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JOM KIRA! : A 2D INTERACTIVE ANIMATION APPLICATION OF MATHEMATICAL LEARNING

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Abstract:

Memorization-based learning methods and static worksheets remain common approaches in early mathematics education, but these approaches are less effective in engaging children aged 4 to 6 years to master basic numeracy skills. Therefore, this study aimed to develop and evaluate the effectiveness of a touchscreen-based 2D interactive animation application, "Jom Kira!", as a learning medium that supports the skills of number recognition, object counting, and simple arithmetic operations. The application was developed using ADDIE's teaching design model and guided by Mayer's Cognitive Theory of Multimedia Learning (CTML) to ensure effective content delivery and reduce the cognitive burden on users. The app contains interactive games, animated elements, audio guides, and a kid-friendly interface to increase engagement during the learning process. The summative assessment involved 30 children aged 4 to 6 years, consisting of 15 students of PASTI Al A'la Kindergarten and 15 students from other institutions in the same age group. The assessment focuses on the usability aspects, level of engagement, and learning achievement through comparisons before and after the use of the app using a pre and post-test. The findings of the study showed that the "Jom Kira!" application managed to improve number recognition and calculation skills, with an increase in scores ranging from 24% in the pre-test to 36% in the post-test, while sustaining children's engagement during the learning session. In conclusion, this application has the potential to be an effective teaching aid in early childhood education. The integration of interactive animation, gamification, and instant feedback not only enhances the learning experience, but also supports the development of

basic numeracy skills and may provide a more engaging alternative to conventional approaches.

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Early Childhood, 2D Interactive Animation, User Experience (UX), Gamified Education, Multimedia Learning



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Introduction

Early math instruction is an important foundation in forming the logical reasoning skills, critical thinking, and problem-solving skills needed throughout life. However, the process of introducing abstract mathematical concepts to preschoolers between the ages of 4 and 6 still faces various challenges. Traditional teaching methods that rely on textbooks, flashcards and printed worksheets are often less successful in maintaining children's focus due to their passive and repetitive learning activities. This condition can reduce interest, motivation and early understanding of number concepts and basic mathematical operations (Zulfikri & Masnan, 2022; UNESCO, 2023). In addition, as stated by Qanabita et al., (2026), traditional teaching methods may be insufficient to facilitate deep and meaningful learning, highlighting the need for innovative, evidence-based instructional strategies that enhance knowledge acquisition and promote long-term understanding.

The development of educational technology has opened up opportunities for the use of interactive digital media as a more interesting and effective learning medium. It has become an integral component of education in many developed countries over the past few decades (Al-Zoubi et al., 2016). Recent studies have shown that interactive multimedia applications are able to make abstract number concepts easier to understand through a combination of visual, audio, animation and direct interaction elements. This approach not only increases children's involvement, but can also stimulate the development of thinking skills, intrinsic motivation and more meaningful learning experiences (OECD, 2023; Jarrah, 2025). However, most of the educational apps available on the market still feature content in the form of linear animations that only allow children to watch without the opportunity to actively interact. The lack of these interactive elements causes the learning process to be less interesting and cannot optimally improve learning achievement and motivation (Zulfikri & Masnan, 2022; Jarrah, 2025).

Additionally, complex interface designs, unchild-friendly layouts, and a lack of positive feedback elements can lead to young users experiencing confusion, emotional distress, and frustration when using learning apps. These factors ultimately reduce the effectiveness of the learning process as well as affect their level of engagement. Therefore, the development of learning applications for children should focus on aspects of User Experience (UX), usability, design that is appropriate for children's cognitive development, as well as the use of rewards and positive feedback to support effective learning (Crescenzi-Lanna et al., 2026; UNICEF, 2023).

To address these issues, this study developed and evaluated Jom Kira!, which is a 2D interactive multimedia learning application designed to replace a passive learning approach with active learning that is fully controlled by the user. The study has four main objectives, namely: (i) to develop a 2D interactive animation application that is optimized for touch screens and allows users to control navigation between basic math modules; (ii) analyze functional, non-functional and user needs through systematic data collection techniques; (iii) design engaging 2D animated content appropriate to the child's developmental stage, with emphasis on number identification and object counting activities; and (iv) assess the usability of the prototype through observational tests to determine its effectiveness in supporting the mastery of basic numeracy skills.

The scope of development of this application is limited to the basic concept of numeracy, which includes the recognition of numbers 1 to 10, the activity of counting objects, as well as basic operations of add and subtract. The system developed is also optimized for use on various devices such as laptops, tablets, and smartphones with touchscreen support. To enhance the user experience, the app is equipped with large buttons, easy navigation, and coordinated audio and visual feedback to help children interact more confidently and enjoyably. This approach is expected to increase engagement, motivation, and mastery of early numeracy skills among preschoolers.

Literature Review

In this study, the literature highlights the use of interactive multimedia and Digital Game-Based Learning (DGBL) in early mathematics education for preschoolers. Not only that, but the principles of Multimedia Design also based on the Cognitive Theory of Multimedia Learning (CTML) introduced by Mayer as used as a guide in developing the Jom Kira! application. These highlights aim to identify best practices in the development of interactive learning applications, while also supporting the selection of appropriate design approaches to improve early numeracy skills in preschoolers.

Analysis of Existing Studies

In the preschool education ecosystem in Malaysia, the use of Digital Game-Based Learning (DGBL) is gaining attention as an effective approach in increasing children's engagement and motivation during learning process. Compared to traditional teaching methods that rely on textbooks and worksheets, the DGBL approach provides a more interactive learning experience through the use of multimedia elements such as animation, audio, graphics, and game-based activities. This approach has been found to increase concentration, active involvement and

understanding of mathematical concepts among preschool children (Zulfikri & Masnan, 2022; OECD, 2023).

Recent studies have also shown that the use of digital games in early childhood education has a positive impact on the development of cognitive skills, problem-solving, and mathematical achievement. According to Boonarchatong and Pantrakul (2026), the use of systematically planned digital games can increase the level of engagement, knowledge retention and application of mathematical concepts among children by 24% to 36% compared to conventional approaches. These findings show that game-based learning can make the learning process more enjoyable without neglecting the learning objectives.

In terms of interface design, preschoolers find it easier to pay attention to apps that use bright colors, clear icons, large buttons, simple animations as well as audio and visual feedback that is given instantly. These characteristics allow children to explore learning content at their own pace, thus increasing intrinsic motivation and positive learning experiences (Abdul Rauf & Prihadi, 2024). In addition, the use of digital games as the main medium of teaching has also been reported to increase the level of active participation and enjoyment of learning compared to the use of traditional worksheets (Zulfikri & Masnan, 2022).

However, some studies have also reported that learning apps that rely too much on text-based descriptions, complex mathematical symbols, or dense interface layouts can increase cognitive load and cause children to feel confused and quickly lose interest in continuing learning (Aremi & Omar, 2025). Therefore, the development of learning apps for children needs to take into account the balance between learning content, visual design and user experience so that the learning process takes place in a fun atmosphere and does not burden young users (Crescenzi-Lanna et al., 2026). Based on this literature highlight, it can be concluded that the development of mathematics learning applications for preschool children needs to incorporate interactive multimedia elements, user-friendly interface design and game-based learning activities to increase the effectiveness of early numeracy learning.

Application of Multimedia Learning Principles

Design of the interface and learning content in the Jom Kira! developed based on the Cognitive Theory of Multimedia Learning (CTML) introduced by Richard E. Mayer. This theory asserts that learning becomes more effective when information is delivered through a combination of appropriate visual and audio elements and is designed to reduce the cognitive load on users (Mayer, 2021). By applying the principles of CTML, this app aims to help children understand basic math concepts more easily, increase the focus of learning and encourage independent learning.

Table 1: Application of Multimedia Learning Principles in the Jom Kira Application!

CTML Principles	Theory Description	Implementation in the Jom Kira!
Multimedia Principle	Learning is more effective when words are combined with images rather than using words alone.	Use colored 2D cartoon characters with numbers and objects to help children

		visually understand the concept of numbers.
Modality Principle	Verbal information is more suitable to be conveyed via audio rather than long text to reduce the visual load.	Provide voice commands in Malay Language and minimize the use of on-screen text.
Coherence Principle	Unrelated information, sounds or graphics should be avoided to minimise disruption to the learning process.	Each screen displays only one math activity with no decorative elements that distract the user's attention.
Segmenting Principle	Learning content should be divided into small sections that can be explored according to the user's learning pace.	The learning module is broken down into several menus such as Know Numbers 1–5, Know Numbers 6–10 and Simple Add Operations.
Spatial Contiguity Principle	Text and graphics that are interconnected should be placed nearby to facilitate information processing.	Numbers are displayed next to the calculated object so that the relationship between numbers and quantities is easier for children to understand.

Application of CTML principles in the Jom Kira! is expected to improve the effectiveness of basic mathematics learning through the delivery of content that is more systematic, engaging and appropriate to the level of cognitive development of preschoolers. In addition to improving the understanding of numeracy concepts, this approach can also reduce cognitive load, increase learning motivation and provide a more enjoyable learning experience (Mayer, 2021; OECD, 2023; UNICEF, 2023).

Research Methodology

This study uses the ADDIE Model as the main framework in the development process of the Jom Kira! interactive multimedia application. The ADDIE model was chosen because it is one of the systematic, flexible, and widely used instructional design models in the development of digital learning materials. The model consists of five main phases, namely Analysis, Design, Development, Implementation and Evaluation. Each phase is interconnected and allows continuous improvement throughout the development process to ensure that the resulting application meets the needs of users and achieves the set learning objectives (Branch, 2020; Kurt, 2023). Figure 3.1 shows the application development framework based on the ADDIE Model used in this study.

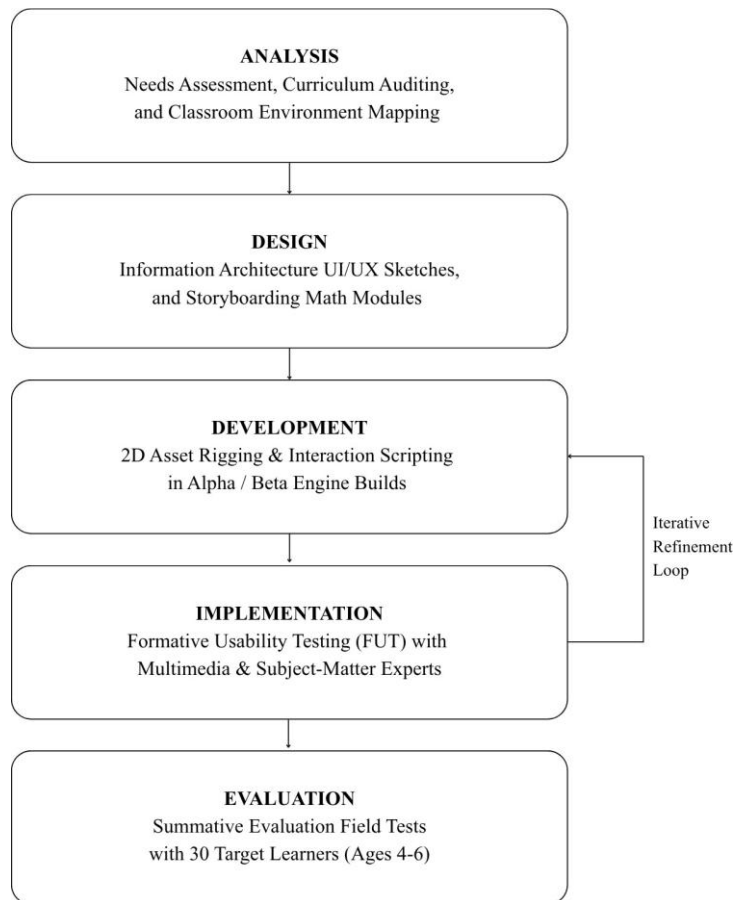


Figure 1: ADDIE Model as a Framework for the Development of the Jom Kira!

This model starts with the Analysis phase which aims to identify user needs, learning problems as well as the application usage environment.

Analysis Phase

The analysis phase is conducted to identify user needs, learning problems as well as the state of the application usage environment. The needs study was carried out at Tadika PASTI Al A'la through an interview session with a preschool teacher, Teacher Fatini, as the main client of the project. The results of the interviews showed that most of the pupils were familiar with numbers from 1 to 10 but still had difficulty maintaining focus during the learning process and understanding the concepts of basic mathematical operations such as addition and subtraction. This condition is due to the use of less interactive learning materials and not providing enough visual stimulation to attract children's attention. In addition, an analysis of the existing facilities found that the kindergarten has a laptop with a touch screen as well as a projector that can be used during the teaching and learning process. Therefore, the Jom Kira app! developed as a web-based application that can be run offline to ensure system stability without relying on Internet access.

Design and Development Phase

Based on the results of the needs analysis, the application design was developed using the Hub-and-Spoke navigation structure, where the main menu acts as the central one that connects users to each learning module. This approach was chosen because it is easier for preschoolers to understand and allows them to quickly access each module. The interface development process begins with the production of the storyboard, screen design as well as the arrangement of the learning content. All graphic assets, character illustrations and 2D animations are generated using Adobe Illustrator and Adobe Animate. To ensure that the Jom Kira! To meet the needs of the target users, several aspects of usability, accessibility and user experience have been addressed during the application design and development process. Among the main features applied are as follows:

Use Oversized Buttons To Make It Easier For Children To Touch

Preschoolers are still in the developmental stage of fine motor skills, making it difficult for them to press buttons that are small or too close to each other. Therefore, each button in the app is designed to be large in size and spaced enough to reduce mis-touch. This design allows children to interact with the app more easily, confidently, and independently without the need for the help of a teacher or parent.

Reduces The Use Of Long Texts.

Since most children between the ages of four and six have not yet fully mastered reading skills, the app uses sentences that are simple, easy to understand and appropriate to their level of language development. Lengthy information is replaced by illustrations, icons, and animations so that users can understand instructions more quickly without experiencing a high cognitive load. This approach is also in line with the Coherence Principles and Multimedia Principles in Multimedia Learning Cognitive Theory (CTML).

Use Clear Icons And Graphics.

The icons and graphics used are designed with bright colors, easily recognizable shapes and have consistent functionality on every display. The use of clear visual elements helps children identify the function of a button or menu without having to read lengthy instructions. In addition, illustrations of objects such as fruits, animals and toys are used to help children's associate numbers with real objects, thus facilitating the understanding of basic numeracy concepts.

Provide Voice Commands In Malay.

To improve user comprehension, each activity in the app is accompanied by voice commands in Bahasa Melayu that use clear, slow and easy-to-understand pronunciation. These audio instructions help children who are not yet fluent in reading to follow each step of learning independently. Additionally, the use of voice narration can reduce reliance on text and support learning through the auditory channel, in line with the Modality Principle proposed by Mayer (2021).

Eliminate Reliance On The Keyboard By Using A Single Tap Interaction.

All functions in the app are designed using single tap interactions, without the need for a keyboard or mouse. This approach makes it easier for children to operate apps using tablets, smartphones, or touchscreen computers. This simple method of interaction reduces user confusion, speeds up the learning process, and allows children to fully focus on the math activities provided.

Provide Audio And Visual Feedback After Each User Action.

The app provides feedback instantly after every action taken by the user. If the answer chosen is correct, the app will display an interesting animation accompanied by a cheerful sound such as "Congratulations!" or a cheerful sound effect. On the other hand, if the answer chosen is incorrect, the app will provide a soft sound and encourage the user to try again without causing stress or frustration. This direct feedback helps to increase motivation, self-confidence and strengthen the learning process through positive reinforcement. In addition, children are able to identify their mistakes immediately and correct them immediately, thus increasing the effectiveness of learning.

This approach aims to ensure that the application is easy to use by children who are still at a stage of fine motor development and minimal reading skills. Figure 3.2 to 3.8 displays the application interface based on the main features above.



Figure 2: Start Page



Figure 3: Main Page



Figure 4: Quiz Module Selection Page



Figure 5: Quiz Module Page



Figure 6: After Quiz Ending Quiz



Figure 7: Learning Module Page



Figure 8: Feedback Popup



Figure 9: Animation Page

The application interface is developed using large buttons to facilitate interaction through the touch screen, the use of clear icons and graphics to improve visual comprehension, as well as the reduction of the use of long texts to reduce the cognitive load on users. In addition, the app also provides voice commands in Malay, *single tap* interactions, as well as audio and visual feedback immediately after each user's action. The combination of these features aims to create a more user-friendly, interactive and fun learning experience, while also increasing motivation and making it easier for children to understand basic math concepts.

However, the development of an educational application does not only depend on the design of an attractive interface but also needs to be ensured to meet the needs of the user and achieve the learning objectives that have been set. Therefore, a formative evaluation process was conducted to identify strengths, weaknesses and aspects that need to be improved before the application is used by the target users. This assessment involves a panel of experts who have expertise in multimedia, interface design, and preschool learning content. The feedback obtained from the expert panel is used as a guide to streamline the design, functionality and usability of the app before entering the final evaluation phase with real users. The following sections describe the findings of formative evaluation and system improvement based on expert evaluation.

Formative Evaluation

Formative assessment is an evaluation process that is carried out during the application development phase to identify strengths, weaknesses and improvements that need to be made before the system is used by actual users. In contrast to summative evaluations that evaluate the effectiveness of the final product, formative evaluations focus on the process of continuous improvement through feedback from experts. This approach allows any issues related to

content, interface design, system functionality, and user experience to be identified and fixed at an early stage of development. Thus, the quality of the application can be improved before entering the co-evaluation phase of the target user (Branch, 2020; Dick et al., 2024).

In this study, a formative evaluation is carried out after a functional prototype has been successfully developed. The evaluation is carried out using the *expert review* method, where each panel of experts is given the opportunity to use the Jom Kira! evaluate the functions provided and provide reviews and suggestions for improvement based on their respective areas of expertise. All comments and suggestions are systematically recorded before being analyzed and translated into improvements to the application. The formative assessment involves three expert panels with expertise in their respective fields to ensure that applications are evaluated comprehensively. Multimedia experts evaluate aspects of graphics, animation, audio, multimedia integration, and overall system performance. The interface design experts evaluate the aspects of usability, *user experience*, navigation structure, display layout and accessibility features of the application. Meanwhile, the content experts consisting of preschool teachers assessed the suitability of the learning content with the preschool curriculum, the level of difficulty of the activities, the use of language as well as the suitability of the application to be used in teaching and learning sessions in the classroom. The formative assessment involves three expert panels with expertise in their respective fields to ensure that applications are evaluated comprehensively.

1. Multimedia Expert

Dr. Mohd Fairuz bin Zaiyadi is responsible for evaluating the graphics, animation, audio, multimedia integration and overall performance of the system.

2. Interface Design Specialist

Mrs. Aeni Zuhana Saidin evaluated the aspects of usability, interface layout, navigation structure, user control as well as accessibility features of the application.

3. Content Specialist/Client

Teacher Fatini acts as a content expert to ensure that the application meets the preschool syllabus, language suitability, level of difficulty of the activity and usability in real learning situations.

Findings of Qualitative Assessment and System Improvement

Overall, the expert panel agreed that the Jom Kira! has an attractive design, appropriate use of colors as well as animations that are capable of attracting the attention of preschoolers. However, some suggestions for improvement have been put forward to improve user experience and learning effectiveness.

Table 2: Findings of Expert Assessment and System Improvement

System Components	Expert Panel Recommendations	Implemented Improvements
Arrangement of Learning Modules	The number identification module must be completed before students access the quiz or learning video activities.	The system is programmed so that advanced modules can only be accessed after the user completes the basic module.

Visual Connection	Display the number along with the object that is being counted so that the child can associate the number with the quantity of the object.	Numbers are dynamically displayed next to the objects that are counted throughout the animation.
Application Accessibility	Provide a clear start button so that children can start the app without the help of a teacher.	A large, brightly colored “Start” button is added to the app’s homepage.
Navigation	Reduce the number of menus to avoid user confusion.	Unnecessary menus have been removed and the navigation structure simplified.
Button Function	Fixes button links that don’t work perfectly.	All navigation scripts are updated to ensure smooth transitions between pages.
User Feedback	The sound of feedback needs to be clearer to distinguish between right and wrong answers.	The audio is updated with a cheerful sound (“Ting”) for the correct answer and a soft sound (“Tet”) for the wrong answer.
Language Alignment	The subtitle text needs to be in sync with the audio being played.	The text display is fully aligned with the voice narrative in each module.

The feedback received from the three expert panels was used as a basis to improve the interface design, navigation functionality, learning content as well as feedback mechanisms in the application. This improvement process ensures that the Jom Kira! Not only does it meet the specified technical specifications, but it is also suitable for use by preschool children and is able to support the early mathematics learning process more effectively. The recommendations given by the expert panel have succeeded in improving the usability, user experience and learning effectiveness of the Jom Kira! Before proceeding to the assessment phase with the target user. These improvements ensure that the app meets the needs of preschoolers in terms of content, interface design, and user interaction. After improvements are made to the application, a summative assessment is carried out to see the applicability of the application to students. The following section describes the summative evaluation carried out on 30 Kindergarten students.

Summative Evaluation on Jom Kira! Application

Summative evaluation is an evaluation process that is carried out after all phases of development and improvement of the application have been completed. The main purpose of this evaluation is to assess the effectiveness of the final product in achieving the predetermined objectives as well as to determine the level of user acceptance of the developed application. In contrast to formative evaluation which focuses on the improvement process during development, summative evaluation is performed when the application is in the final stages to measure the performance of the entire system in actual usage situations (Branch, 2020; Dick et al., 2024). In this study, the summative assessment aims to assess the extent of the Jom Kira! Can support the learning of basic mathematics in preschoolers. This assessment focuses on

several key aspects, namely usability, ease of navigation, learning engagement, attractiveness of interface design, and user experience. In addition, this assessment also measures the ability of children to use the app independently without the need for constant help from teachers or parents.

To obtain more objective findings, summative assessment was carried out using a combination of structured questionnaire methods and direct observation as users interacted with the application. The data obtained was analysed to identify the level of effectiveness of the application from the point of view of achieving learning objectives, ease of use and user satisfaction level. The findings of this evaluation further serve as empirical evidence that the Jom Kira! Meet the needs of target users and potentially be used as teaching aids to support early mathematics learning at the preschool level.

After all the improvements resulting from the formative assessment have been implemented, the Jom Kira! Undergoing a summative evaluation process to assess the overall effectiveness of the application when used by real users. Summative evaluation aims to determine whether the developed application successfully meets the learning objectives, is easy to use by the target user and is able to provide a positive learning experience. In contrast to formative evaluations that focus on the process of improvement during development, summative evaluations evaluate the performance of the final product based on actual use by preschoolers. The findings from this evaluation are used as empirical evidence to verify the effectiveness of the application in terms of usability, user engagement and achievement of development objectives.

Assessment Methods and Participants

The summative assessment was conducted using a quantitative approach through structured questionnaires supported by observational methods during the application usage session. As the respondents consisted of children aged between 4 and 6 years, the questionnaire was conducted by the researchers through face-to-face interview sessions. Each question is read to the respondents using easy-to-understand language, while the answers are recorded using the icon-based Smiley Face Likert Scale. This approach was chosen to overcome the constraints of reading skills among children and to ensure that the data obtained is more accurate and reliable. In addition, the researchers also observed the behaviour, how the respondents interacted and the ability to use the app throughout the assessment session.

A total of 30 preschool children aged between 4 and 6 years old were selected as survey respondents. Respondents were divided into two groups to get an idea of how to use the app in different situations. The first group consisted of 15 students from Tadika PASTI Al A'la, who represented a real learning environment in the classroom. This group is used to evaluate the effectiveness of the application in a real teaching and learning setting. While the second group consisted of 15 children who were randomly selected in the same age range but had never used the app before. This group aims to assess how well the app can be understood and used by new users without any prior description or training. Dividing respondents into these two groups allowed researchers to assess the level of usability, understanding of the interface, and user experience more comprehensively.

Usability and Navigation Performance

Analysis of data obtained from questionnaires and observations shows that the Jom Kira! achieve a high level of usability among the target users. In terms of the initial use of the application, all respondents (100%, 30 out of 30 people) managed to start the application independently by pressing the "Start" button without the need for help from teachers or researchers. These findings show that the design of the home page and the start buttons developed are clear, easy to understand and appropriate for the developmental stage of preschoolers.

In terms of navigation, a total of 23 respondents (76.7%) managed to complete the entire learning module and quiz activities independently. They are able to move from one module to another without facing any significant difficulties. However, 7 respondents (23.3%) needed some help when using the app, especially when selecting a menu or returning to a previous page. Based on the researchers' observations, most of the respondents who needed help consisted of four-year-olds, who are still in the early stages of developing motor skills and understanding of the use of digital applications. Overall, these findings show that the Jom Kira! has a good level of usability and is easy to use by the majority of preschoolers. Any difficulties experienced are minimal and are more influenced by the age factor of the user than the weaknesses of the app's design.

User Satisfaction and Interface Ratings

User feedback on the app is obtained through a questionnaire after they have finished using the Jom Kira! app. The evaluation results show that the app is successful in providing a positive learning experience to users in terms of ease of use, engagement in learning as well as visual design. Figure 5.1 shows a summary of the results of user evaluations of the Jom Kira! application.

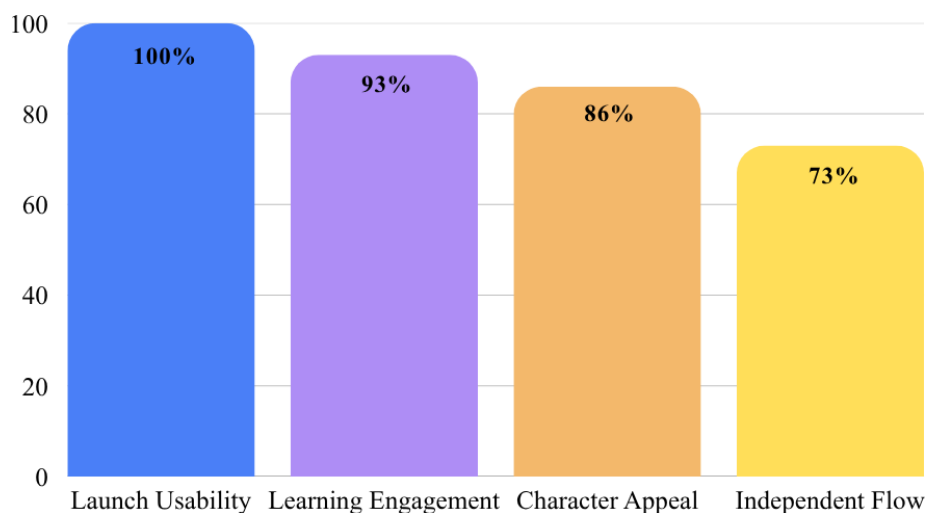


Figure 10: Usability and User Engagement Assessment Results

Based on the evaluation results, the application scored 100% in terms of Launch Usability, indicating that all respondents managed to open the app independently using the "Start" button provided. These findings prove that improvements made during formative assessments

successfully improve the accessibility of applications. In addition, the application scored 93% in terms of user engagement (Learning Engagement). These results show that the use of interactive animations, game elements, audio, and learning activities successfully capture and maintain children's focus throughout the maths learning process. In terms of visual design, the application scored 86% of character appeal and graphics (Character Appeal). Most of the respondents showed interest in the use of 2D cartoon characters, bright colors and interesting animations, thus making the learning process more enjoyable. As for the Independent Flow aspect, the app scored 73%, indicating that the majority of respondents were able to use the application without the help of an adult. Although there were a small number of users who needed some guidance, observations showed that they were made up of the youngest children in the study group. Therefore, this situation is more influenced by the level of cognitive development and motor skills of the user than by the weaknesses of the application itself.

Overall, the results of the summative assessment show that the Jom Kira! successfully meet the development objectives that have been set. The app is not only easy for preschoolers to use, but it is also able to increase user engagement, engage them in maths learning, and provide a fun and interactive learning experience.

Discussion

Findings from formative assessment and summative assessment show that the Jom Kira! successfully meet the development objectives that have been set in terms of pedagogy, usability and technical implementation. Formative assessments involving expert panels have helped identify some weaknesses in the early stages of development, further enabling improvements to be made to the interface design, navigation structure, learning content and user feedback mechanisms. These improvements contribute to improving the quality of the app before it is tested by real users. It can also help to investigate the connection between users and the usability of the application (Rasli et al., 2022).

Meanwhile, the results of the summative evaluation prove that the Jom Kira! able to provide a positive learning experience to preschoolers. A high level of user engagement indicates that the use of interactive multimedia elements such as animation, audio, graphics, and game-based activities is successful in capturing children's attention and maintaining children's focus throughout the learning session. These findings support the view that the use of interactive multimedia can increase students' motivation and engagement in early mathematics learning compared to traditional approaches that are more passive in nature (Mayer, 2021; OECD, 2023). In addition, the development of applications guided by the Cognitive Theory of Multimedia Learning (CTML) also contributes to the effectiveness of learning. The application of the Coherence Principle through the reduction of unrelated elements as well as the Spatial Contiguity Principle by placing numbers near the calculated object has helped to reduce the cognitive load of the user. This approach allows children to process information more easily and improves their ability to understand basic numeracy concepts. The effectiveness of this approach can be seen through the ability of the majority of respondents to complete learning activities and use the application independently.

Despite this, observations during the summative assessment showed that a small percentage of respondents, specifically children as young as four, still needed some guidance when navigating the app. This situation shows that age factors and the level of cognitive development

also affect the user's ability to use the app independently. Therefore, several improvements are proposed to further improve the effectiveness of the application in the future. The first suggestion is to add adaptive visual guides such as animated arrows, light effects (highlights) or interactive indicators that will appear automatically to help users identify which buttons or activities to select. This feature is expected to reduce confusion among younger users as well as increase the level of self-use of the app. The second suggestion is to add an audio volume level adjustment function that allows teachers or users to increase the strength of the narrative voice according to the conditions of the learning environment. This function is important because observations during the assessment find that the ambient noise in the classroom sometimes interferes with the hearing of voice commands provided in the app. With the availability of audio adjustment options, learning instructions can be heard more clearly and thus increase the effectiveness of using the app in various learning situations. Overall, the results of the study show that the Jom Kira! has the potential to be an effective teaching aid in supporting early math learning at the preschool level. The proposed improvements are expected to further improve the usability, user experience and effectiveness of the application in meeting children's learning needs in the future.

Overall, the development of the interactive multimedia application Jom Kira! has successfully achieved the main objectives of the study in terms of education, design and technical development. The application was successfully developed based on the ADDIE Model by integrating interactive multimedia elements such as 2D animation, audio, graphics, instant feedback and game-based learning activities. This approach not only makes the learning process more engaging but also helps children understand basic math concepts such as number recognition, counting activities and add and subtract operations more easily. In addition, the app is developed based on the principles of Multimedia Learning Cognitive Theory (CTML) which helps to reduce the cognitive burden of users through the delivery of information that is more systematic, clear and appropriate to the developmental stage of preschoolers.

The findings from the formative assessment and summative assessment also prove that the Jom Kira! application has a high level of usability and is well accepted by the target users. The majority of children are able to use the app independently, demonstrate a high level of engagement and provide positive feedback on the design of the interface and the learning content provided. These results prove that the use of the Digital Game-Based Learning (DGBL) approach combined with interactive multimedia elements has the potential to increase motivation, interest and mastery of early numeracy skills in preschoolers. Therefore, the Jom Kira app! has the potential to be used as a digital teaching aid that supports the teaching and learning process in early childhood education institutions. In the future, the app can be expanded with the addition of more complex math modules, more diverse gamification elements, artificial intelligence (AI) technology for adaptive learning, as well as learning analytics features to help teachers monitor the progress of student achievement more systematically. These improvements are expected to further enhance the effectiveness of the app as a comprehensive digital learning platform that is relevant to the needs of 21st century education.

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