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Enhancing English Proficiency in Non-Native Speaking Children Through Design Thinking-Driven Game-Based Learning App

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ABSTRACT

This paper describes the interaction between the design thinking process and design sprint activities in developing a game-based learning (GBL) app for teaching English to non-native speaking children in a Borneoan state of Malaysia. The research gap in GBL app development lies in the absence of a structured framework for integrating children's preferences and attitudes towards the subject into the app design. While design thinking presents an iterative, human-centred strategy for comprehending learning challenges among non-native speakers, its application in GBL tool development is inadequately explored. The study's objective is to investigate the potential of design thinking in fostering a fun and educational game app for improving vocabulary acquisition. Collaborating with a rural school, design thinking activities were performed to capture requirements and refine game features. Interviews, observations, artifact analysis, and surveys facilitated personalized user input. Pre- and post-tests gauged the tool's impact, with data collected during the design stages, assessing usability, user satisfaction, and involvement. The study's outcome is projected to illuminate design thinking's efficacy in shaping GBL tools and extracting user requisites, contributing to educational technology by highlighting its constructive role in creating engaging learning solutions.

Keywords:
Game-based learning; Primary school students; Teachers; Design thinking; Vocabulary acquisition; Design sprint

1. Introduction

Design thinking is a problem-solving technique unique to design, examining known and unknown factors contributing to the problem [4]. This technique focuses on solving "multidimensional and extremely complex" problems that require deep human understanding, which is why a collaborative method available in a design thinking process is potentially a key to solving such problems [6]. Design thinking is a way to bring together these highly specialised fields of knowledge so that they can be used together to solve the new problems we face in the world today [5]. It comprises five phases: Empathize, Define, Ideate, Prototype, and Test. The process begins with building empathy and understanding the needs of the targeted individuals in the Empathize phase. In the Define phase, the

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appropriate challenge to address is identified. The Ideate phase focuses on generating multiple solutions, and the Prototype phase transforms the best solution into an interactive form. User testing is conducted during the Test phase, with iterations to refine the prototype [15]. Design thinking methodology is an iterative and user-centred approach to solving complex problems. The framework of the design thinking process is depicted in Figure 1.

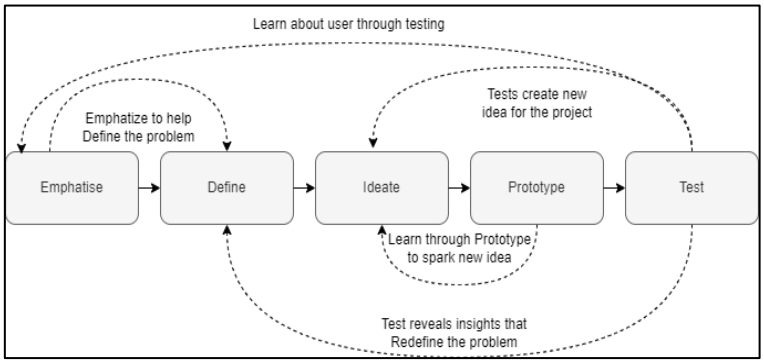


Fig. 1. Phases and activities in design thinking

When developing a game-based learning (GBL) tool for a target group, one of the main challenges is collecting accurate and comprehensive user requirements. This is especially difficult when the users may not have the ability or experience to clearly express their needs and preferences. Additionally, users' needs and preferences may vary and change over time, making it difficult to keep up with the latest trends and developments in game-based learning. Design Thinking methodology can be used as a problem-solving strategy to overcome these challenges given the user-centric phases. The five stages of design thinking - empathize, define, ideate, prototype, and test - offer a solution-based approach to issue resolution [5]. By empathizing with the users and understanding their needs, defining their problems and insights, ideating by challenging assumptions and creating ideas for innovative solutions, prototyping to start creating solutions and testing the solutions, the developer can ensure that they are listening to the users' needs and creating a product that meets their requirements. This is the strength of design thinking as it ensures that the developer is constantly in touch with the clients' needs throughout the development process.

The term "educational game" is commonly associated with GBL, which utilizes computer or video games to provide an engaging learning experience [8]. GBL falls under serious games, which use games in a non-game setting for educational purposes [7]. It is an innovative approach that combines computer games with instructional value to improve learning outcomes [1]. In terms of learning theory integrated with GBL mostly sociocultural theory of learning and the flow theory [18]. Providing highly realistic and immersive worlds in which players can learn through role-playing is an example of the sociocultural theory's use in video games [18]. Flow theory enables the player to lose track of time, and intrinsic delight rather than extrinsic rewards motivates goal-directed action [18]. Flow provides a natural foundation for motivation in games and learning.

Research on GBL focuses on four categories of outcomes: behavioural, cognitive learning, emotional, and motivational [12]. Motivational outcomes include self-efficacy and engagement, which are influenced by internal and external factors [14]. Flow, a state of psychological immersion, and self-efficacy contribute to positive affective outcomes [14]. In the context of GBL, positive motivational outcomes are associated with increased engagement and the desire to overcome challenges in the game [12]. Behavioural outcomes show improved performance and increased interest and participation in academic and occupational tasks [3,12]. Cognitive learning outcomes involve critical thinking, creative thinking, information acquisition, and subject understanding [18].

However, the combination of cognitive learning outcomes with affective and motivational outcomes is crucial for successful academic performance enhancement [3].

The study employs the Design Thinking methodology to explore its influence on application development, drawing insights from related research. In [17], researchers highlight Design Thinking's utility in fostering human-centred, creative problem-solving. This approach engages users, enhancing their understanding of their experiences and perspectives. Moreover, past research emphasized Design Thinking's structured nature, which aids developers in early issue identification and resolution, preventing potential obstacles [19,20]. By embracing this methodology, developers can devise innovative solutions aligned with user needs, ultimately elevating user satisfaction and experience. Furthermore, Design Thinking fosters collaboration and teamwork, merging diverse viewpoints and expertise to create high-quality products [20]. Overall, Design Thinking ensures the development of relevant, engaging, and effective applications that align with their intended goals and enhance user experience.

Hence, this paper aims to investigate the use of design thinking for developing a GBL tool that addresses the lack of engagement among primary school students. The research gap in GBL app development is the lack of a systematic process for incorporating students' needs and attitudes towards the subject in the design and development of the tools. While design thinking is an iterative process and a human-centred approach to gaining insight into students' subject mastery problems, there is limited research on effectively implementing it in developing GBL tools.

To guide our research, we seek to answer the following question: How can we integrate design thinking into constructing features for a GBL tool that facilitates teaching and learning? There are three research objectives:

i. to investigate design thinking methodology in developing a game-based learning tool to address the lack of interest in learning English among non-native speaking children from a primary school
ii. to implement the design thinking process together with the school for collecting target needs and preferences on the proposed GBL tool
iii. to observe and evaluate pupils' English vocabulary before and after using the proposed GBL tool.

For the evaluation, our initial hypothesis is that the proposed GBL tool developed via design thinking can improve the vocabulary learning of non-native speaking pupils. To test this hypothesis, we conduct a pre-test and post-test with the pupils where the pre-test is given before using the tool and the post-test is given after using the tool. The anticipated result of this investigation includes an improvement in student performance and level of engagement, both achieved through creating a personalized GBL application backed by design thinking principles. The study was conducted at Sekolah Kebangsaan Kampung Rembus, a primary school in a rural area in Sarawak, Malaysia, where the pupils have been found to have a low mastery of the English language.

2. Methodology

2.1 Case Study and Sample

Sekolah Kebangsaan Kampung Rembus is located at Kota Samarahan, Sarawak, Malaysia. The school is in a remote area of Sarawak and serves around 110 pupils from nearby villages including Kampung Rembus. The school has 20 teachers who are dedicated to the pupils' growth. The school's uniqueness stems from its remote location, posing challenges regarding resources and technology

access. English is not the primary language spoken; the pupils mainly communicate in the Iban language, with some use of Malay Sarawak. This linguistic diversity presents teaching complexities that demand innovative approaches. We focus on primary four and five pupils, totalling 15 primary four and 22 primary five pupils. These grades are pivotal in language learning and cognitive development. Even though English is not their main language, its significance for broader educational prospects is recognized. Our research targets bridging the English language gap through a GBL tool. This tool employs design thinking to ensure an engaging and effective learning experience, tailored to the linguistic diversity and challenges of Sekolah Kebangsaan Kampung Rembus. The objective is to improve the pupils' language skills considering the distinct needs of this culturally and linguistically rich school environment.

2.2 Identifying Factors That Can Influence GBL Experience

Projected outcomes should always emphasize motivational growth and language understanding expansion. To include flow and sociocultural theories, game design must be interactive, immersive, and entertaining, with problem-solving intermingled throughout. However, game design should also encompass a holistic approach that considers the specific context of implementation and the target audience's needs. To address this, we conducted a comprehensive analysis on existing games, aiming to uncover their inherent advantages and disadvantages.

From our initial observation, three factors influencing GBL implementation at Sekolah Kebangsaan Kampung Rembus were identified. First, we considered the pupils' competence to adapt to game complexity. Secondly, the availability of school equipment like computers or laptops was evaluated. Lastly, the instability of the internet connection was considered due to potential disruptions during gameplay. To assess these factors, we compared several gameplays from selected research articles. Table 1 describes the learning tools based on the three factors.

Table 1
Comparison of gameplay and learning apps from articles

Research Article	Gameplay	Pupils' Adaptability	School facility /Equipment Availability	Internet Connection
Visual Novel Game Subtitles and the Improvement of Vocabulary Comprehension Ability: Does It help L2? [13]	Navigate through the story by clicking and reading.	Able to adapt (Target group: University Students, 21-22 years old)	Yes. The game can be played on schools' laptops using a web browser.	No internet connection required; It can be played offline.
"PowPow" interactive game in supporting English vocabulary learning for elementary students [2]	Participating in activities such as question-answer matching, colouring, and drawing based on instructions. Not a visual novel game.	Easy to adapt (Target group: Primary schoolchildren, 7-12 years old)	Yes. The game can be played on schools' laptops using a web browser.	No internet connection required; It can be played offline.
Using Augmented Reality to Teach Kindergarten Students English Vocabulary [15]	Control mobile device through motions and clicking virtual objects in the game via augmented reality setting, students may see them from multiple perspectives and learn their terminologies along the way.	Easy to adapt (Target group: Kindergarten pupils)	No. Mobile devices are not available.	No internet connection required; It can be played offline.

Our proposed game represents a merging of storytelling with interactive gameplay inspired by "PowPow," tailored for pupils aged 10 to 12, playable offline on laptops. The intention is to enhance learning enjoyment and refine reading and problem-solving abilities. While the study on "Visual Novel Game Subtitles" [13] targeted university students, we hypothesize that incorporating similar game dynamics could be beneficial for the pupils. Integrating visual novel elements could potentially render reading more interactive and captivating. This strategy strives not only for educational outcomes but also for an enjoyable learning experience. Despite the age divergence in the original study, the application of visual novel mechanisms might offer a fresh approach to aiding the understanding of the pupils. This proposed game is in line with our fundamental objective: to create an engaging learning environment and enhance English proficiency where many learners face English language challenges. By innovatively satisfying the student adaptability, school resource, and internet accessibility factors, our game design seeks to distinguish itself in addressing the unique needs of the context.

2.3 Data Collection and Materials

Table 2 shows the following materials we used in our investigation. These materials were selected both for documentation and analysis purposes and in alignment with the recommendations derived from the five steps of the Design Thinking and Design Sprint methodology.

Table 2
Materials and Descriptions

Materials	Description
Observation and interview data collection sheets	Sheets used to record observations and conduct interviews with pupils and teachers.
Usability test and User Acceptance Testing (UAT) questionnaires	Questionnaires administered to assess usability and user acceptance of the GBL tool.
Design Sprint materials	Tools used during the Design Sprint activities, such as sticky notes, whiteboard, A4 paper and marker to create sketches of the game design.
Pre-test and post-test instruments (including game-based post-test scores)	Instruments used to evaluate pupils' performance, including pre-test and post-test scores collected from the GBL tool.
Software and hardware for prototyping and testing	Tools and equipment, such as Figma, Website Resources, Unity, and laptops, used for creating prototypes and testing the GBL tool.
Study materials	English language textbook used at the school, along with online resources like Quizizz and YouTube videos.

All gathered information was subject to consent, and the intention to conduct the study at the school was formally communicated through the university's official letter. All study participants provided their consent by signing a consent form, thereby agreeing to participate in the data collection process.

The interviews were conducted with the school’s Headmaster and Senior Assistant for Student Affairs before specifying the content of game-based learning concerning the selected subject and module. Upon identifying English as the subject with the lowest performance, it was chosen as the focus for developing game-based learning tools. While researching the English subject, the English teacher, Mr. Gary Minin, served as the primary source of information concerning students' vocabulary comprehension skills, interests, and preferences and acted as the principal collaborator. Subsequently, a non-participant research method was employed in the observation phase, involving distant observation without direct involvement in the group. We spent an hour in a classroom during an English lesson with a class of Primary 5 pupils. We observed their learning behaviours and

identified their level of engagement in the class when educational resources such as books and writing materials were given.

2.4 Research activities for Design Thinking

Table 3 describes the activities we carried out for implementing the Design Thinking methodology that comprises five main phases: Empathy, Define, Ideate, Prototype, and Test.

Table 3
Design thinking and its activities

Phase No.	Methodology Phase	Activities
1	Empathy	▪ Observing pupils' engagement and participation in English language classes ▪ Conducting interviews with the headmaster, Senior Assistant for Student Affairs, and English teachers
2	Define	▪ Analysing collected data ▪ Identifying the specific problem to be addressed by the game-based learning tool
3	Ideate	▪ Collaborating with the teacher ▪ Utilizing Design Sprint activities to generate ideas for the GBL tool
4	Prototype	▪ Developing the game using Unity Engine based on the defined design
5	Test	▪ Conducting surveys with five Year Four pupils and a usability test with an English teacher ▪ Evaluating the game with thirty-three primary school pupils and an English teacher through User Acceptance Testing ▪ Analyse the survey result by comparing pre-test and post-test scores using matched pairs hypothesis testing

2.5 Testing and Data Analysis

The current strategy in Design Thinking lacks a testing approach to evaluate the effectiveness of its method in developing GBL applications. To address this gap, our study proposed a testing framework comprising three distinct methods: usability test, pre-test and post-test, and user acceptance test. Table 4 describes the tests and when they were conducted.

Table 4
List of tests conducted

Test	Purpose	Phase
Usability Test	Assess ease of use and user experience	Ideate Phase
Pre-Test and Post-Test	Measure knowledge/skill improvement	Test Phase
User Acceptance Test	Evaluate user satisfaction and acceptance	Test Phase

These testing methods were incorporated into our project to measure various aspects of user interaction and tool effectiveness. The usability test focused on interface enhancements, the pre-test and post-test measured knowledge improvement, and the user acceptance test assessed overall tool acceptance. Collectively, these tests ensure a comprehensive evaluation of the GBL tool's design and impact on users. We also conducted data analytics via matched pairs hypothesis testing using the pre-test and post-test scores from the pupils. This statistical analysis aimed to determine if there was a significant improvement in pupils' vocabulary knowledge after utilizing the GBL tool.

3. Results

3.1 Observations after the Empathy Phase

We collected various information to develop a deep understanding of the pupils' needs, goals, and challenges. The data was obtained through interviews and observations with the schoolteacher and administrator. Interviews were conducted with both the headmaster and Senior Assistant to assess the pupils' English proficiency. Additionally, conversations with the English teacher, Mr. Gary Minin, provided insights into the pupils' vocabulary comprehension skills, interests, and preferences. Furthermore, a one-hour classroom observation was carried out to actively observe the pupils' engagement and involvement. This comprehensive data collection approach enabled a thorough understanding of the pupils' linguistic abilities, preferences, and classroom dynamics.

The data from interviews and classroom observations provided valuable insights into the pupils' behaviours and preferences. The observations revealed a noticeable level of active engagement among the pupils when utilizing supplementary materials like Quizizz or any visually appealing and interactive content. This indicates that interactive learning tools capture their attention effectively. The identified needs of the pupils include a distinct interest in specific module topics such as “Where are you from?”, “Eating Right”, and “Amazing Animals” from their Year 4 English Textbook. This insight suggests that creating educational content related to these topics could enhance their engagement. The primary goal outlined from these findings is to develop a game that offers an immersive, interactive, engaging, and fun learning experience. This aligns with the pupils' desire for captivating and enjoyable learning methods. Based on our observations, we notice that the pupils encountered difficulties in grasping new vocabulary words when the teacher used the conventional pen and paper method. This highlights the need for innovative and entertaining approaches to vocabulary acquisition, which the proposed GBL tool aims to address. By collecting this data, the GBL project aimed to comprehensively understand the pupils' needs, goals, and challenges.

3.2 Defining the Users’ Gaps during the Define Phase

Table 5 summarizes the key elements of the Define phase, providing a clear overview of the identified problem/opportunity and the desired learning outcomes for the GBL tool. It shows a detailed overview of the Define phase, highlighting its crucial components. This phase sought to identify the main problem or opportunity in the context of the research. From our interview session with the teacher, the pupils have difficulties in learning English vocabulary. They struggle to understand meanings and using new words, thus hindering comprehension and expressive English writing skills.

Table 5
Summarization of the key elements of the Define phase

Define Steps	Summary
Problem/Opportunity	Lack of vocabulary skills among pupils
Problem Statement	Sekolah Kebangsaan Kampung Rembus pupils struggle with understanding and using new vocabulary words
Desired Learning Outcomes	▪ Help pupils learn and retain new vocabulary words ▪ Enhance understanding of word meanings ▪ Improve usage of vocabulary words in context ▪ Provide feedback on pupils' progress

The desired learning outcomes from this phase encompasses several key goals. The primary objectives were to aid pupils in learning and retaining new vocabulary words, enhance their

understanding of word meanings, refine their usage of these words in context, and offer feedback on their progress.

3.3 Brainstorming Ideas through the Ideate Phase

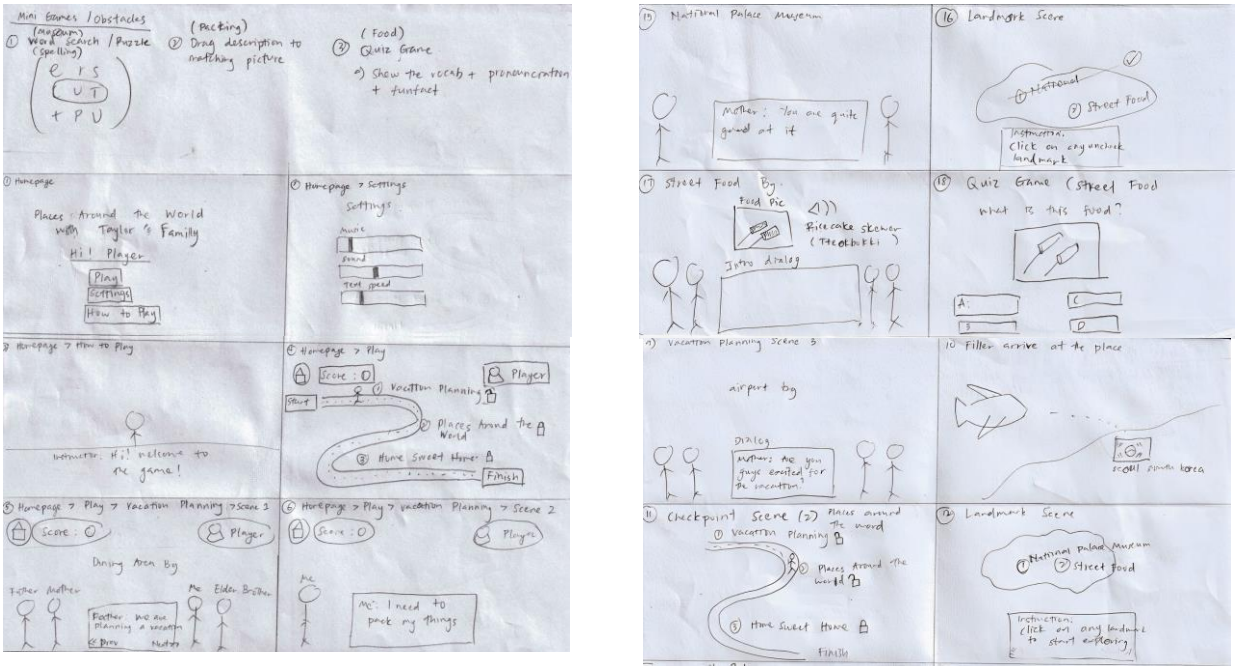
The Ideate Phase was carried out using the Design Sprint strategy. Although Garcia [10] advised conducting the sprint within 5 days, the schedule can also be flexible according to the capacity of the designers. The session took about 2-3 hours in each subphase. Below Table 6 shows the schedule of the design sprint with Mr. Gary Minin including its date of execution, description, implementation and deliverables.

Table 6
Schedule of design sprint with the English teacher

Date	Phase	Description	Implementation	Deliverables
29/11/2022	Map	Gather information about the problem or opportunity and define the problem statement.	Discuss the needs, goals, and challenges of the pupils. Agree on the problem and opportunity already defined and identified in the Define stage of Design Thinking.	Selected modules based on Get Smart Plus 4 Student's Book. Confirmation on problem, opportunity, needs, goals and challenges.
1/12/2022	Sketch	Generate a wide range of ideas for addressing the problem or opportunity.	Using design thinking tools like brainstorming and sketching on paper. Finding similar apps for review purposes can be inspiration. Produce sketches on paper together with the teacher.	List of game ideas, Physical sketches
2/12/2022	Decide	Select the most promising ideas to pursue and evaluate them based on criteria such as feasibility, impact, and alignment with business goals.	Critique and give opinion on a sketch done to turn it into a real solution. Create storyboarding (Create a real flow of your prototype) Create Flow chart and Activity Diagram for the game flow.	Storyline dialogue, Storyboard sketches, Class Diagram and Activity Diagram
3/12/2022 until 28/12/2022	Prototype	Create a simplified version of the final product using tools such as Figma.	The team would create a simplified version of the vocabulary comprehension game to test with the teacher only. Prototype limited to wireframe only.	Wireframe
3/1/2023	Testing	Gather feedback and insights from real users through user interviews, usability tests, and other types of user research.	The team would review the prototype and gather feedback to refine and improve the game's wireframe.	Teacher's and pupil's feedback

After conducting the Ideate phase, we obtained valuable sketches as shown in Figure 2(a) and Figure 2(b). The storyboards in the form of paper-based sketches were created together with the English teacher during the Map phase in Design Sprint. An activity diagram was also designed to map the application's logical flow, incorporating teacher insights and sketches from Figure 2(a)-2(b). This diagram outlines user interactions and technical elements, guiding the user experience. The process

initiates from the "Home Menu," offering options like "Start," "Settings," "Score," or "Exit." After generating a game account, users can modify profiles or create new ones. "Start" leads to the "Choose Gender" screen, impacting avatar selection. New accounts have a tutorial phase before entering the first scene via the "Checkpoint" page, while existing accounts directly access it. Dialogue integrates learning aids, enriching player experience. Mini games offer points, tallying in a final score. Upon finishing scenes, the game signals completion. "Settings" allows volume adjustment, "Score" shows mini game scores, and "Exit" ends the game. This diagram serves as a blueprint for user journey and functionality.



(a) (b)

Fig. 2. Sketches of the game design that was created with the English Teacher

In the Test phase, an interview session was conducted with Mr. Gary Minin, and five pupils to obtain feedback on our proposed prototype created using Figma [9]. The teacher was given a set of usability test questions for evaluation. Below Table 7 shows the questions and answers from the teacher's perspective.

Table 7
Usability Test questions

Questions	Answer (Verbatim)
Is the game easy to navigate and understand?	Yes
Are the instructions for each mini game clear and concise?	Yes. Keep it short and simple.
Is the game visually appealing and easy on the eyes?	Yes. Maybe include characters wearing Korean traditional clothes to make the theme clearer.
Is the game suitable for the intended age group?	Yes
Is the game enjoyable and engaging?	Yes. Can add background music for improvement.
Are the objectives of each mini game clear and achievable?	Yes
Are there any confusing or unclear aspects of the game that need to be addressed?	Some words need to be simplified. The term use like "Miscellaneous" is too complex for the pupils

Then, we interviewed five pupils from Year Four to learn about their thoughts and feelings after playing our proposed game. Table 8 shows Year Four's feedback.

Table 8
Year Four Pupils' Feedback

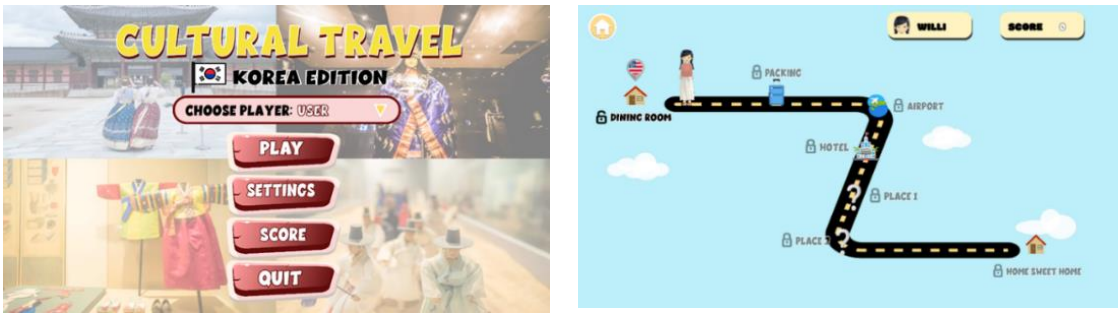
Question	Answer (Summary)
Can you understand the storyline?	All of them said yes. Most of them can summarize what the story is about, and they were able to read each sentence in the visual novel correctly.
Is the graphic visually appealing and easy on the eyes?	All of them said yes. Although some problems with the user interface design especially the click button. They prefer it to be seen clearly at the Checkpoint pages.
Do you like the game?	All of them said yes. They like the game concept, but they find it a bit boring as there is no music or sound incorporated in the game.

Table 8 shows that the game concept is suitable for the pupils since the majority agreed on the proposed design. Minor changes were requested such as removing a category called "Miscellaneous", where they found the term quite confusing. After testing the prototype with the teacher, he suggested improvements in the choice of words used in the game. Overall, the game complexity is acceptable for Year Four pupils to play and learn. This valuable feedback was used to confirm our proposed design and gameplay and to help build our final prototype.

3.4 Outcomes from the Prototype Phase

We utilized the game engine Unity (https://unity.com/), to construct a simplified version of the final game product. Screenshots of the game are depicted in Figure 3, Figure 4, Figure 5, and Figure 6 to show the key features. The main menu is shown in Figure 3. Figure 4 showcases the checkpoint page, providing an overview of the player's story progression. Subsequently, Figure 5 portrays the scene dialogue, where players engage with the narrative. Dialogue choices, which impact the story direction, are demonstrated in Figure 6. Additionally, the figures reveal visual aids, interactive vocabulary materials, and three mini games integrated into the learning application.

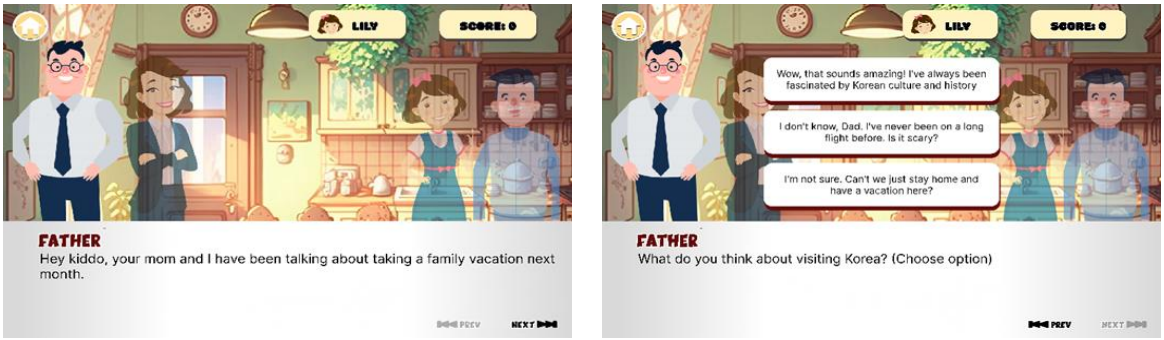
Figure 3 depicts the GBL tool's Main Menu and Checkpoint pages. The Main Menu offers five options: "Choose Player," "Play," "Settings," "Score," and "Quit." "Choose Player" allows account creation or selection, while "Settings" permits customization of audio settings. "Score" displays the user's score, and "Play" leads to gender selection for new players and directly to the Checkpoint page for returning users. This page showcases the game's storyline across seven scenes, each unlocking as the previous one is completed, enhancing the narrative flow.



(a) (b)

Fig. 3. Main Menu (a) and Checkpoint Page (b)

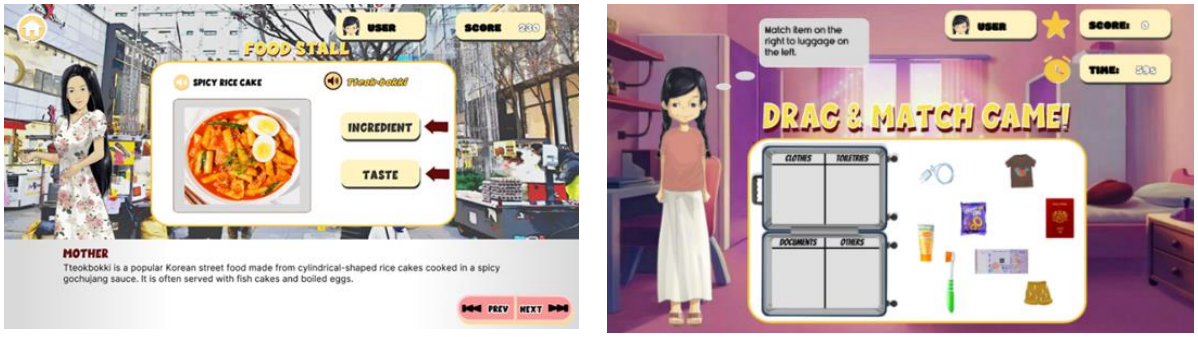
Following the scene selection on the Checkpoint page, the narrative progresses through dialogue scenes as depicted in Figure 4(a). Within these dialogue scenes, various options are available as shown in Figure 4(b), each leading to a distinct line of dialogue, contributing to the game's interactive nature.



(a) (b)

Fig. 4. Scene Dialogue (a) and Scene Dialogue with option (b)

In scenes with mini games, dialogue is supported by visual aids as seen in Figure 5(a), acting as learning tools for upcoming quizzes. The Drag and Match mini game, depicted in Figure 5(b), is embedded in dialogue scenes to evaluate vocabulary understanding.



(a) (b)

Fig. 5. Scene Dialogue with visual aids (Left) and Mini game Drag and Match (Right)

Figure 6 introduces two more mini games. The first, Word Quiz (Figure 6a), presents multiple-choice questions, requiring players to pick the right answer within a time limit. The second, Word Puzzle (Figure 6b), tasks players with arranging letters to form words. These elements enhance interactivity and make learning engaging.

(a) (b)

Fig. 6. Minigame Word Quiz (Left) and Minigame Word Puzzle (Right)

3.5 Statistical Results and UAT from the Test Phase

We present statistical results based on pupils' post-test and pre-test scores obtained for conducting hypothesis testing. The pre-test and post-test questions were developed with the teacher to test the pupils' performance before and after using the GBL tool. Table 9 shows 33 pupils' pre-test and post-test scores. The group participating in the study consists of fifteen girls and eighteen boys. These pupils are in Primary 4 and Primary 5. Using these scores, we conducted hypothesis testing to demonstrate a significant improvement in the English vocabulary learning of non-native-speaking pupils from the primary school.

At α = 0.05, the null and alternative hypotheses are as follows:

H_0: $\mu_d = 0$
H_1: $\mu_d > 0$ (1)

Table 9
Scores of 33 Primary School Pupils

Student ID	Pre-Test	Post-Test	Student ID	Pre-Test	Post-Test	Student ID	Pre-Test	Post-Test
1	17	23	12	16	23	23	13	23
2	18	12	13	16	23	24	21	23
3	6	22	14	17	15	25	19	23
4	13	17	15	16	22	26	21	23
5	15	23	16	16	17	27	21	23
6	8	23	17	21	23	28	21	23
7	7	23	18	21	23	29	18	23
8	10	20	19	21	23	30	20	23
9	12	23	20	17	23	31	21	23
10	9	17	21	20	23	32	21	23
11	16	23	22	16	23	33	19	23

where H_0 denotes score shows no improvement after playing "Cultural Travel: Korean Edition" and H_1 denotes score shows improvement after playing "Cultural Travel: Korean Edition". With sample size, *n*= 33, degree of freedom, *df* = 32, mean difference, $\mu_d = 5.27$ and standard deviation of the sample, *s* = 4.81, we obtained hypothesis testing results as shown in Table 10.

Table 10
Hypothesis Testing results

Test Statistic, t	6.29	P-value	0.00001
Critical t	±2.0	95% Confidence interval	$3.56 < \mu < 6.96$

The *p*-value is less than α = 0.05. Therefore, there is enough evidence to reject H_0. Thus, the statistical evidence confirms that the pupils' performances improved after using the GBL tool.

3.6 Feedback

The User Acceptance Test (UAT) was conducted to collect feedback from SK Kampung Rembus English teacher, Mr. Gary Minin, and the 33 pupils regarding the new GBL tool. The questionnaire for teacher focussed on acceptance requirements related to the game's features. Table 11 shows the overall acceptance requirements information by the teacher.

Table 11
Overall acceptance requirements information by the English teacher

Criteria	Answer
User interface	The teacher agreed that the user interfaces were intuitive and easy to navigate.
Game engagement	The teacher found the game to be fun and engaging for the pupils.
Mini-games and obstacles	The teacher felt that the mini-games and obstacles were appropriately challenging for Primary 4 and Primary 5 pupils.
Learning visual aids	The teacher found the learning visual aids to be appropriate and helpful.
Learning audios	The teacher agreed that the learning audios were appropriate and helpful.
Dialogues	The teacher found the dialogues to be appropriate and engaging.
Unexpected errors	The teacher did not encounter any unexpected errors or glitches while playing the game or using the menus.

The teacher's feedback indicated positive ratings for user interface, engagement, and the effectiveness of learning materials. We also received suggestions to improve the game, including adding an introductory video and a feature that can increase the difficulty level of vocabulary and word spelling modules. The pupils were given 10 questions that utilized balanced emoji-based responses (nine) and one open-ended query. This approach replaced conventional Likert-scale options such as "strongly agree" and "disagree". Furthermore, the pupils are familiar with emojis and understand how to use them to express their feelings. The pupils were asked to circle the emoji that best represented their response to a question in the questionnaire. Emojis choices are 😢 (Sad), 😳 (Confused), 😊 (Satisfied), and 🤩 (Excited), facilitating easy and accurate expression. The questions focussed on enjoyment, comprehension, learning outcomes, challenges, engagement, and development in English language skills, navigation experience, graphic preferences, and the likelihood of recommending the game to others. For the open-ended question, pupils were asked to express their thoughts about what they learned through the game by drawing on paper. The pie charts in Figure 7 show the feedback from the pupils based on four of the questions asked. Most of them chose "Excited" to express their happiness after playing the game.

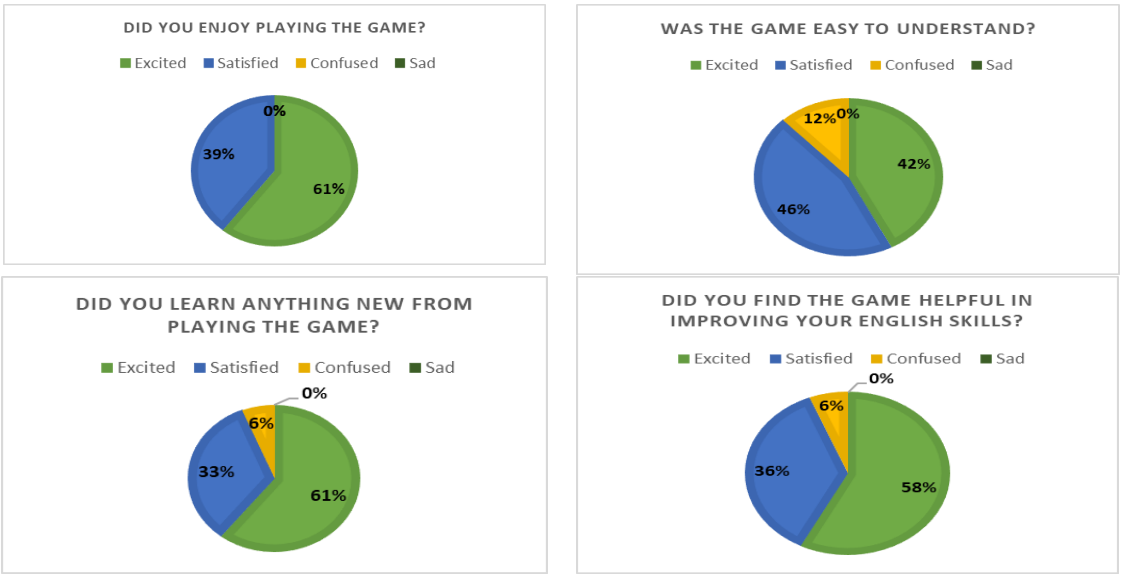


Fig. 7. UAT survey results obtained from the pupils' responses

To ensure the objectivity and accuracy of the pupils' responses, we measured the UAT data using Cronbach's Alpha calculation as shown in Eq. (2) and consequently obtained values as presented in Table 12. By applying the formula, Cronbach's Alpha value (α) is 0.71 which shows an acceptable threshold for internal consistency.

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\Sigma\, s^2\,(Xi)}{s^2\,(Y)}\right) \tag{2}$$

Table 12
Values for calculating Cronbach's Alpha

Total Questions (*k*)	9
Total variance of all individual questions ($\Sigma\, s^2\,(Xi)$)	3.5
Variance of all questions ($s^2\,(Y)$)	9.67

We also conducted casual interviews with the pupils to get their opinions over the new approach in learning through gameplay. Overall, they commented that the game was engaging, challenging, and it did help some of them to improve their English. The pupils appreciated the game's graphics and design, and most expressed their willingness to recommend it to others.

3.7 Discussions

In this project, the design sprint methodology was incorporated alongside the Design Thinking process, as introduced by Jake Knapp [11]. The design sprint successfully facilitated rapid idea generation, collaborative problem solving, guided steps of idea generation based on output and deliverables. The output of the design sprint included tangible deliverables such as a design prototype that aligned with user requirements and the targeted group's preferences. The benefits of this approach lie in the utilization of Design Thinking phases and design sprints because the combination allows a comprehensive output and insights through a structured process. Incorporating design sprint expedited the prototype development process, ensuring rapid iterations and enhancements. When considering data elicitation for developing GBL tools for non-native speakers, the user requirement process was centred on collaborative problem-solving. The requirements were not taken in a literal

sense but were aimed at uncovering the underlying root causes and fostering mutual understanding between collaborators. This approach heightened engagement and trust among users, demonstrating a commitment to understanding their needs. This is particularly evident in the third phase of Design Thinking, where the Design Sprint method was integrated to gather feedback before actual development commenced.

However, one limitation is that the project was carried out within the context of SK Kampung Rembus, which may limit the generalizability of the findings to other educational settings. The specific needs, preferences, and constraints of SK Kampung Rembus may not be representative of other nearby schools. Nevertheless, the GBL tool can be used to study the impact of learning English using the tool for other schools in the same setting. Besides that, lack of any guided evaluation strategy specifically tailored for measuring the effectiveness of design thinking in game app development. Thus, we have proposed three tests; usability test, pre-test, post-test and UAT to evaluate the effectiveness of our initial designs, prototype and gameplay. Feedback from the usability test helped the prototype designs from the design sprint. The pre-test and post-test results gave us positive insights on using games for effective learning while UAT provided a level of satisfaction on the prototype that we have developed. Although we have received promising feedback and results, we have yet to measure the effectiveness of design thinking in developing the context of a game. Hence, the absence of a standardized evaluation metric in the domain of design thinking specific to game-based learning technology highlights the need for further investigations.

4. Conclusions

In conclusion, this study demonstrated the effectiveness of the Design Thinking methodology in developing a GBL app for primary school pupils. The app successfully engaged pupils and improved their English language skills, as indicated by improved vocabulary knowledge. Feedback from teachers and pupils highlighted the positive reception of the game, emphasizing its user interface, engagement, and effectiveness. Moreover, it is recommended to further refine and enhance the game prototype based on user feedback. Expanding the app to cover other subjects and grade levels can provide a comprehensive learning experience. Integration of offline components can address limited technology access. Additionally, incorporating emotional design elements can enhance student connection, motivation, and enjoyment during learning.

Hence, the study's research objectives have been met. The first objective was fulfilled through positive feedback from pupils and teachers, signifying high usability and user satisfaction with the design prototype. Furthermore, the active involvement of users in the development process, a key facet of the Design Thinking methodology, further supports achieving this objective. The second objective was realized using the Design Thinking methodology to gather user requirements and create a GBL tool for non-native children. This inclusive approach involved users extensively through various data collection methods such as interviews, observations, artefact analysis, and surveys. Lastly, the third objective was attained by conducting hypothesis testing to assess the difference in student performance before and after using the game-based learning tool, revealing a statistically significant improvement in student performance following its implementation.

In this paper, we have presented our approach to applying Design Thinking for developing a GBL tool and proposed three types of tests to measure the effectiveness of our strategy. However, these tests need further refinements to explain the impacts of design thinking for building such learning tools. Thus, there is a need for a systematic method to evaluate ideas developed from design thinking activities. Overall, this study contributes to the field of education technology for primary schools and provides valuable insights for developing future GBL tools.

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