SHORT-PAPER

Game-based Augmented Reality Mobile Application for Enhancing Primary School Students' Collaborative Learning in English as a Foreign Language in Cambodia

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Abstract

This study explores the effectiveness of a game-based Augmented Reality (AR) mobile application in enhancing collaborative learning and English as a Foreign Language (EFL) acquisition among primary students in Cambodia. While the benefits of AR in primary EFL education are known, limited attention has been given to game-based, movement-driven AR in low-resource settings. To address this, the first author developed an AR mobile application using Unity Engine, embedding vocabulary and directional tasks in an interactive environment that promotes physical movement and teamwork. The user study was conducted in a Cambodian primary school with limited-resource settings. Data from English tests, teacher and observer questionnaires, and the first author's observations evaluated language development, collaboration, and engagement. Findings revealed the AR tool improved student engagement, collaboration, and English proficiency, despite some technical challenges. Overall, game-based AR mobile applications show promise as accessible tools for inclusive primary EFL education in low-resource settings like Cambodia.

CCS Concepts

• **Applied computing → Interactive learning environments**; • **Human-centered computing → Mixed / augmented reality**.

Keywords

augmented Reality, gamification, English as a Foreign Language, collaborative learning, low-resource settings, primary education

1 Introduction

English remains one of the world's most widely spoken international languages, with over 1.5 billion users [52]. The context for learning English differs depending on whether it is taught as a Second Language (ESL) or a Foreign Language (EFL). ESL is taught in English-speaking nations like Australia, where students have access to English outside class. In contrast, EFL is taught in non-English-native countries, like Cambodia, where exposure outside the classroom is limited [48]. Teaching approaches must adapt to ESL and EFL [57].

Augmented Reality (AR) has developed as a tool that overlays virtual elements onto the real world, creating new opportunities in education [43]. While research shows AR can enhance English learning, most focus on non-game-based or non-movement AR applications in high-resource environments, which limits adoption in low-resource schools facing financial, curricular, and teacher training challenges [33, 49, 71]. However, mobile AR technology can be affordable and effective without advanced hardware [40, 55].

This study explores a game-based AR mobile application developed using a free version of Unity Engine[1] to support EFL classes and collaborative learning among Cambodian primary students with limited resources, like digital infrastructure, funding, and qualified teachers. The application integrates vocabulary learning with physical movement, teamwork, and directional language practices. The effectiveness was evaluated through English vocabulary tests, observer and teacher questionnaires, and researcher observations. Results indicate the AR application improved student engagement, teamwork, self directed learning, and English proficiency. Some technological and usability challenges were also observed, offering insights for future development. This study demonstrates how

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[1]Unity Engine is a game and app development software engine that enables developers to build 2D and 3D experiences and deploy them on any platform [64].

AR mobile applications can enhance primary EFL education in low-resource settings.

2 Literature Review

2.1 The role of primary EFL education

English proficiency enables young learners to communicate across languages, appreciate cultural diversity, develop empathy, and global awareness [69]. Children under 12 acquire a second or foreign language more effectively than older learners, motivating many countries to integrate English education at the primary level [16, 70].

However, challenges remain in the Association of Southeast Asian Nations (ASEAN) [2], where teacher competency and training remain major concerns [17, 45]. In Cambodia, English has been taught since grade 5 [44] and supported by government internationalisation policies [37, 42]. Despite these efforts, shortages of qualified teachers, textbooks, and materials persist, especially in rural areas [50]. Consequently, Cambodia remains in the low proficiency category with a score of 408 out of 800 [14].

2.2 Collaborative learning in primary EFL education

Collaboration in EFL enhances engagement and language acquisition by sharing knowledge, engaging with diverse perspectives, and working effectively in group settings, abilities that mirror real-world cross-functional teamwork [66, 67]. Furthermore, it contributes to improving writing performance, grammatical accuracy, and syntactic complexity [32].

Inter-group competition through games can help primary students with low scores improve their English abilities and creative thinking by gamification elements like scoring and rankings, which stimulate competition and engagement [4, 29, 35]. However, competitive elements may discourage some students who lack self-confidence and feel pressured, so traditional learning remains important for sustained improvement [39, 68].

2.3 Technology in EFL

Successful primary EFL education depends on parental involvement, teacher competence, and a supportive learning environment [53]. While traditional classroom methods remain the foundation, e-learning platforms like the iPad-based iTEO application enhance engagement through collaborative activities, vocabulary and oral practice [36]. In Cambodia, smartphones and iPads are widely used and easy to operate, making them more accessible and affordable than other educational technologies.

AR can enhance student engagement, motivation, and retention compared to traditional e-learning by providing interactivity, immersion, and multisensory experience [2, 34]. AR, which overlays virtual elements onto the real world, is more practical and affordable, especially in low-resource settings [19, 72].

2.4 AR in EFL education

AR-based English education can improve test performance for students in Grade 4 and above by providing logical reasoning, deeper

interaction, and real-time feedback [10, 46, 56]. This highlights AR's potential to offer more interactive, engaging experiences for primary-level language learning.

AR has potential in enhancing primary EFL education, particularly in vocabulary acquisition and comprehension through immersive and engaging environments [8]. Studies show AR impacts various language skills, including writing, reading, vocabulary, and question-answering, with limited impact on grammar and listening skills [5, 28, 54]. Gamified AR applications, MOW (Matching Objects and Words) game and AR 3D Pop-Up Book, significantly improved motivation, engagement, and comprehension among primary school students [6, 65]. Students using the AR application performed nearly twice as well as those who did not with the AR application [26]. However, overuse can lead to cognitive overload and reduce concentration, highlighting the need for careful design through collaboration among teachers, students, and designers [11, 62].

AR also enhances collaborative learning by providing discussion, idea exchange, and peer support, often more effectively than traditional methods in early childhood and higher-level EFL education [3, 7, 41, 51].

2.5 Research gaps and opportunities

AR mobile applications provide an effective solution for educational use, as they require minimal training and are compatible with widely available devices such as smartphones and iPads [12]. Despite the growing number of AR mobile applications for EFL, few studies have examined their use in low-resource educational settings, leaving this area largely unexplored.

AR is an ideal educational tool for low-resource settings due to its capacity to offer real-time feedback and the relatively low cost of AR mobile applications. Consequently, AR apps may help bridge educational gaps in Cambodia. Further research is essential to explore AR implementation and effectiveness. This study aims to evaluate the effectiveness of a game-based AR app by designing one that incorporates movement-based interaction and collaborative learning in low-resource settings.

3 "Where shall I go?" Game-based AR mobile application design

3.1 Purpose and pedagogical rationale

In this study, a game-based AR mobile application titled *"Where shall I go?"* was developed using the Unity Engine to enhance the English vocabulary, listening, speaking, and collaborative skills of students in grades 4 to 6 (typically aged 9–12 [18, 30]). This application serves as a complementary tool rather than replacing traditional teaching methods by providing output-focused practice following teacher-led classroom activities. Integrating traditional instruction with game-based AR approaches is considered most effective for enhancing student engagement [39, 68]. Therefore, the goal is to support and enrich local teachers and the existing educational environment [31, 63].

Unlike typical seated activities or QR-code-triggered AR, this application uses physical movement to activate AR content, creating more engaging and immersive learning experiences, especially for

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low-knowledge learners [9]. Inspired by the popular AR game *Poké-mon Go* [47], it aims to enhance student engagement and English acquisition through active physical involvement.

3.2 Game setup

The AR mobile application consists of ten 3D objects: koala, kanga-roo, dance, apple, talk, balloon, cake, dress, car, and Watty[3]. The 3D objects were obtained from freely available online repositories[4]. They arranged in a circular pattern around students in the AR environment. This spatial configuration exists only in the AR environment and is visible through the application when students hold up their phones; no physical objects are present in the real-world environment.

Before using the application, students are expected to learn the ten 3D objects English vocabulary and four basic directional phrases: "turn left", "turn right", "go straight", "go back", selected from Cambodian English textbooks for grades 4 and 7 [13, 15]. Since the application is targeted to grades 4 to 6, the list combines familiar words from Grade 4 to maintain motivation and more challenging words from grade 7 to encourage vocabulary growth.

Figure 1: "Where shall I go?" game-based AR mobile application Unity

3.3 Team structure and roles

The AR mobile application is designed for collaboration by teachers and students. Students are grouped into teams of at least two members. Each team is assigned two roles: explorers and guides. The role of teachers is to show the written English word card that students must locate in the AR environment. The guides are responsible for listening to the teacher, understanding the English vocabulary word, identifying the matched 3D object in the AR environment while holding up their phones, and giving verbal directions for the explorers. The explorers must listen and follow the directions from the guides.

3.4 Game rules

To ensure a smooth and effective experiment, four rules are established:

(1) Guides must not physically touch the explorers.
(2) Guides must not walk faster than the explorers.
(3) Explorers must not use or look at phones.
(4) All communication must be in English.

3.5 Game procedure

Once all teams are ready, the explorers position themselves at the front, with the guides standing behind the explorers. Hence, the guides launch the AR mobile application using their phones. The teachers present an English word card, prompting the start of the game. Figure 2 illustrates the interaction between students and teachers throughout the game procedure when using the application.

In this activity, guides identify the target 3D object in the AR environment and direct the explorer to navigate toward it. When the explorer reaches the object, the guide selects it on their phone. If the selected object matches the teachers' English word, the AR application displays a green check icon and a confirmation feedback (Figure 3), and earns one point. An incorrect object triggers a red cross icon and error sound (Figure 3).

1. Launch the AR mobile application   2. Teachers present an English word card

3. Identify the target 3D object

4. Navigate a explorer to the target 3D object   5. Goal! Next game!

Figure 2: Storyboard demonstrating how students and teachers play their roles in the AR mobile application "Where shall I go?"

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[3]Watty is a national character inspired by Angkor Wat, a UNESCO World Heritage Site in Cambodia. The character is frequently featured in many public broadcasts and educational content on Cambodian national television [59].
[4]All 3D models were downloaded from free resources such as Sketchfab[58].

Figure 3: Correct effect (left) and Incorrect effect (right)

4 Methodology

4.1 Study aims

This user study aims to observe how the game-based AR mobile application titled "Where shall I go?", developed for this research, enhances collaboration and participation among grade 4 to 6 EFL students in Cambodia. This grade range was selected based on previous research highlighting AR effectiveness from grade 4 [56]. The primary objective is to evaluate the AR's role in promoting collaborative learning in low-resource primary EFL classes during a 1-hour EFL lesson.

Prior literature shows that collaborative learning enhances engagement and language acquisition in primary EFL education [66, 67]. Hence, AR can improve vocabulary, comprehension, and motivation [2, 32, 34]. This study focuses on the combined effect of collaboration and movement on learning outcomes in EFL education in Cambodia.

The main research question is: **"Can game-based AR mobile applications enhance collaborative learning in traditional primary EFL classes?"** Success was defined by observable indicators of collaboration: team communication, joint problem-solving, and mutual correction of errors. Collaborative learning was considered enhanced when students actively interacted and supported each other to complete tasks without teacher guidance, as reported by the local teacher, observers, and the researcher.

The secondary research question is: **"How might game-based AR mobile applications contribute to improving English proficiency in primary education as part of EFL learning?"** Success was measured using pre- and post-tests: vocabulary acquisition and comprehension were assessed through performance in movement-based AR activities, including identifying objects, following instructions, and completing tasks using the AR mobile application.

4.2 Participants

This user study was conducted at Ai Center, an NGO school in Phnom Penh, addressing limited Cambodian public school hours [1]. Five grade 4–6 EFL students with no prior AR or private tutoring experience, one teacher, and three observers participated. The teacher, a university student, had no formal teaching qualifications or AR experience. Observers monitored lesson delivery and collected data on student engagement and AR usage. One observer was a former primary teacher from Japan, and two had AR and teaching experience through Social Compass workshops.

4.3 User study

This user study was conducted for 1 hour and was facilitated by the teacher. The teacher also provided interpretation when necessary to support comprehension and participation due to the language barrier.

Phase 1: Pre test Students were assessed on the ten key English vocabulary words and four basic directional phrases introduced earlier, using a PowerPoint presentation (see Appendix A). Each word was displayed, and students raised their hands or provided verbal directions in English to demonstrate reading, listening and speaking.

Phase 2: Traditional EFL class A 15-minute traditional EFL class was conducted to teach relevant vocabulary and expressions related to giving directions.

Phase 3: Post test after EFL class An English test identical to Phase 1 assessed their ability to apply the directional phrases in a practical context.

Phase 4: AR mobile application "Where shall I go?" Students played the *"Where Shall I Go?"* AR app following the previously introduced instructions. Two smartphones with the application were provided. The game had five rounds targeting: *koala, dress, dance, apple,* and *talk.*

Phase 5: Post test after AR mobile application An English test identical to Phases 1 and 3 assessed changes in the students' English proficiency.

4.4 Data collection

Data was collected through classroom observations of the five students and questionnaires completed by one local teacher and three observers through Microsoft Forms (see Appendix B and Appendix C). The participants offered insights into student engagement, collaboration, and their evaluations of the AR application during the EFL class. In addition, results from the three English tests were used to assess changes in students' language proficiency.

4.5 Data analysis

Data from the three English tests and multiple-choice questionnaires were analysed quantitatively by calculating correct answer rates and selection percentages. The open-ended questionnaires and the researcher's observations were analysed thematically. The analysis focused on student engagement, the AR application's impact on EFL learning collaboration, the potential of AR technology, challenges, and suggestions. This mixed methods approach combines qualitative and quantitative techniques to understand the AR application's impact on EFL learning and collaboration [27].

5 Results

5.1 English test

To evaluate the students' understanding of the target vocabulary and their ability to give directions, English tests were administered at three stages throughout the user study. In Test 1 (Phase 1: Pre traditional class), students demonstrated limited vocabulary knowledge, with an overall accuracy below 50%. The lowest accuracy rates were "kangaroo", "koala", "dress", and "talk", and no students could demonstrate giving directions.

In Test 2 (Phase 3: Post traditional class), some vocabulary items improved, like "go straight", "go back", and "balloon" were answered correctly by all students. The four lowest vocabulary items from Test 1 also improved, with 2-3 additional students answering them correctly. However, the demonstration of giving directions remained absent. Overall accuracy increased from 45.33% in Test 1 to 77.33% in Test 2, reflecting the positive impact of traditional instruction (see Table 1).

In Test 3 (Phase 5: Post AR mobile application), a significant improvement was observed, with 98.67% vocabulary accuracy, and most students successfully provided directions in English. Most students confidently answered all questions in Test 3, while they were observed being hesitant and slower in responding during Tests 1 and 2.

Vocabulary	Test 1: Pre EFL class (n=5)	Test 2: Post EFL class (n=5)	Test 3: Post AR mobile application (n=5)
koala	0	2	5
dress	0	3	5
dance	2	5	5
apple	5	5	5
talk	0	3	5
car	5	5	5
kangaroo	1	2	5
cake	5	5	5
balloon	2	5	5
turn left	3	5	5
turn right	3	5	5
go straight	0	5	5
go back	0	5	5
stop	5	5	5
Demonstration of giving directions	0	0	4
Correct answer rate	45.33%	77.33%	98.67%

Table 1: English test results

5.2 Questionnaires for the local teacher

The local teacher's questionnaire offered valuable insights into the usability of the AR application, its impact on EFL teaching, and student engagement (see Appendix B). Despite being their first experience with AR, they responded with a positive experience without suggesting improvement, indicating the application was easy to use, effective, and satisfactory.

5.2.1 Student engagement and English proficiency improvement. The teacher stated that students demonstrated active engagement while identifying 3D objects corresponding to English vocabulary through the AR environment. They strongly believed the application was interactive, engaging, and effective for teaching new vocabulary.

5.2.2 Support for self-directed learning and collaborative learning. The teacher observed that the application encouraged self directed learning, with students navigating tasks with minimal assistance. They also highlighted the application supported collaborative learning, adding educational value beyond individual instruction. They recommended using AR applications in other subjects due to their potential to enhance learning.

5.3 Questionnaires for observers

The questionnaire completed by three observers provided valuable insights into student engagement, interaction, and the overall impact of using the AR mobile application in primary EFL education (see Appendix C).

5.3.1 Student engagement and enjoyment. All observers reported that students were highly active and engaged while using the application. All agreed students enjoyed the experience, frequently displaying positive emotions. In the questionnaires, comments such as "They had fun" and "Their facial expressions showed they were enjoying themselves" were noted. All agreed that students understood how to use the application, though one observer was unsure whether it fully maintained student attention throughout the whole activity.

5.3.2 English proficiency improvement. Two observers noted that the AR mobile application contributed to improvements in the students' English proficiency, while one observer was unsure. All agreed that the application supported collaborative learning and could be beneficial in other subjects, and was more effective than traditional classes. One observer particularly appreciated combining physical activity with language acquisition, noting in the questionnaire that students could "learn new words while moving their bodies".

5.3.3 Challenges. One observer reported a spatial perception issue where an object appeared too far away to understand the distance. Another noted some students were initially confused by directional vocabulary like "turn left" and "turn right," as they had not fully memorised these terms. A safety concern was also raised, emphasising the importance of considering the physical environment since the application involves movement and immersion.

5.3.4 Recommendations. While one observer described the application as "an interesting approach with room for improvement" in the questionnaire, another suggested improving overall functionality. One observer proposed implementing features to support group play, like a referee system to monitor which group finds an object

first, allowing a single teacher to facilitate large groups more efficiently. They also suggested introducing different difficulty levels so students can progress after mastering beginner-level vocabulary.

5.4 Researcher observations

The first author observed students' actions and reactions throughout the user study. For example, Team A (two students) struggled to identify the "dress" object due to visual interference from the real-world environment like bicycles and scattered rubbish with the AR environment. The guide told the explorer to "turn left," but the explorer instead turned right, which highlighted a limited understanding of directional vocabulary. However, this presented a valuable opportunity for collaborative learning and improved communication.

Team B (three students) faced challenges with limited physical space. Some virtual elements were positioned beyond the physical boundaries, making them inaccessible. During the "dress" activity, the team initially selected an incorrect object but identified the correct one on their second attempt. The presence of two guides facilitated effective collaboration, enabling the students to use real-time feedback to correct their mistakes and complete the task independently of teacher support.

Many guides forgot to say "stop" when the explorer reached the AR object, which likely assumed the explorer could see the screen or recognise the goal. These experiences not only facilitated vocabulary acquisition but also fostered students' understanding of clear communication and teamwork.

6 Discussion

This study aimed to evaluate the effectiveness of a game-based AR mobile application in enhancing collaborative learning and student participation in EFL classes at primary school in a low-resource setting. Insights delivered from English test scores, teacher and observer questionnaires, and researcher field notes provide valuable evidence regarding the educational impact and implementation challenges associated with the application.

6.1 Answers to research questions

6.1.1 Can game-based AR mobile applications enhance collaborative learning in traditional primary EFL classes? The application significantly enhanced both collaborative and self-directed learning. Its interactive and gamified format encouraged required teamwork and verbal coordination during the guiding and exploration phases. For example, a misunderstanding in Team A between "turn left" and "turn right" led to peer correction and clarification, reinforcing directional vocabulary through shared experience. Similarly, Team B showed effective problem-solving during the "dress" object task, quickly communicating and adjusting after an initial error. The application's usability supported self-directed learning by enabling students to navigate tasks independently with minimal teacher support.

Physical movement enhanced collaboration through interaction with digital content and real-time communication, creating an immersive, socially engaging learning environment. Students often

expressed excitement, confidence, and enjoyment with deeper learning and increased motivation. In conclusion, the application effectively fostered collaboration, independence, and engagement, making it a valuable tool for enhancing primary EFL education in low-resource settings.

6.1.2 How might game-based AR mobile applications contribute to improving English proficiency in primary education as part of EFL learning? Pre-implementation test scores revealed a correct answer rate of only 45.33%, rising to 98.67% after integrating the AR application with traditional teaching, highlighting the strong potential to enhance primary EFL education in low-resource settings. The AR application was effective in teaching unfamiliar vocabulary like "koala", an animal students would not encounter in daily life due to geographical and socioeconomic constraints.

Students internalised directional phrases like "Stop," "Turn left", by actively applying them during the activity, boosting retention and language use. The application can improve in reading, listening, and speaking by requiring students to listen to instructions, read vocabulary cues, and speak vocabulary while completing tasks. For instance, when locating virtual objects, students followed verbal prompts like "go straight" or "turn left," improving their listening comprehension. Reading was practised through on-screen labels and instructions. Speaking was reinforced through peer collaboration as students verbally guided and corrected each other, such as when clarifying "turn right" and "turn left." Real-time use of new vocabulary bridged the gap between recognition and active expression, a key milestone in second language acquisition.

Collaboration served as a scaffold to authentic verbal interaction with students, clarifying, explaining, and repeating phrases to peers. This reinforced vocabulary learning and enhanced communication, motivation, and confidence, leading to greater participation and a positive attitude toward EFL.

Finally, the multimodal nature of AR, combining visual, sound effects, and kinesthetic inputs, helped solidify understanding by placing words in memorable and contextualised scenarios. This was especially beneficial for abstract terms like "stop" or unfamiliar words like "koala." In conclusion, the AR application effectively strengthened reading, listening, and speaking skills through the combination of AR and real-world environments, showing strong promise for EFL in low-resource settings.

6.2 Challenges of implementing game-based AR mobile applications in primary EFL education in low-resource settings

The integration of a game-based AR mobile application to primary EFL education in low-resource settings offers substantial educational benefits alongside notable challenges related to spatial recognition, user experience, and infrastructure constraints. While smartphone ownership is increasingly common, it is important to note that some primary school students may not have access to devices due to their parents' concerns or restrictions regarding device usage.

Students struggled to interpret the position and scale of 3D objects in the AR environment, particularly when the digital content

blended into cluttered real-world backgrounds, which could negatively impact their learning experience. Safety concerns about overcrowded or cluttered classrooms were also raised.

The development of AR mobile applications requires high-level technical knowledge and expertise, although the cost of the development is affordable. To make AR technology more accessible, it is essential to explore low-cost solutions, such as leveraging smartphones that students may already own or developing open-source AR platforms that can be easily adapted to local areas, ensuring that more students can benefit from this learning tool.

Observers suggested that future improvements could include increasing the number of interactive objects within the application and enhancing group-play features to support collaborative learning better. These insights underscore the need for continuous refinement and contextual adaptation of mobile AR applications to meet educational goals while addressing the physical, technological, and social limitations in low-resource settings.

In conclusion, thoughtfully designed AR mobile applications show the potential for enhancing language learning opportunities, provided that identified challenges are adequately addressed in low-resource settings.

7   Limitations and future research

While this study promises the potential of game-based AR mobile applications in enhancing EFL learning in low-resource settings, several limitations must be acknowledged. Firstly, the study involved only five students from grades 4 to 6, three observers, and one teacher. Future research should involve larger, more diverse groups across regions and grades to strengthen validity and applicability.

Secondly, the one-hour user study may not reflect long-term impacts. Extended classroom use may lead to technology fatigue, reducing engagement. Longitudinal studies are recommended to evaluate sustained effects over weeks [38].

Thirdly, the application was developed by the researcher under practical constraints, which potentially affected performance and learning experience. Future studies should collaborate with professional developers and advanced AR platforms to improve quality and reliability.

Spatial design constraints posed challenges. Future research should explore the spatial mapping, real-time environment scanning, and adaptive object placement to keep AR content accessible. Accessibility is another gap, as this study did not address the needs of students with disabilities. Future AR applications should follow inclusive design principles.

Another limitation is the potential learning effect of the within-subjects design. Students experienced all conditions sequentially, which may have increased familiarity with target words and contributed to improved performance in the final AR condition. Future studies should consider counterbalancing conditions or adopting a between-subjects design to isolate the unique outcome of AR.

Lastly, future research should investigate other subjects, teacher training, infrastructure readiness, and community to support sustainable adoption in low-resource settings. Despite limitations, this study highlights the strong potential of AR mobile applications for primary EFL education in low-resource settings.

8   Conclusion

This study investigated the effectiveness of game-based AR mobile applications in enhancing collaborative learning and improving English proficiency in a low-resource Cambodian primary EFL context. The findings show that AR technology can enhance student engagement, participation, and language acquisition when thoughtfully integrated.

The interactive and gamified AR application promoted both collaborative and autonomous learning. Students actively communicated, solved problems together, and made group decisions, creating a peer-driven learning environment that supported language development alongside critical social skills.

The application substantially improved English test scores, highlighting the educational value of immersive learning. Engaging students with real-time, multimodal AR that integrates visual and kinesthetic elements has proven particularly effective for teaching abstract or unfamiliar vocabulary.

Students' positive emotions and increased confidence demonstrate the motivational benefits of AR. Despite challenges such as limited space, occasional confusion between virtual and real elements, and device constraints, AR shows strong potential in EFL education. Thoughtful design and contextual adaptation can foster participatory, inclusive, and impactful learning in low-resource settings.

In conclusion, this study shows that game-based AR applications can be effective tools for primary EFL education in low-resource settings, requiring minimal expense or space. By aligning digital innovation with local needs, AR can enhance language proficiency, foster collaboration, and support equitable access to quality learning.

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A English test

The test consisted of 15 question-answer pairs, with the question displayed on the left slide and the corresponding answer shown on the right slide.
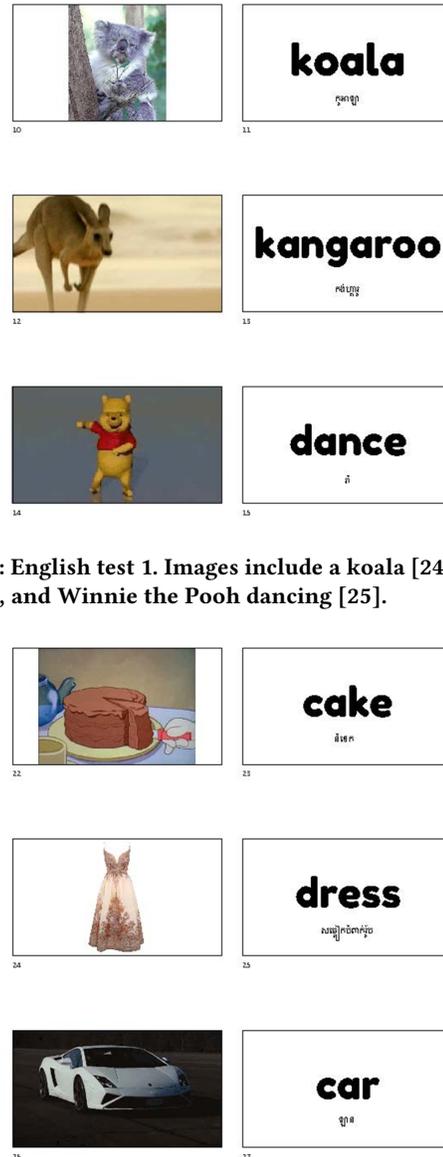

Figure 4: English test 1. Images include a koala [24], a kangaroo [23], and Winnie the Pooh dancing [25].

Figure 5: English test 2. Images include a cake [20], a dress [22], and a car [21].
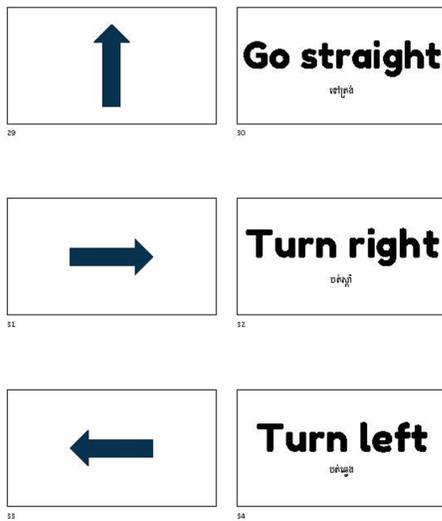
Figure 6: English test 3

Figure 7: English test 4. Image of a police officer signalling "stop" [60].

B Questionnaire for local teachers

(1) How did you feel about using the AR app for teaching?
- Positive
- Neutral
- Negative

(2) Did the students seem interested and engaged in the activity?
- Yes
- No
- Maybe

(3) What part of the AR activity did the students enjoy the most?
(open-ended)

(4) Did you think the AR app helped the students learn English?
- Yes
- No
- Maybe

(5) Was it easy for you to use the AR app during the lesson?
- Yes
- No
- Maybe

(6) Did you feel the students were able to use the app without too much help?
- Yes
- No
- Maybe

(7) Did the AR app work well for teaching new English words?
- Yes
- No
- Maybe

(8) Do you think the students learned more effectively with the AR app than with traditional methods?
- Yes
- No
- Maybe

(9) Do you believe the app helped improve the students' confidence in speaking or understanding English?
- Yes
- No
- Maybe

(10) What did you like the most about the AR app?
(open-end)

(11) What do you think could be improved in the app?
(open-end)

(12) Would you recommend using this AR app for teaching other subjects?
- Yes
- No
- Maybe

(13) Please share your overall thoughts on the AR app and any additional comments.
(open-end)

C Questionnaire for observers

(1) How would you describe the students' engagement with the AR app?
- Very active
- Somewhat active
- Not active

(2) Did you notice any improvements in the students' English proficiency after using the AR app?
- Yes
- No
- Maybe

(3) Did the AR app seem to hold the students' attention throughout the activity?
- Yes
- No
- Maybe

(4) Did the students appear to enjoy using the AR app?
- Yes

- No
- Maybe

(5) Did you observe any challenges the students faced while using the AR app?
   (open-end)

(6) Did the students seem to understand how to navigate the AR app?
   - Yes
   - No
   - Maybe

(7) Did you notice any specific emotional reactions from the students while using the AR app?
   (open-end)

(8) How would you rate the overall impact of the AR app on the learning experience?
   - Exceptional
   - Good
   - Fair
   - Poor
   - Very poor

(9) Did the AR app support collaborative learning among the students?
   - Yes
   - No

- Maybe

(10) Would you recommend using the AR app for teaching other subjects?
   - Yes
   - No
   - Maybe

(11) What did you like the most about the AR app?
   (open-end)

(12) What aspects of the AR app could be improved?
   (open-end)

(13) Do you think the AR app could be effective in other educational settings?
   - Yes
   - No
   - Maybe

(14) How would you compare this AR learning experience with traditional methods?
   - Better
   - Same
   - Worse

(15) Please share your overall thoughts on the AR app and any additional comments.

 (open-end)