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Research Article

Enhancing reading capability of young Thai students with augmented reality technology: Design-based research

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ABSTRACT

The Thai language, which is part of the Indo-Iranian language family, carries on rituals and local knowledge that have been passed down from generation to generation. The Thai National Statistics Office found that 10% of elementary school students in Thailand cannot read. This means that 90% of elementary school students in Thailand can read. The numbers disagree with a report from an international assessment agency that said young Thai students' reading skills were the 50th best out of 65 countries. So, it is still hard for young Thai people to read well. The main goals of this research are to: (i) make an augmented reality platform that will help students improve their reading skills and (ii) figure out how well the platform works. This study uses a method called "research design" (R&D) to look at how students feel about an educational product or method that was designed and then used. Research and development can be thought of as going through three different stages (research phase, development phase, and implementation phase). According to the results, the picture word inductive model (PWIM) strategy was put into place because the professionals said it should be. The most popular method of teaching was called "precision teaching." Reading out loud and reading the same thing over and over were two ways that vocabulary was taught. According to the results of the experiment, the students' scores after finishing the reading are higher than their scores after the first reading. As part of the second part of the study, reading comprehension skills were tested. The students have also gotten a lot better at understanding what they read as a whole.

Keywords: augmented reality, elementary school students, PWIM, reading ability, precision instruction

INTRODUCTION

Read is a very important skill for learning. Early reading development in young learners encourages them to look for more information and take part in activities that connect what they already know (Triwahyuni et al., 2020). It also helps them keep their emotions in check by giving them a way to focus (Mata et al., 2020; Tyng et al., 2017). Reading abilities involve recognizing and understanding words (Pearson & Cervetti, 2013). Reading ability consists of two parts: the capacity to recognize the alphabet, sound, word, its meaning, and how to speak it correctly, and reading comprehension, the ability to link information, infer, synthesize, predict, and make sense of what you read (Bellinger & DiPerna, 2011; Cotter, 2012; McInnes et al., 2018).

The Thai language is 2,000 years old and connected to Indo-Iranian and Indian. Through spoken and written language, rituals and local knowledge are carried down. Reading at the novice level is either "readable" or "unreadable" based on phonics and understanding (Thai National Reading Committee, 2010). 10% of primary kids cannot read or write, according to statistics. The Thai National Statistics Office reported young Thai youngsters read more after 2000, which boosted their literacy rate. Large IT infrastructures make it simpler for consumers to access digital books, which increases reading hours (Thailand National Statistical Office, 2019). However, PISA (OECD, 2019) indicated Thai pupils' reading skills had declined over the past decade. Thai kids' reading ability ranked 50th out of 65. 43% of Thai pupils are below the standard level (level 2). According to PISA data, Thailand's assertion that 90% of primary school kids can read is false. Thai pupils can read, but their abilities are poor.

Reading boosts imagination and memory. Students focus on, arrange, and employ new words to decode and encode information (Troscianko, 2013). Reading materials are most often printed (Spencer, 2006). They're easy to touch and imagine, and they offer complicated learning experiences (LXs) with text and visuals. Print materials may teach readers in intangible ways. Students use technology to read when digital technology promotes learning and literacy. Using technology in learning activities helps students work together, solve issues, enhance listening skills, and retain information (Bower et al., 2014; Dunleavy et al., 2009).

The term "augmented reality (AR)" is used to describe any situation in which real-world environments are "augmented" by the addition of virtual (or computer-generated graphic) elements (Milgram & Kishino, 1994). There has been substantial use of technology to facilitate and improve reading (Jamshidifarsani et al., 2019). AR moves written word out of the abstract and into the practical world and blends media. A platform is written software that integrates augmented media, records student learning, identifies the proper activities, and displays graphical tutoring. A teacher employs touch-sensitive materials to develop young children' fine motor skills and display useful virtual media over printed text. AR books integrate physical learning, spatial organization, and verbal relationships to improve memory, retention, and motivation (Chara, 2013; Izzaty et al., 2019; Na-songkhla, 2011; Nasongkhla et al., 2019; Pariyawatit, 2015; Wu et al., 2018). However, the integration of AR technology in the classroom has been criticized because it has been proven to be teacher-dominated and to have lower levels of student engagement than non-AR classroom usage (Kerawalla et al., 2006). In this study, the AR-reading platform helps teachers be more honest with kids. It features a built-in monitoring function as a reading evaluation tool to track student progress and delivers remedial pupils exact training through an individual set of activities to improve their fluency, accuracy, and reading comprehension. The program provides auditory and visual reminders for pupils to drill and practice reading. Exercises that assist students recall what they forgot can improve their reading. Even if a child cannot read, teachers and parents can help.

THEORETICAL BACKGROUND

Teaching Reading

Reading is the process of receiving and decoding information encoded in language form via the medium of print (Urquhart & Weir, 1998). Reading deals with mental imagery (Grabe, 2004). Readers can easily connect to the writing with familiar prior knowledge, background experiences, or schema. A cognitive schema, a mental framework or concept, helps organize and interpret information. The mental model represents real or imaginary situations in the mind and mirrors the perceived structure of the modeled external system (Jones et al., 2011). There are three schema types for language learning (An, 2013); linguistic, content, and formal schemas. Linguistic schemas refer to traditionally recognized phonetics, grammar, and vocabulary knowledge (Zarei, 2012). Content schemas involve familiarity, cultural understanding, and previous experience (Kafipour et al., 2017). Formal schemas relate to rhetorical organizational structures of different types of texts (Carrell, 1984). Reading is, in a sense, a bridge between the new and the old. Thanks to this bridge, the unfamiliarity drops, and the interest arouses. Then it becomes possible to make predictions in reading. Schemas help students solve problems in reading and interpreting an overwhelming amount of information, enabling them to relate new information to their prior experience. In addition, Image schemas are considered embodied prelinguistic structures of knowledge that motivate conceptual metaphor mappings (An, 2013; Urquhart & Weir, 1998).

Furthermore, cognitive load theory describes the teaching of new material and influences the processing and organization of students' knowledge for long-term memory (Ibili, 2019) (**Figure 1**). Increasing intrinsic motivation and reducing a distracting or unnecessary load might result in a cognitive load that is important or pertinent to the learning process. A teaching strategy that facilitates the degree of content comprehension

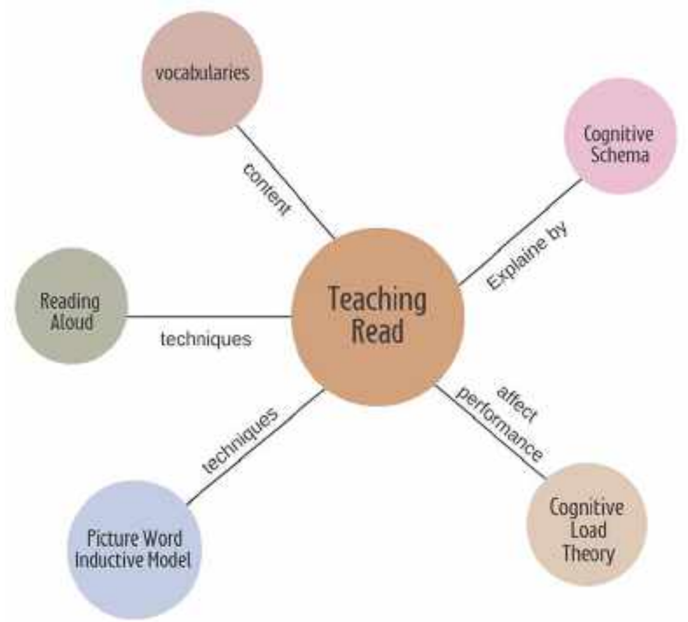

Figure 1. Relationship theories, techniques, and teaching read (Source: Authors' own elaboration)

that directly contributes to learning has an effect on the relevant cognitive load (Debue & van de Leemput, 2014). Controlling cognitive load during instruction is essential for effective learning. The instructional design must decrease irrelevant load and increase relevant load. Consequently, the larger the rate of relevant cognitive load, the bigger the learning potential. If the intrinsic load is large, the memory capacity available to dedicate to the extraneous load in working memory decreases, hence increasing the mental effort required (Cheng, 2016; Debue & van de Leemput, 2014; Ibili, 2019).

Both the first language (L1) and the second language (L2) suggest that vocabulary knowledge is one of the most accurate indicators of reading ability (Moghadam et al., 2012). Two vocabularies, productive and receptive, can be used to describe knowledge of word connections: productive and receptive vocabularies. A person's productive vocabulary consists of well-known, familiar, and often used terms. In contrast, receptive vocabulary is comprised of known words that appear in circumstances that pupils are unable to effectively traverse. The gap between familiar receptive and productive information might be bridged through cue recall (National Reading Panel, 2000).

The picture word inductive model (PWIM) is a regularly used strategy using media to connect words into a familiar context that utilizes visuals to enhance students' memory and move the vocabulary into an active or productive mode (**Figure 1**). PWIM has become a teaching strategy to improve the reading and writing skills of elementary students. When pupils concurrently repeat pronunciation and spelling, they strengthen their language skills. Utilizing familiar images, this method assists in the resolution of reading and writing ability issues. In addition, it improves inductive reasoning, boosts creativity, stimulates involvement, and inspires study (Triwahyuni et al., 2020).

To learn language, PWIM students seek knowledge from things or forms. The technique stresses the inductive process in which students generate knowledge or vocabulary lists to promote connections based on prior knowledge. Learners connect images and words through the interaction between sound and symbol (pictures), so fostering mutual comprehension (Calhoun, 1999; Triwahyuni et al., 2020). Visuals facilitate the association between visuals and language, particularly for the development of pronouncing abilities. Reading using the visual picture, students create their own rules until they master the language and can read and spell words accurately. Students see and hear the correctly written words in a visual incorporating recognizable items, events, and settings. They may observe phonetics, synonyms, antonyms, and pronunciation when analyzing words. Teachers increase memorization by hearing and reading (Jiang, 2018).

In accordance with literature review (Calhoun, 1999; Gu & Lornklang, 2021; Jiang, 2018; Lee et al., 2019; Srithamma & Songserm, 2020; Triwahyuni et al., 2020), PWIM directs student reading events, as follows:

(1) display the necessary image,

(2) identify and utter the word,

(3) read repeatedly or loudly,

(4) link and classify relevant sounds and information,

(5) use inductive reasoning by producing a new phrase, and

(6) read and review the sentence.

This strategy may be used with learners of all ages, both individually and in groups, by emphasizing inductive reasoning. Through guided activities and questions, students are led to infer a general rule as part of the inductive approach to reading. Students find the ruling based on the evidence of the feedback, which enables them to become proficient language learners. PWIM instructional technique enhances students' reading skills, particularly the ability to appropriately combine words into coherent grammatical structures and grasp their meaning (Jiang, 2018).

Phonics reading out loud helps students learn (Triwahyuni et al., 2020; Urquhart & Weir, 1998). To read, you must know what words mean and do not say. You must also identify the major concepts, forecast what will happen, and some reading instruction research focuses on word recognition. This is done by emphasizing vocabulary, activating reading context knowledge, and encouraging independent reading (Carreiras et al., 2014). In class, students learn to express, comprehend, and think about word meanings, developing higher-order thinking abilities (Cotter, 2012). The National Reading Panel (2000) advocated repeated reading (RR) as a reading instruction method (Samuels, 2013). RR is a method for teaching fluency in which the learner reads and rereads a material quietly or loudly several times in order to achieve a predefined level of speed, accuracy, and understanding. In addition to sustained silent reading programs, shared reading, aided reading, and extended reading, a number of other reading-as-recreational-activity-assistance programs have been established, all of which provide extra support, such as reading materials or activities (Rasinski, 2006). The approaches stated emphasized pupils mastering their learning via repeated practice till reaching a certain learning aim. This technique asserts that all students may achieve success if they are provided with guidance and sufficient time to study, as well as a knowledge of learning design. Several interactive media designs utilize the behaviorist philosophy to allow students to practice a certain skill. Mastery-level learning is a lengthy process in which students raise unknown information to skill level via practice. Utilizing proper strategies, rapid and efficient mastering of learning enables the transfer of learning to skills (Triwahyuni et al., 2020).

Precision teaching, which was established by Ogden Lindsley in 1991 (Potts et al., 1993), is an assessment strategy that use precise data collecting to aid students in acquiring knowledge (Potts et al., 1993; West et al., 1995). The teacher assigns pupils learning activities and tracks the observable and quantifiable learning behaviors throughout time. Eventually, the data is transformed into information that may be used by instructors to identify and address certain learning or behavioral objectives (Downs & Morin, 1995). Precision instruction determines the number of responses a certain learner has to a particular exercise. Setting explicit learning objectives that are broken into little learning chunks and giving drill and practice tasks constitute precision instruction. With specific indications and criteria, teachers monitor measurable student performance and implement corrective measures as needed. This kind of education is a basic practice in behavioral modification and needs curriculum-based examination of standards, the determination of learning outcomes, and the organization of consistent material (Evans et al., 2021; Mannion & Griffin, 2018; Martinho et al., 2022).

Augmented Reality Platform

AR is a sort of mixed reality (MR) technology that encompasses both the physical and virtual worlds. As seen in the **Figure 2**, the simplest method to observe an MR environment is one in which real-world and virtual-world items are presented simultaneously on a single display, that is, anywhere along the virtuality continuum (Milgram & Kishino, 1994). AR applications combine the physical and virtual by extending the virtual into the real world. AR interpolates between the real and virtual worlds by comparing the continuum of "virtuality" to the X-axis and then projecting the "X-axis" to the Y-axis (Mediality). It might mediate and manipulate reality through head-mounted or wearable technologies (Mann et al., 2018). Using a camera view or a smartphone, AR may easily merge the actual environment with virtual items. So that both the actual and

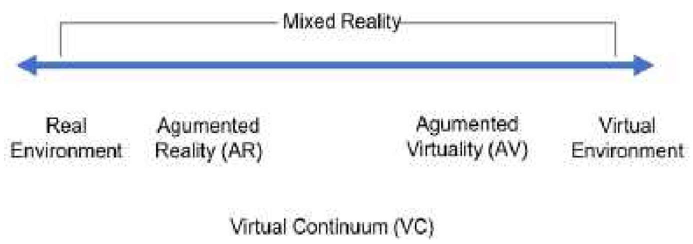

Figure 2. Simplified representation of a "virtuality continuum" (Milgram & Kishino, 1994)

virtual worlds may be experienced concurrently, computer-generated material is added to or integrated inside the real world (Dunleavy & Dede, 2014; Izzaty et al., 2019).

AR can serve as an interactive medium with computer-generated elements that display 2D visuals, 3D models, or VDO experiences over the learners' vision of the actual world, according to a broad perspective of AR technology (Jasche et al., 2021). AR is primarily divided into two types based on its technological characteristics: marker-based AR and markerless AR. AR may be divided into four categories under the markerless category: location-based AR, projection-based AR, superimposition/overlay AR, and outlining/contour AR (da Silva et al., 2019; Jasche et al., 2021). Location-based AR merges smart device location capabilities and GPS to overlay pertinent information on the screen. In a physical setting, projection-based AR puts digital representations onto actual things. Superimposition AR imposes a partial or complete replacement of an object's initial view with an updated, augmented view of that object, as many perspectives or more pertinent information of the target item. Outlining/contour AR provides outlining of objects such as limits and lines (da Silva et al., 2019; Dunleavy & Dede, 2014; Jasche et al., 2021).

Regarding AR in education, the New Media Consortium (NMC) announced at the early 2017 horizon in K-12 that Nordic schools have prioritized MR, which includes virtual reality and AR (Cheng, 2016). The collaboration recommended research in AR to promote educational comprehension and application (Dunleavy et al., 2009) and to ensure the appropriate use of technology in K-12 settings (Radu, 2012). A survey of studies conducted between 2017 and 2019 identified four classes of educational AR applications:

(1) discovery-based learning (DBL), providing additional real-world places such as museums, astronomical education, and historical sites,

(2) object modelling (OM), providing different viewpoints of an object illustrated in 2D for specific tasks or skills visually trained as hardware and mechanical maintenance, which drastically reduces operating costs,

(3) psychological learning outcomes, including learners' state of mind, motivation, engagement, concentration, and satisfies learners' needs, and

(4) game-based learning (GBL), which elevates to another level of engagement by significantly bringing 2D objects to life in the archaeology, history, anthropology, and geography disciplines (Majeed & Ali, 2020).

In addition, comprehensive literature reviews of 45 publications published between 2009 and 2017 and indexed by the IEEE, ACM, and ScienceDirect databases have been done on the potential educational use of AR. More than 50% of the research examined the effect of AR on knowledge retention or performance, with 50% examining its utility. These studies also discovered that basic AR book apps increase student motivation, engagement, and satisfaction. Several research examined the impact of AR on academic success. AR decreases mental load and aids in knowledge retention, hence facilitating cognitive activities in higher-order thinking, such as analysis and critical thinking (da Silva et al., 2019).

AR also contributes to the student-centered idea of collaborative learning by enhancing the visual attractiveness and interactivity of learner presentations. For example, mobile augmented reality (MAR) installs a camera phone that enables learners to gather pertinent information from paper and transform it into interactive LXs. The selection and design of significant multimedia superimposed on real-world items add to the learning process and serve as expanded material to speed, prompt, and stimulate the LX. Reading with images and sounds increases language abilities, according to research and practice (Braud et al., 2020).

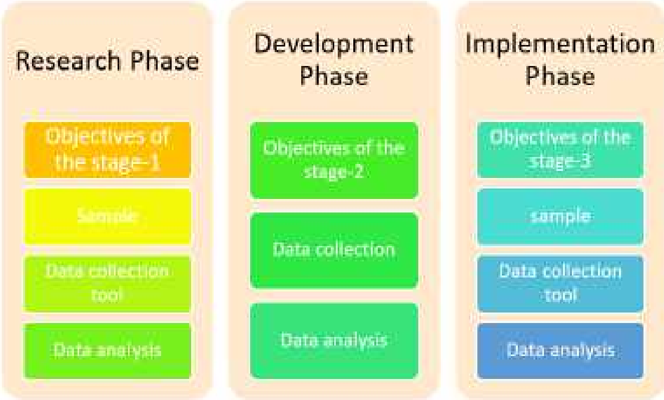

Figure 3. Research and development process (Source: Authors' own elaboration)

According to the findings of the aforementioned studies, it has been determined that AR is applied in the field of education for a variety of subjects and functions. According to the findings of this research, AR technologies have the potential to improve pupils' reading abilities. The primary objectives of this research are to create an AR-reading platform that is suitable for this purpose, and to investigate the degree to which it is effective. Essentially, the study will strive to address the following research questions:

1. What are the experts' suggestions for creating the conceptual basis of the AR-reading platform:
    a. words to be taught,
    b. activities to be used, and
    c. what are the teaching approaches to be used in the implementation process?
2. Comparing the features of the top-ten Thai reading apps.
3. What is the effect of the AR-reading platform on the reading skills of third-grade students?

METHODOLOGY

This study uses an approach known as research design (R&D), to analyze the views of learners on an educational product or process that was designed and then put into practice. An AR-reading platform is going to be developed as part of this research project. Components of this platform will include an AR application, multimedia worksheets, and an analytical learning system. A cycle of research and development may be thought of as having three distinct phases (as shown in **Figure 3**).

Research Phase

The primary objective of this stage is to establish a conceptual framework and data gathering procedure based on professional perspectives on the materials and procedures planned for use in the model's development.

AR-reading platform's conceptual architecture included a series of worksheets supported by multimedia and an AR application for reading practices. The AR-reading platform design is then decided as an algorithm of an analytic learning system so that reading activity data may be gathered and processed. Individual pupils are assigned reading lists that are appropriate for them.

There are four primary data gathering processes during this phase:

1. theories and best practices in Thai education,
2. available features of the top-ten Thai reading apps,
3. in-depth interviews with 21 Thai teaching and instructional technology experts about the AR-reading platform design, and
4. focus group with experts for the storyboard/blueprint of the AR-reading platform, which includes reading worksheets, an AR application with augmented multi-media design, and an analytic learning system.

Table 1. Skewness and kurtosis of the measurements

	Skewness			Kurtosis		
	Value	SE	Zs	Value	SE	Zk
Read aloud 1	-0.07	0.41	-0.17	-1.39	0.81	-1.72
Read aloud 2	0.02	0.41	0.06	-0.08	0.81	-0.10
Reading comprehension 1	-0.45	0.41	-1.09	-0.76	0.81	-0.94
Reading comprehension 2	-0.69	0.41	-1.66	0.09	0.81	0.12

For the data analysis, subject matter experts examined the instruments for the quality of reading exercises and test items, assigning validity ratings that measure certain characteristics. Validation by professionals utilizing the item objective congruence (IOC) metric yielded reading scores.

Development Phase

The primary goal of this phase is to build software based on the AR-reading platform blueprint. It is also the stage of technological progress. During this stage, the LX and learning interface (LI) are also designed.

The alpha-test was administered to a group of 20 third-grade pupils as part of the data collection process. The application's technical difficulties have been identified. It was established what the students' general experiences with the application were. In addition, the application was required to analyze characteristics such as font size, sound quality, text appropriateness, and animation clarity.

At this point in the data analysis, the general perspectives of the students were examined as content.

Implementation Phase

This phase's purpose is to assess the effectiveness of the AR-reading platform on student reading. The researcher utilized a strategy of selective sampling from schools provided by the National Testing Committee to represent the average range of top and lowest reading performance scores in the Central and Northeastern regions of Thailand. The volunteer sampling group of 126 students from four classrooms at two schools utilized the AR-reading platform for roughly 30-minute sessions daily in class or beyond regular school hours for six weeks. 91 out of 126 students sat the placement examination. 32 of the 91 pupils who took the exam were included in the therapy procedure because they were unable to acquire satisfactory results. These 32 students' exam scores form the basis of the study's data.

In the data analysis, comparisons were done between the students' pre- and post-test performance in reading aloud and reading comprehension. Prior to the inferential analysis, the normal distribution of the measurements was calculated. To maintain the normal distribution, the skewness and kurtosis values were analyzed. According to Kim (2013), if absolute z-scores for either skewness or kurtosis are greater than 1.96 for small samples ($n<50$), then reject the null hypothesis and conclude that the sample distribution is non-normal. On the basis of **Table 1**'s data, it is presumed that the measurements follow a normal distribution. For statistical analysis, the paired sample t-test was used.

RESULTS

Part I: The Research (R1): Survey, Interview, and Focus Group for the AR-Reading Platform Working Concept

The data obtained as a result of working with the experts were presented as a whole.

1. In general, the reading-aloud strategy is used to promote phonemics and word identification in Thai reading education. By reading from a traditional Thai book, the reader must comprehend both the explicit and implicit meanings of each sentence.
2. The top-ten media for teaching Thai, mostly for Thai language learners. The YouTube channel only features a small number of teaching resources created by Thai language instructors. The teaching method used in the media was similar to the one used in the classroom; it gave pupils the opportunity to practice and repeat the right pronunciation at their own paces. The majority of interactive self-learning programs are available on standalone, for-profit DVDs.

3. The working concept of the AR-reading platform, which consists of five crucial components, was agreed upon by the expert focus group:
   - The required Thai vocabulary for third grade includes 36 subtopics with 30 words each, for a total of nine main categories and 1,080 words.
   - The AR worksheets that may be compiled into a book and made available in print or electronic form are the reading exercises. Reading aloud and reading comprehension are the two primary divisions of the learning activities. The reading-aloud practice offers key words derived from each student's pre-reading assessments. The read-aloud session's word list serves as a guide for the stories that will be read. Each reading story is accompanied by one or two insightful images.
   - The multimedia component displays 2D, 3D, animation, still images, visual graphics, and visual effects in accordance with how readable the provided word drills are. In "view master" mode, the multimedia shows a trio of panels painting cartoons. In each section, students engage in virtual push and click interactions. This activity, which is based on behaviorist theory, encourages students to recall knowledge and identify ideas through cues given during the exercise.
   - The worksheets/books in the multimedia material are extended by the AR application over the actual worksheets/books. Motion graphics are used in the reading-aloud activity to highlight visual components, and music is used to inspire children to practice lists of active words with phonics and meaning. Use the AR program to project images onto the worksheet or page in the book to aid in reading comprehension. When the text and static images become animated, they direct students to a three-panel cartoon drawing that serves as a "view master" and (i) follows a timeline, (ii) enables students to get a closer look at the environment and objects, and (iii) starts simulated situations in which students interact with the virtual environment based on the context in the reading.
   - The algorithm used by the learning analytics software to assess and control the learning process determines the learner's reading proficiency before the learning process even begins. For instance, the algorithm analyzes and transforms information such as learner interactions, reading speed, quiz scores, and mistake counts into input data. The formula and quantitative assessment are used by the algorithm to determine, which treatments best fit the learners' capacity to reach the goal reading competency. In order to precisely track each learner's demands and follow their progress as readers, the quantitative measure of learners' reading ability should be provided as chart.
4. The reading resources for the third grade in Thailand include phonics and reading comprehension and include nine categories and 1,080 words of Thai index vocabulary. The worksheets are automatically generated by the system and are available for printing or reading online. For the program's words and storylines, the acceptable IOC of the 21 expert judgments is.85.

The AR-reading platform presented in this design study is built on a cognitive process that links words, pictures, sounds, and made-up scenarios under the PWIM. Additionally, the teaching approach made use of precision instruction (PI), a repeated method that helps students organize their cognitive model. **Figure 4**'s conceptual representation of the platform shows how phonics and understanding may be improved through the AR-reading platform with PWIM, which also includes interactive multimedia and narratives similar to those found in view-master reels. When students read and interact with the application, precise education takes place, and the recorded learning is shown in chart style. By creating a schema through an images mental model, the reading ability is accomplished.

Part 2: The Design and Development

Working concept model of AR-reading platform

This research uses a learning design of AR that follows the PWIM and has animated visuals of words that are coordinated with sound. The cognitive schema and concept model are both theoretical concepts that form the basis of this research. Aside from the words and sound, a cartoon scenario delivers a tale in a view-master form, so establishing a mental model in a student's mind that represents the fictitious circumstance. Students are presented with an advanced mental image in three different formats thanks to the learning media: chronological visual components, object exploration and explanation, and numerical tasks. Because of this,

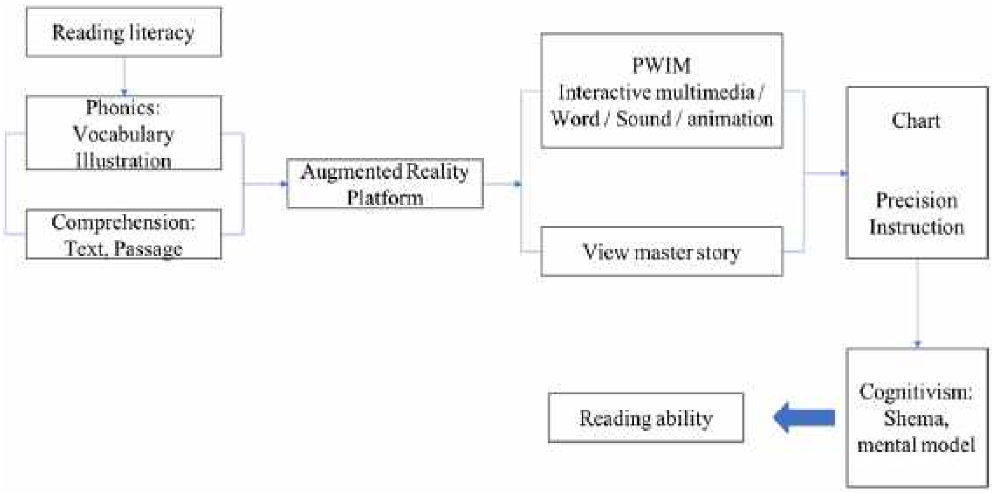

Figure 4. Conceptual framework for AR-platform (Source: Authors' own elaboration)

the reading is transformed into a tangible and vivid tale, which assists young students in committing a new word and its context to their long-term memory. For the purpose of learning retention, students engage in a series of carefully planned tasks that involve drilling and repeated repetition.

These learning strategies interact effectively with the learning analytics platform, which produces practice sessions that are tailored to an individual's reading profile. The system is designed to assist students who have issues studying and provides sources of knowledge that are matched to each student's profile. The analytical platform is responsible for delivering the learning activities and collecting the learning data that functions as a remedial mechanism, electronically prescribing content to an individual student in a manner that is precisely similar to the nature of direct instruction in order to improve reading ability. Therefore, mastery learning is an essential component in the process of keeping students interested in the process of cognitive building, which begins with the abstraction of words and the creation of meaningful visuals and progresses progressively toward the formation of a mental model.

Learning experience and interface design

Students must log in to identify themselves and create profiles before the LX via an LI design can begin. The profile includes the essential academic data, such as instructors and parents who will encourage reading and have the power to keep track of students' academic development. A 30-minute pre-reading exam evaluates reading proficiency and identifies reading levels and areas that need improvement.

After registering for the learning system, each student is given a pre-reading to complete with the guidance of their guardians, parents, or tutors. The assigned reading material aims to screen students' reading ability and divides them into three reading proficiency levels. It then presents a set of individual reading tasks that are randomly chosen from nine categories and 1,080 words from the Thai index vocabulary in the phonics and meaning comprehension sections. There are stories about the words in the individualized phonic exercise that follows. Students are instructed to go through the prescribed worksheets either printed out or read from a digital screen display as part of the pre-reading from the diagnostic learning system.

Once students (or teachers) or parents (or both) download the reading AR application, the program directs pupils to complete the prescribed worksheets or book pages that provide them access to the interactive learning resources. Motion graphics, together with the word, spelling, and sound for learners, appear animated on the screen as they lie over the image on the website as students point the camera toward the photos on the page.

For the reading comprehension portion, a cover-story image links to an overview animated tale that is delivered frame by frame. When ready, the students read the book and respond to inquiries regarding the narrative. The data from and to the AR application that overlays a specific word or image on the page is received and sent by the AR-reading platform. After then, the platform creates a person's unique Chart based on their mastery of the accuracy of teaching at that particular moment. Finally, the analysis of learning data directs students to advance to the subsequent level or remain for continued practice.

Table 2. Results of the reading screening test

Number of students from two regions	Reading aloud (pronunciation)		Reading comprehension		Total screen test		Participate in remediation program
	Fail	Pass	Fail	Pass	Total	Pass	
Central	3	55	3	55	58	55	3
Northeastern	15	18	29	4	33	4	29
Total students	18		32		91	59	32

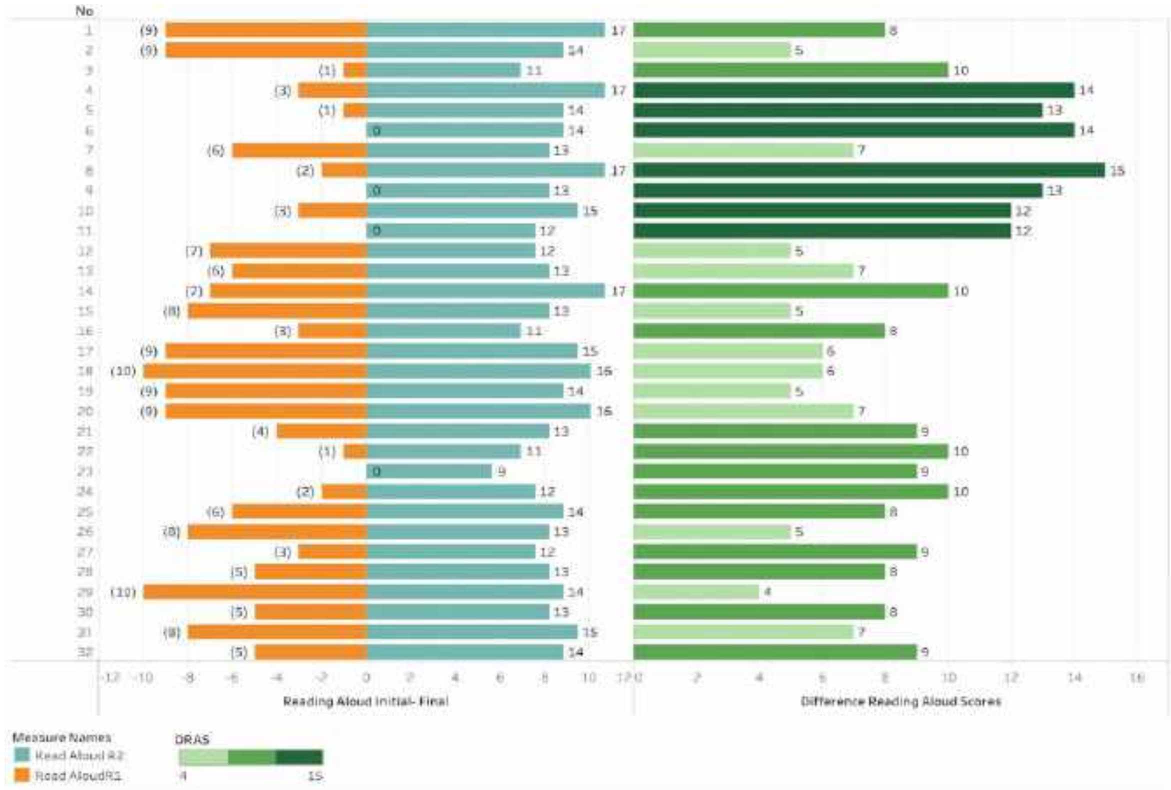

Figure 5. Pre-post reading aloud test score for each student (Source: Authors' own elaboration)

The technical development

The platform consists of four main technological components: (i) a database constructed with PHP and JavaScript, (ii) authoring tools for 2D and 3D media created with Unity, (iii) marker-based tracking with Vuforia, and (iv) worksheets with pages that have been registered as markers.

The worksheets might be read digitally or combined into a book. A set of 20 third-grade pupils were given the alpha exam. Technical issues with the reading worksheets' suitable size, the sound quality, and the media area layered on top of the text were the main causes of the revisions. The creation of this stage, the so-called Beta version, assures the first-run performance following the technological improvements.

Part 3: The Effect of the AR-Reading Platform on Students' Reading Ability

Thailand's Central and Northeastern areas provided the sample population for analyzing the platform's effects (**Table 2**). 58 kids from central region schools took the reading screen exam. The pre-reading test found just three kids with poor scores who need a reading improvement program, whereas 55 pupils were in the reading group with the highest results. 33 kids from schools in the Northeastern area took the reading exam; 29 students required to improve their reading skills. 33 children have consented to engage in the AR-reading platform initiative. Students participated in the program either during or after academic hours for six weeks. On the platform, both the reading performance and the post-test were recorded.

Reading aloud test

Figure 5 displays the reading-aloud test results of 32 kids who participated in the research.

Table 3. t-test results according to read aloud pre-post test

Test	n	Mean	SD	t	df	p	Cohen's d
Read aloud 1	32	4.97	3.36	-16.3	31	<.001	-2.89
Read aloud 2	32	13.66	1.96				

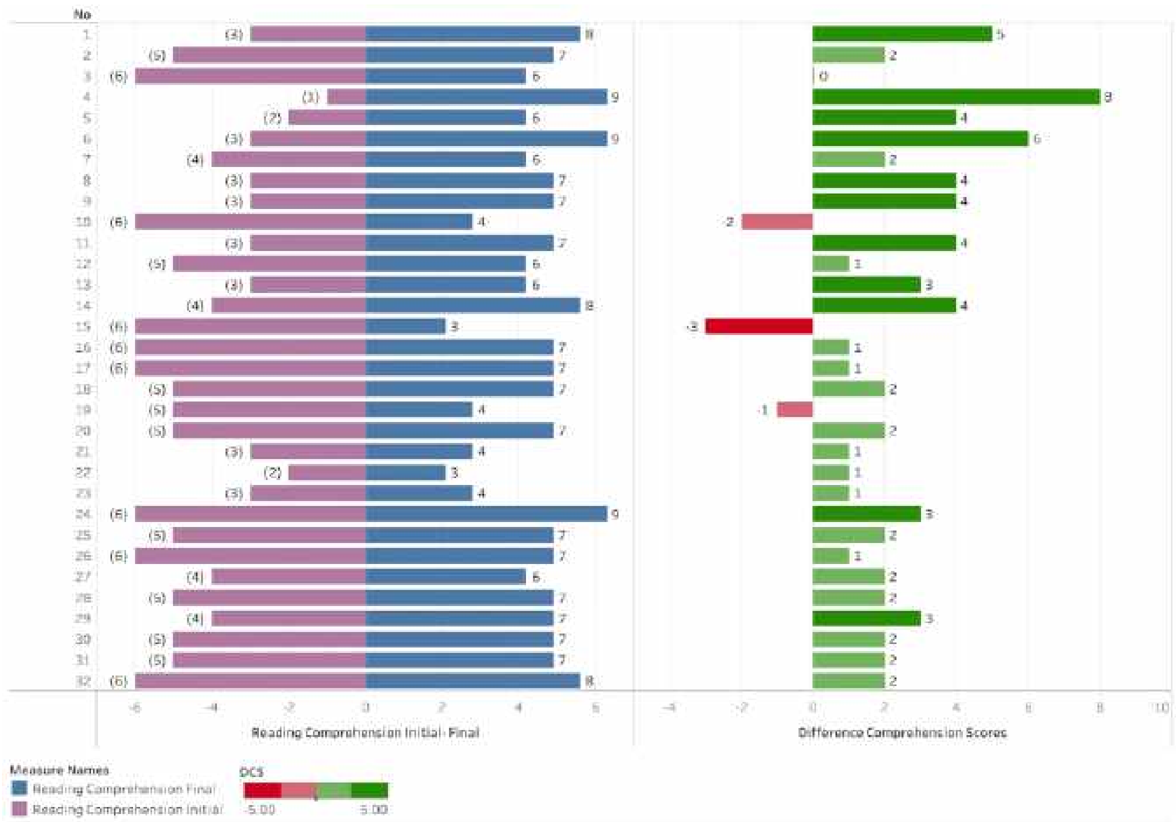

Figure 6. Pre-post reading comprehension test score for each student (Source: Authors' own elaboration)

They were required to read a total of 20 words. The scores in the first graph represent the number of properly read words by pupils. For instance, the fifth student on the pre-test could not read a single word properly and received no points. On the post-test, he was able to correctly read 14 words. Number 18 is one of the students with the highest score on the pre-test. While there are 10 accurate reading-aloud responses on the first exam, there are 16 on the final exam. The highest score on the post-test was 17 points. The second graph depicts the pupils' success based on the most recent and initial measures. The achievement is worth between four and 17 points. In the reading-aloud test, every student demonstrated growth. In order to ascertain whether or not the development is statistically significant, a paired sample t-test was carried out (**Table 3**).

While the average of the students was 4.97 on the pre-test, it was 13.66 on the final measurement. The difference between the means was 8.69. According to the results of the paired t-test ($t=-16.3$ and $p<0.001$), the difference between the post-test and the pre-test is statistically significant. In other words, students' post-test performance is higher than in the pre-test. In addition, Cohen's d is calculated to calculate the effect size. Since the absolute value of d is greater than 0.8, it has a large effect size.

The students' reading comprehension test results are presented in **Figure 6**. In the first graph, students' pre-test performances and post-test performances are given together. When the pre-test performances are examined, the scores of the students vary between one and six points. Their post-test performances range from three points to nine points. In the second graph, the difference between the last performance and the first performance of the students is graphed. Three of the students got a lower score than their first performance. On the other hand, positive improvement was recorded between one and eight points. In general, it can be said that there is a progress record. Paired sample t-test was performed to determine whether the differentiation was statistically significant (**Table 4**).

Table 4. Paired-sample t-test results according to reading comprehension pre-post test

Test	n	Mean	SD	t	df	p	Cohen's d
Reading comprehension 1	32	4.31	1.42	-5.66	31	<.001	-1.00
Reading comprehension 1	32	6.47	1.61				

While the average of the students' reading comprehension test was 4.31 in the first measurement, it was 6.47 in the last measurement. There was an improvement of 2.16 points between measurements. According to the paired t-test result (t=-5.66 and p<0.001), the difference between the last measurement and the first measure is statistically significant. In other words, students' reading comprehension skills have improved. Cohen's d was calculated to determine the effect size. Since the absolute value of Cohen's d is greater than 0.8, it can be expressed as a large effect size.

DISCUSSION

The key aims of this study are to develop an AR-reading platform suitable for enhancing students' reading skills and to assess the platform's efficacy. In line with the recommendations of the experts, the PWIM approach was used. Precision teaching was preferred as the teaching approach. In vocabulary teaching, reading-aloud and RR strategies were used. The PWIM instructional method utilizes images as a trigger for language experience tasks (Joyce & Weil, 2004). PWIM has been utilized successfully in both L1 (Triwahyuni et al., 2020) and L2 (Gu & Lornklang, 2021; Jiang, 2018; Lee et al., 2019) instruction, particularly with lower age groups (Calhoun, 1999). In AR-reading platforms (Wahyuni et al., 2020), the PWIM teaching approach is preferred for vocabulary instruction.

Precision teaching has been used effectively in the development of students in teaching because it provides performance-based measurement (Gist & Bulla, 2022). In this way, it was possible to follow the progress of the students individually. Precision teaching is also used for teaching vocabulary (Mannion & Griffin, 2018; Martinho et al., 2022). Precision teaching is used effectively on some AR-reading platforms (Wang, 2021; Y. Wu et al., 2019). Reading aloud and RR are the preferred strategies for teaching vocabulary in both electronic especially AR (Alqahtani, 2020; Santosa et al., 2021; Yuan, 2021) and non-electronical sources (Ardoin et al., 2013; Triwahyuni et al., 2020; Urquhart & Weir, 1998).

The word groups, pictures, and animations to be taught should be suitable for the level of the student. Necessary improvements were made with the opinions of the experts and the feedback obtained in the alpha version. The intrinsic properties of AR, including direct interaction, virtual and 3D aspects, and the mixing of 3D virtual elements with real-world elements (Kesim & Ozarslan, 2012; Redondo et al., 2014). According to Santosa et al. (2021), word frequency and word-building capacity are key criteria in the standard vocabulary selection on AR data.

The effect of AR-reading platform on students' reading skills was discussed in two dimensions. The first is the correct reading of the words. According to the experimental study results, students' post-reading scores are higher than their first-reading scores. In the second dimension, reading comprehension competencies were measured. The improvement in students' reading comprehension proficiency is also statistically significant. There are studies in which AR-reading platform is used to improve students' reading skills and the results are effective (Cheng, 2016; Jamshidifarsani et al., 2019; Majeed & Ali, 2020; Wahyuni et al., 2020; P. Wu et al., 2018).

CONCLUSION

The primary objectives of this research are to (i) design an AR-reading platform that is appropriate for improving students' reading skills and (ii) evaluate the effectiveness of the platform. The PWIM strategy was implemented as a result of the recommendations made by the professionals. The method of instruction known as precision teaching was the one that was favored. Reading aloud and RR were two of the tactics utilized in the process of teaching vocabulary. The results of the experimental investigation indicate that the students' scores after finishing the reading are higher than the scores they received after the first reading.

Reading comprehension skills were evaluated according to the second factor of the study. The pupils' overall comprehension of what they are reading has also significantly improved.

It is recommended that educators who are interested in using the AR-reading platform utilize the application on a consistent basis. It is recommended that researchers who wish to establish an AR-reading platform first determine the demands of the target audience, and then carry out the development process together with field experts after the needs have been determined. In the future, researchers will be able to construct studies that can leverage this already developed platform with a variety of student populations. In addition, the execution of longitudinal research will provide a lot of information regarding the efficiency of the platform. The fact that just a limited number of people participated in the study is the primary drawback of the investigation. The data were acquired through a quasi-experimental approach, which is another drawback of the research.

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