On the other hand, kinesthetic learners can interact more efficiently by tapping, dragging, or choosing items on the screen. This multisensory design is aligned with the principles of individualized instruction and Universal Design for Learning (CAST, 2018), promoting adaptable environments that cater to individual differences.

Furthermore, augmented reality apps can facilitate independent learning. Children who feel overwhelmed in traditional classroom environments could interact more confidently through the use of self-directed digital platforms. With suitable scaffolding and instructor direction, augmented reality may cultivate a sense of accomplishment and enable children to take responsibility for their learning journey. This is especially crucial in inclusive classrooms, where diverse ability levels must be managed and addressed together. An effectively designed AR application can enhance classroom learning and provide supplementary practice without augmenting instructor effort.

Besides reading advantages, augmented reality can also enhance wider educational objectives, including social-emotional growth and classroom inclusivity. Collaborative augmented reality exercises can foster peer connection and enhance communication among students with varying skill levels. When intelligently incorporated, AR functions as both a technology advance and a catalyst for fostering equitable and powerful learning experiences.

The development of AR tools should be done based on curriculum standards, linguistic considerations and user-centered design to guarantee successful application. Educators, speech-language pathologists, and special education specialists must be involved from the initial phases of content preparation to guarantee pedagogical suitability. Moreover, research into user experience and input from children, parents, and educators should inform iterative enhancements to the program.

In conclusion, augmented reality presents considerable potential as a resource for enhancing literacy skills in children with learning difficulties. Despite its nascent acceptance in Thailand, the technology presents a significant chance to revolutionize reading instruction, making it more accessible, entertaining, and successful. Ongoing investment in research, educator training, and culturally attuned content development will be crucial for realizing AR's complete promise in inclusive education.

AR Application for Children with Learning Disabilities

Children with learning disabilities (LD) demonstrate one or more challenges in fundamental psychological processes associated with language understanding or utilization. These challenges can impair their capacity to think, articulate, read, write, spell, or do fundamental mathematics. Although possessing average intellect, children with learning disabilities frequently encounter difficulties in academic settings due to their cognitive processing and knowledge retention methods. These issues immediately affect their academic performance and, if neglected, may lead to prolonged underachievement and disengagement.

The pedagogical strategies employed by educators when instructing children with exceptional needs profoundly affect learning outcomes. Studies in developing nations indicate that numerous educators possess inadequate training in inclusive education. Consequently, teachers may perceive themselves as inadequately prepared to address the particular requirements of kids with learning difficulties. Ford, McLeskey, and Waldron (2011) underscored the need

of acknowledging individual student abilities and providing suitable tools and resources to facilitate effective classroom integration. In the absence of these supports, achieving genuine inclusion becomes challenging.

Augmented reality (AR) offers a viable solution for tackling these difficulties. Augmented reality applications have demonstrated the ability to transform abstract literacy concepts into tangible, engaging experiences. This approach improves both fundamental reading abilities and self-assurance, and motivation. Klopfer and Squire (2008) discovered that augmented reality environments can enhance literacy development by facilitating pronunciation, broadening vocabulary acquisition, and strengthening reading comprehension. Their research indicated that students who engage with knowledge via visual and aural stimuli in augmented reality environments exhibit enhanced information retention and sustained learning engagement.

Chen and Tsai (2012) investigated the impact of mobile augmented reality applications on student motivation and educational outcomes. Their research validated that augmented reality (AR) substantially enhanced reading comprehension by enabling students to see narratives and engage with story parts in real time. These immersive settings provide contextual assistance that enhances comprehension, especially for youngsters who find conventional, text-dense learning challenging. Augmented Reality (AR) facilitates the establishment of digital learning environments that replicate real-world circumstances, enabling children to forge significant connections among words, concepts, and experiences.

The application of augmented reality for children with learning difficulties is particularly advantageous due to its multimodal characteristics. Students are presented with visual animations, auditory language, interactive text, and kinetic feedback. This variety stimulates many sensory pathways, enhancing the probability of content retention. An AR application instructing users on the term “school” in Thai may exhibit a three-dimensional representation of a classroom, articulate the pronunciation of the word, and present associated terminology such as “teacher” or “students.” This comprehensive method enables pupils to construct vocabulary networks instead of acquiring solitary words.

Moreover, AR-based applications can be designed to facilitate learning by commencing with basic vocabulary and progressively including more intricate phrases and sentence constructions. Prompt feedback enables learners to identify mistakes and modify their comprehension without apprehension of failing. This technique promotes active engagement and facilitates the cultivation of autonomous learning strategies.

Besides academic advantages, augmented reality can facilitate the enhancement of executive function skills, including attention regulation, sequencing, and task perseverance. Numerous children with learning disabilities encounter challenges in these domains, hindering their advancement despite their comprehension of the material. Augmented reality platforms can incorporate reminders, sequential instructions, and progress monitoring to assist learners in maintaining organization and focus. This not only facilitates academic advancement but also cultivates behaviors that enhance autonomy in learning.

3. METHODOLOGY

The augmented reality (AR) application was developed by a diverse team that included educators, special education specialists, AR developers, software engineers, and visual designers. The collaboration guaranteed that the application fulfilled both technological requirements and educational needs, especially for children with learning difficulties in inclusive school environments.

The Unity game engine functioned as the primary development platform owing to its compatibility with mobile devices and its adaptability for 3D content creation. The Vuforia SDK was included into the Unity environment for picture recognition and tracking, allowing the application to interact with printed items like language flashcards. Blender was utilized to create 3D animated models illustrating essential Thai terminology, and Adobe Illustrator was applied to construct the user interface and iconography. The final program was tailored for Android-compatible tablets and smartphones for augmented reality, frequently utilized in Thai educational institutions.

During creation, the design adhered to the principles of Universal Design for Learning (UDL) to guarantee accessibility for a variety of learners. Visual components were crafted with significant contrast, interactive cues were enhanced with auditory guidance, and navigation was streamlined to cater to diverse literacy and cognitive capabilities.

The application was designed based on active and multimodal learning methodologies. Each vocabulary word was introduced using 3D animations, auditory pronunciation, and brief interactive exercises to enhance comprehension. For instance, scanning a flashcard may elicit a student to observe an animated item, listen to the word articulated, and engage in a matching exercise. This method enhances memory retention and accommodates various learning preferences.

To guarantee usability, initial prototypes were evaluated in school settings with children who have learning difficulties. Teacher observations and student comments guided modifications to enhance clarity, interaction flow, and engagement. Modifications were implemented to streamline interface components and diminish extraneous cognitive burden.

The application was built via an iterative, learner-centered approach that integrated technology innovation with inclusive instructional design. The outcome is a mobile augmented reality technology that improves Thai language acquisition in accessible and engaging manners for students with specific educational requirements.

4. RESULTS AND DISCUSSION

Expert feedback and classroom-based pilot testing were employed to assess the AR application's implementation. A small group of first-grade students with cognitive disabilities participated in the study, which was conducted in an inclusive Thai language classroom. Students' engagement and sustained attention were observed to increase during the pilot sessions when they engaged with the AR-enhanced vocabulary materials. In class activities, learners demonstrated substantial enhancements in their ability to recognize words, pronounce them accurately, and participate. Teachers reported that students who typically avoided reading assignments were more inclined to attempt them when the content was presented through interactive animations and audio-visual cues. Students were able to effectively navigate challenging aspects of the language, including tone and vowel length, through the incorporation of 3D models and spoken Thai. These elements are frequently obstacles in traditional instruction. Educators also praised the application for its potential for classroom integration, content alignment with the curriculum, and usability.

These findings are consistent with previous research that has illustrated the effectiveness of augmented reality in facilitating language acquisition among students with a variety of requirements. AR technology has the potential to improve vocabulary acquisition and reading comprehension by providing immersive, multisensory experiences that are tailored to the learning preferences of individuals, as Fecich (2014) has observed. The results of this study broaden that perspective to the Thai context, where the linguistic complexity presents distinctive obstacles for early readers. The implementation of AR enabled students to establish connections between visual, auditory, and conceptual representations of vocabulary, thereby enhancing their comprehension and vocabulary retention. In addition, the application's adherence to Universal Design for Learning principles guaranteed that learners could access the material in a variety of ways, thereby reducing their reliance on text alone. AR is not only a motivational tool, but also an effective strategy for addressing the specific phonological and cognitive difficulties encountered by children with learning disabilities in inclusive classrooms, as these outcomes suggest. The potential for integrating AR into broader educational practices to support more equitable learning outcomes is illustrated by the success of this application.

Key Features of the AR Application:

The AR application that was created for this study incorporates a variety of pedagogical features that are intended to improve the reading fluency, vocabulary acquisition, and learner engagement of children with learning disabilities. These attributes are founded on evidence-based practices and are consistent with the tenets of inclusive and multimodal education.

Interactive Storybooks

The application transforms traditional printed storybooks into interactive AR experiences. Characters and locations from the narrative are rendered as animated three-dimensional elements when scanned with a mobile device. These virtual elements encompass interactive behaviors, speech, and movement, which enable students to interact directly with the narrative. This feature is intended to improve the comprehension of stories, maintain the reader's interest, and make the reading experience more pleasurable and meaningful.

Vocabulary Learning

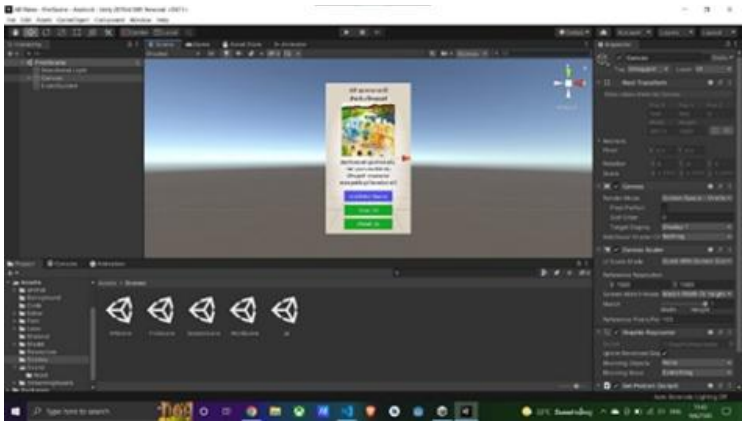
Interactive 3D models and dynamic visual aides, including animations and brief videos, are employed by the application to introduce new Thai vocabulary. The models can be manipulated by students, who can also observe them from various perspectives and receive audio support that includes word pronunciation and utilization in various sample sentences. This multi-sensory approach supports contextual understanding of new words and memory retention.

Pronunciation Practice

The application will include interactive pronunciation exercises allowing students to practice and improve their Thai pronunciation skills. For instance, students may be prompted to speak a specific word, and the application will provide immediate feedback on the accuracy of their pronunciation.

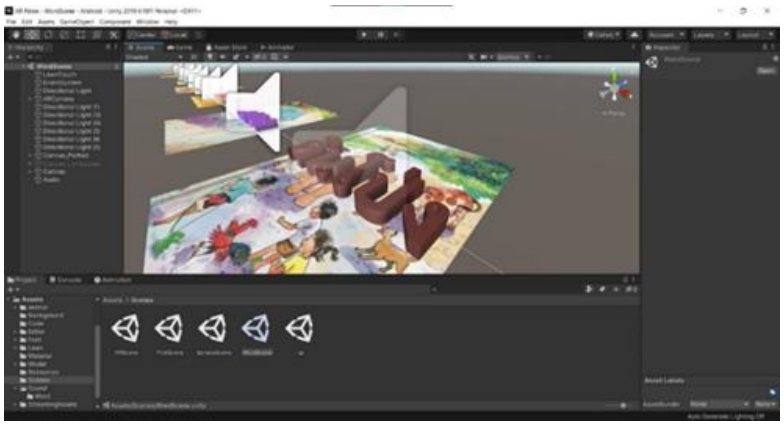
The research will collect both quantitative and qualitative data to evaluate the application's effectiveness in improving Thai reading skills. Quantitative measures may include reading test scores, while qualitative data may be gathered through observations, interviews, and surveys.

Once you open the program, you will find the First Scene page, which is the first page of the application.

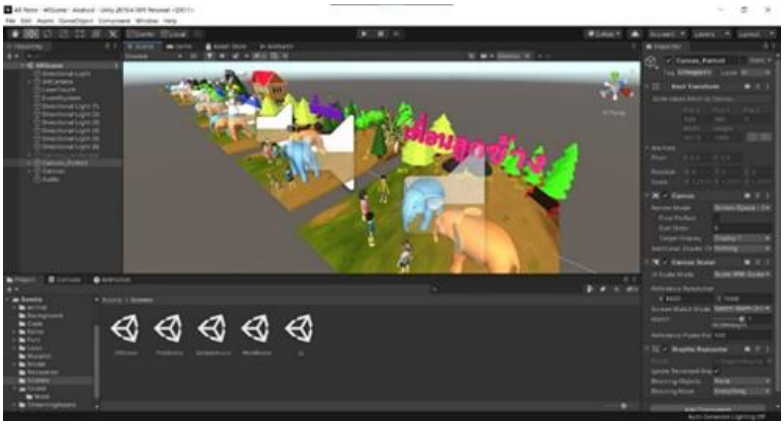


Materials prepared for coloring in various 3D models.

AR 3D Vocabulary Pages



AR Pages 3D Models.



Usually, AR images related to word definitions are two-dimensional visuals or animations that are superimposed on the actual world using augmented reality. For example, learners may be able to associate vocabulary with concrete visual references by observing an AR image of an "elephant" along with a real-world scene in which the word is contextually pertinent. One of the primary benefits of utilizing AR images is their easy integration in comparison to 3D models. They are more adaptable to various learning contexts and require less time to create. Additionally, these 2D assets are simpler. Therefore, they are particularly advantageous in classrooms with inadequate technological infrastructure. By allowing students to more organically visualize and internalize words, AR images that are associated with everyday vocabulary can facilitate long-term retention. They are applicable to a variety of learning formats, including interactive picture books, vocabulary flashcards, and supplementary exercises. Along with other instructional materials, AR images facilitate comprehension and establish more compelling learning environments. They provide a flexible and effective method for vocabulary instruction, particularly for students with learning difficulties who may benefit from visual reinforcement and contextualized content, by supporting a variety of learning styles and reducing cognitive burden.

The text discusses the application of Augmented Reality (AR) in teaching vocabulary, specifically highlighting the use of 3D models and AR images.

3D AR Models for Vocabulary Instruction

The application of augmented reality (AR) to vocabulary instruction is gathering strength in the field of educational research. One of its most promising applications is the incorporation of three-dimensional (3D) models, which enable students to interact with and visualize vocabulary terms in a dynamic environment. These models provide distinctive advantages that surpass conventional instructional methodologies.

Enhanced Learning Experience: Immersive learning environments are created by 3D AR, which enhances pupil engagement and enables a more profound comprehension. Interactive models, in contrast to inert images or text, assist students in establishing more robust cognitive connections, which leads to enhanced comprehension and longer-term retention of new vocabulary.

Increased Contextual Understanding: Students are able to carry out a more thorough examination of vocabulary terms by having the capacity to manipulate and observe models from various perspectives. For instance, learners can improve their literal and situational comprehension by utilizing a 3D model of an "elephant school" to visualize the term in context. The acquisition of more sophisticated language skills is facilitated by this spatial interaction.

Motivation and Engagement: When learning incorporates interactive and exploratory components, students are more inclined to learn. 3D AR introduces a playful and discovery-based component to learning, which increases student enthusiasm and willingness to participate. This interaction is especially beneficial for students who encounter difficulties with conventional classroom methodologies.

Multi-Sensory Learning: 3D AR creates a multisensory learning experience by integrating visual, auditory, and occasionally tactile inputs. In addition to observing and hearing vocabulary in use, students are also able to interact with digital objects, which reinforces comprehension through a variety of sensory channels. This multi-modal environment is particularly effective in supporting vocabulary acquisition and conceptual learning for students with diverse educational requirements, as per Bower et al. (2014).

AR Images Related to Word Definitions

Augmented reality (AR) can also be utilized to facilitate vocabulary development by superimposing two-dimensional (2D) images or animations on the physical environment. These AR images offer learners visual representations that aid in the reinforcement of the meaning of specific words and the improvement of retention. For instance, when a student encounters the term "elephant," an AR image that corresponds to the word can be displayed in the surrounding environment, thereby contextualizing it in a real-world context. This method enhances comprehension by facilitating immediate visual association.

AR images are more easily produced and integrated into classroom settings than 3D models, rendering them highly adaptable to a variety of learning environments. Their adaptability enables educators to integrate them into a variety of instructional formats, including digital worksheets, flashcards, and picture books. This adaptability is especially advantageous in inclusive classrooms, where learners possess distinct cognitive and linguistic requirements.

By reinforcing familiar contexts, the use of AR images that are aligned with everyday vocabulary supports durable learning. These tools are not only a valuable addition to conventional teaching materials, but they also enable a more diverse instructional design, which is crucial for involving students with learning disabilities. AR images are a practicable and effective alternative for vocabulary instruction, particularly when resources are scarce, although they may not provide the same level of immersion as 3D models.

In summary, vocabulary acquisition is significantly influenced by both 3D AR models and AR images. The choice between the two should be determined by the instructional objectives, the requirements of the learners, and the resources that are available. The most comprehensive benefits for students with diverse learning profiles may be achieved by incorporating both tools into a balanced instructional strategy.

AR Augmented Reality Integration for Children with Learning Disabilities in Pati Language Grade 1: Exploring Basic Thai Vocabulary through the "โรงเรียนลูกช้าง" AR Experience

This example demonstrates the integration of Augmented Reality (AR) technology to support children with learning disabilities in the Grade 1 Thai Language Curriculum. AR Experience "Elephant School" is an interactive vocabulary learning tool that complements the Grade 1 Thai curriculum. Baby ช้าง (Elephant) ครู (Teacher) Each word comes with a visual representation, making it easier for children with learning disabilities to understand and remember words.

Interactive Learning: AR applications allow students to engage with vocabulary in a hands-on manner. When tapping on an AR element, students will hear the pronunciation of the word. See words in context, and even participate in mini-games related to each word. Personalized Learning Experience: The "Elephant School" AR experience is designed to accommodate each student's learning pace and preferences. The application adapts to the student's progress, offering repetitive practice or advanced challenges based on their level of expertise. Benefits for children with learning disabilities: AR technology provides a multi-sensory learning experience that is especially beneficial for children with learning disabilities. Visual and auditory elements help strengthen memory retention and improve comprehension. Moreover, the interactive nature of AR helps students stay motivated and engaged in the learning process. Integrated into the Grade 1 Thai Language Curriculum.

Enhance vocabulary learning with the interactive AR animation "Friends": Three-dimensional experience

Interactive AR animation "Friends" The AR interactive animation "Friends Together" is an innovative tool designed to enrich vocabulary learning for students. Using Augmented Reality (AR) technology, this three-dimensional experience complements language lessons and promotes an engaging and immersive learning environment for Thai learners. The interactive AR animation "Friends" revolves around the theme of friendship and camaraderie. Students embark on a journey where they will encounter various characters, scenes, and objects that represent the necessary Thai vocabulary related to friendship. Vocabulary expansion: AR experiences introduce students to a variety of vocabulary, such as เพื่อน (friends), เพื่อน (friend), กอด (hug), Each word is presented with visuals within the context of the animation, which helps to better understand and maintain. Interactive learning adventure: Students can actively engage with AR animation by tapping on characters and objects. Doing so stimulates pronunciation and visual cues. AR animation facilitates contextual learning. Students can understand the meaning and use of words in real-life situations, which will improve their overall understanding of the language. Children with learning disabilities: The interactive nature of AR animation benefits children with learning disabilities by supporting different learning styles. Dynamic audiovisual interactions create multisensory experiences that aid in memory retention and comprehension.

Integration with language lessons: The interactive AR animation "Friends" integrates seamlessly with language lessons. Educators can include animation as an auxiliary resource during classroom activities or as a standalone learning module for independent study. Increase student motivation: AR technology promotes a sense of excitement and motivation among students. The interactive nature of the animation promotes active participation and a positive

attitude towards language learning.table highlighting the key differences between using 3D AR for teaching vocabulary and using AR images related to vocabulary:

Feature	3D AR for Vocabulary	AR Images for Vocabulary
Definition	Uses interactive 3D models to represent vocabulary words.	Uses 2D images or animations overlaid on the real world.
Immersion	Provides a highly immersive learning experience.	Provides a less immersive experience compared to 3D AR.
Interaction Level	Allows manipulation and exploration of 3D objects.	Typically involves passive interaction with static images.
Visual Representation	Offers detailed, dynamic, and spatial representations.	Provides clear but static visual representations.
Contextual Understanding	Enhances contextual understanding through spatial exploration.	Contextualizes vocabulary with visual clues in real-world scenarios.
Learning Experience	Highly engaging and motivating due to interactive elements.	Engaging but less dynamic; primarily visual reinforcement.
Multi-sensory Learning	Incorporates visual, auditory, and sometimes tactile inputs.	Primarily visual and auditory inputs.
Ease of Integration	More complex and resource-intensive to create.	Easier and cheaper to create and integrate.
Adaptability	Can adapt to student progress with advanced interactive features.	Generally less adaptable; provides static information.
Educational Benefits	Supports deeper engagement and understanding.	Reinforces vocabulary with visual context.
Research Support	Bower et al. (2014); Cheng & Tsai (2013)	Dünser et al. (2012); Radu (2014)

5. CONCLUSION

This study presents a concept of innovative learning management development for children with learning disabilities. Summary and discussion of the results

1. The "โรงเรียนลูกช้าง" (Elephant School) AR experience demonstrates the potential of Augmented Reality in transforming the learning journey for these students in first-grade Thai language acquisition. The AR innovation promotes inclusivity, engagement, and confidence among all learners as they embark on their language learning adventure. The continuous advancement of AR technology presents boundless possibilities for creating comprehensive and fulfilling educational experiences for children with learning disabilities.

2. The "เพื่อนกัน" (Friends Together) interactive AR animation seamlessly integrates into language lessons. Educators can incorporate the animation as a supplementary resource during classroom activities or as a standalone learning module for independent study, thereby boosting student motivation. AR technology promotes excitement and motivation among students. The interactive nature of the animation encourages active participation and a positive attitude towards language learning. The animation showcases the power of Augmented Reality in enhancing vocabulary acquisition for Thai students by creating an immersive and engaging experience. This innovative tool enables students to explore the world of friendship through language, promoting deeper understanding and appreciation of essential Thai vocabulary. As AR technology continues to evolve, its potential to revolutionize language education for children with diverse learning needs becomes increasingly evident, shaping the future of language learning in Thailand. The application of interactive AR animation for vocabulary learning, with a specific focus on the theme of friendship, is a testament to this potential.

In summary, both AR applications demonstrate the positive impact of AR technology on Thai language learning for students with learning disabilities. The interactive and personalized nature of AR experiences enhances motivation, engagement, and overall learning outcomes. The studies suggest that AR has the potential to revolutionize language education in Thailand and create a more inclusive and effective learning environment for all students.

Moving forward, the proposed learning model can serve as a valuable resource in promoting better learning outcomes and fostering a supportive and inclusive educational ecosystem for children with special needs. Systematic review of literature on augmented reality (AR) supported early language learning. Witch analyzed a total of 53 papers from 2010 to 2019 using qualitative analysis complemented by descriptive quantitative analysis. Our findings revealed three main AR learning activities: word spelling games, word knowledge activities, and location-based word activities. Additionally, we identified five main design strategies: three-dimensional multimedia content, hands-on interaction with physical learning materials, gamification, spatial mappings, and location-based features.

Several combinations of design and instructional strategies were found to be effective. Learning gains were enhanced by using three-dimensional multimedia with advanced organizers (presentation strategy) and/or location-based content with learners' self-exploration (discovery strategy). Motivation was enhanced by using game mechanisms with the discovery strategy.

The paper suggests that future designers of AR early language applications should move beyond these basic approaches. They should consider how the unique benefits of AR can support key activities in early language learning while also addressing sociotechnical factors such as collaboration between teachers and learners and different learning contexts. We conclude with a discussion of future directions for research in this emerging space.

AR Storybooks: Making Learning Fun

AR storybooks combine the magic of traditional storytelling with interactive digital elements. By using smartphones or tablets, children can engage with the characters and scenes, making the reading experience captivating and enjoyable. For children with learning disabilities, this multisensory approach can aid in memory retention, comprehension, and word recognition, leading to improved Thai reading skills.

Interactive Vocabulary Lessons:

Learning vocabulary can be challenging for children with learning disabilities. AR technology enables interactive vocabulary lessons, where Thai words come to life in 3D models or animations. Visualizing objects while associating them with Thai words can help reinforce memory and understanding, making language acquisition more effective and enjoyable.

Phonics Practice in AR:

Phonics is a crucial aspect of reading, particularly in a language like Thai, where letters combine to form different sounds. AR applications can provide interactive phonics exercises, where children can interact with letters and hear their corresponding sounds. This hands-on approach can strengthen their phonics skills and eventually contribute to improved reading fluency.

Personalized Learning Paths:

One significant advantage of AR is its ability to adapt to individual learning needs. AR applications can track a child's progress and tailor the content to suit their specific learning pace and style. Children with learning disabilities often require personalized approaches, and AR can provide a safe and nurturing environment for them to learn and grow at their own pace.

Enhancing Reading Comprehension:

For some children with learning disabilities, reading comprehension can be particularly challenging. AR can help by offering interactive comprehension exercises after reading a passage or story. These exercises may include

answering questions, filling in missing words, or identifying key elements in the story. Through repeated practice, children can develop their reading comprehension skills and gain confidence in their abilities.

Conclusion: Augmented Reality opens up exciting possibilities for improving Thai reading skills for children with learning disabilities. By providing engaging, interactive, and personalized learning experiences, AR can help bridge the gap between struggling learners and successful readers. As educators, parents, and researchers continue to explore the potential of AR in education, the future looks promising for creating inclusive and effective learning environments for all children, regardless of their learning abilities. Remember to adapt the article to your target audience and add specific examples or studies that support the effectiveness of AR in improving reading skills for children with learning disabilities. Additionally, include relevant resources or tools that parents, teachers, or caregivers can use to implement AR-based learning strategies.

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REFERENCES

1. Ainscow, M. (2020). Promoting inclusion and equity in education: lessons from international experiences. Nordic journal of studies in educational policy, 6(1), 7-16.
2. Alhalabi, W. (2019). Augmented reality as a tool for learning English as a second language: A systematic review. Journal of Language and Linguistic Studies, 15(1), 456-469.
3. Anderson, A. (2019). Virtual reality, augmented reality and artificial intelligence in special education: a practical guide to supporting students with learning differences. Routledge.
4. Bacca Acosta, J., Baldiris, S., & Fabregat, R. (2014). AR-Based Learning Tools: Practical Applications in Inclusive Education. Computers & Education, 73(1), 1-14.
5. Badilla-Quintana, M. G., Sepulveda-Valenzuela, E., & Salazar Arias, M. (2020). Augmented reality as a sustainable technology to improve academic achievement in students with and without special educational needs. Sustainability, 12(19), 8116.
6. Bubpha, S., Erawan, P., & Saihong, P. (2013). Inclusion: The Practice of Inclusive Education–Case Study of Best Practices in the United States. Editorial Advisory Board, 37(1), 149-159.
7. Chen, C. M., & Tsai, Y. H. (2012). The effects of mobile-based augmented reality on learning motivation and learning outcomes. Educational Technology & Society, 15(4), 88-99.
8. Danaei, D., Jamali, H. R., Mansourian, Y., & Rastegarpour, H. (2020). Comparing reading comprehension between children reading augmented reality and print storybooks. Computers & Education, 153, 103900.
9. Delello and Bunn (2016) explored the use of AR technology for students with learning disabilities, focusing on its role in creating personalized and engaging educational experiences. The research found that AR can cater to diverse learning needs, enhancing student engagement and learning outcomes.
10. Ebadi, S., & Ashrafabadi, F. (2022). An exploration into the impact of augmented reality on EFL learners' Reading comprehension. Education and Information Technologies, 27(7), 9745-9765.
11. Fecich, S. J. (2014). The use of augmented reality-enhanced reading books for vocabulary acquisition with students who are diagnosed with special needs. The Pennsylvania State University.
12. Ford, J. (2013). Educating students with learning disabilities in inclusive classrooms. Electronic Journal for Inclusive Education, 3(1), 2
13. González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. Sustainability, 14(3), 1493.
14. Haymon, C., & Wilson, A. (2020). Differentiated reading instruction with technology for advanced middle school students' reading achievement. Journal of Educational Research and Practice, 10(1), 5.
15. Johnson, A., & Walmsley, R. (2003). Understanding the Challenges of Literacy Instruction for Students with Learning Disabilities. Special Education Review, 29(4), 78-89.
16. Johnson, K., & Walmsley, J. (2003). Inclusive research with people with learning disabilities: Past, present and futures. Jessica Kingsley Publishers.
17. Kamran, M., Siddiqui, S., & Adil, M. S. (2023). Breaking barriers: Influence of teachers' attitudes on inclusive education for students with mild learning disabilities (MLD). Pedagogika, 13(6), 606.
18. Klopfer, E., & Squire, K. (2008). Augmented reality on the desktop: A tool for developing and studying complex learning environments. Educational Technology Research and Development, 56(1), 67-86.
19. Kormos, J., & Smith, A. M. (2023). Teaching languages to students with specific learning differences (Vol. 18). Channel View Publications.

20. McLeskey, J., & Waldron, N. L. (2011). Educational programs for elementary students with learning disabilities: Can they be both effective and inclusive?. Learning Disabilities Research & Practice, 26(1), 48-57.
21. Murniarti, E., Prayitno, H., Wibowo, G. A., Suparmi, S., Yuliani, E., & Rochmah, R. (2023). Implementing Augmented Reality in Inclusive Education: Experiments and Potential. International Journal of Science and Society, 5(4), 60-72.
22. Niyomyart, P., Bubpha, S., & Bailee, C. (2023). Area--based education strateiges for primary schools in Nong khai province. Journal of Namibian Studies, 34.
23. Pyae, A., Ravyse, W., Luimula, M., Pizarro-Lucas, E., Sanchez, P. L., Dorado-Diaz, I. P., & Thaw, A. K. (2023). Exploring User Experience and Usability in a Metaverse Learning Environment for Students: A Usability Study of the Artificial Intelligence, Innovation, and Society (AIIS). Electronics, 12(20), 4283.
24. Quintero, J., Baldiris, S., Rubira, R., Cerón, J., & Velez, G. (2019). Augmented reality in educational inclusion. A systematic review on the last decade. Frontiers in psychology, 10, 1835.
25. Quintero, M., González, J., & Ramírez, P. (2019). Augmented Reality in Inclusive Classrooms: Bridging Gaps and Enhancing Learning. International Journal of Inclusive Education, 23(5), 562-578.
26. Reimers, F. M. (2020). Educating students to improve the world (p. 131). Springer Nature.
27. Shaaban, T. S., & Mohamed, A. M. (2024). Exploring the effectiveness of augmented reality technology on reading comprehension skills among early childhood pupils with learning disabilities. Journal of Computers in Education, 11(2), 423-444.
28. Thomas, E., & Uthaman, S. (2019). Knowledge and attitude of primary school teachers towards inclusive education of children with specific learning disabilities. Journal of Social Work Education and Practice, 4(2), 23-32.
29. Thomas, L., & Uthaman, V. (2019). Behavioral Issues and Educational Interventions for Children with Learning Disabilities. Learning Disabilities Research, 12(1), 22-35.
30. Tobar-Muñoz, H., Baldiris, S., & Fabregat, R. (2017). Augmented reality game-based learning: Enriching students' experience during reading comprehension activities. Journal of Educational Computing Research, 55(7), 901-936.I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
31. K. Elissa, "Title of paper if known," unpublished.
32. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
33. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
34. M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.