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Algebra Adventure – An Application to Learn Algebra through Gamification Approach

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Abstract: The creation of innovative multimedia applications in contemporary learning can enhance the student learning process. However, there is a limited multimedia application for learning Algebra with features to increase student's engagement. Therefore, the 'Algebra Adventure' learning application integrated with the gamification approach was purposely developed. The learning contents designed with a focus on Algebra topics for Secondary School students ranged from Form 1 to Form 2 syllabus. Gamification elements such as grading and goals were embedded within the modules to help learners achieving the learning objectives. Game Development Life Cycle (GDLC) model as the application development guidelines consists of five (5) phases; the initiation and pre-production phase, production phase, testing phase, and release phase. Interface designs were supported using Ibis Paint with Adobe Photoshop, while the interaction designs utilized Unity 3d with Visual Studio 2019. A school teacher from Sekolah Menengah Kebangsaan (SMK) Tun Syed Nasir Ismail at Johor Bahru, Johor who has vast experience in teaching Algebra was appointed as the subject matter expert (SME) of this project. Findings from the testing conducted with 10 students from SMK Tun Syed Nasir Ismail show that 90% of the respondents agreed that using the 'Algebra Adventure' application helps them learn Algebra easily..

Keywords: Learning application, Gamification, Algebra game

1. Introduction

Mathematics or also known as' ilmu hisab 'is one of the earliest knowledges and yet plays an important role in many areas. One of the hardest topics in mathematics is Algebra. Algebra comes from the Arabic "al-jabr" which means "meeting", "relationship" or "settlement") is a branch of mathematics that can be characterized as generalizations and extensions of arithmetic. Algebra is also the name of an abstract algebraic structure, namely algebra in a field. Algebra is a branch of mathematics that studies structures, relationships, and quantities. To learn these things, in algebra, symbols (usually letters) are

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used to represent numbers in general as a means of simplification and a tool to solve problems. For example, x represents the number to be known and y the number to be known [1].

Teachers may use additional technology and methods to support teaching and learning in the classroom, such as through tutorial videos on YouTube. However, students may easily become drowsy if they watch an informative film for an extended period. Therefore, it may result in the distraction of the learning process. Therefore, 'Algebra Adventure' is an application developed as a learning aid for students studying Algebra concepts while enjoying playing games, in line with 21st-century learning requirements. To some extent, this method will help teachers achieve the goals and objectives of the pursuit planned during the teaching and learning sessions taking place in the classroom. This project aims to produce an Algebra learning application with interesting features for Form One and Two of high school pupils engaging with 3D objects from everyday life and gamification, thereby improving students' and teachers' learning processes in several ways.

In these proceedings, there are five sections covering project development. Section 1 is an introduction that describes the background of the project as an example of a problem statement related to the development of the project, the objectives required in the project, the importance of the project, and the scope covered in the plan. Next, section 2 of the Related Work review includes learning application, gamification, and comparison between applications. While section 3 of the methodology application describes in detail the application development phase using the Games Development Life Cycle (GDLC) model. Section 4 describes the discussion and results of the project through the functionality test and the target user acceptance test, and section 5 related to the conclusion.

2. Related Work

2.1 Learning Application

Learning applications, often known as E-learning, are a method of transmitting knowledge via the use of computer and network skills. It enables students, in particular, to study at their own pace, at any time, and in whatever sequence they choose. Web-based learning, computer-based learning, virtual educational possibilities, and digital collaboration are all examples of e-learning. The third generation of E-learning is a more collaborative learning environment that promotes reflective practice using tools like online communities and interactive technology like games and simulations [2]. However, because e-learning might create a geographical and temporal gap, it is important to customize students' educational experiences to keep them engaged and motivated. Furthermore, the usage of ICT in developing nations is not as prevalent as in developed countries, resulting in a lack of acceptance of technical resources and, as a result, of e-learning, which does not have the desired effect on educational learning [3].

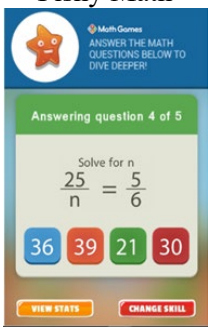
2.2 Gamification

Gamification is the use of game aspects, often video game components, in non-game contexts to increase motivation and participation in learning. Many students are alienated by traditional methods of education, and gamification in an educational setting gives some pleasure. The use of gamification might give a potential solution to the current education system's decrease in student motivation and engagement [4]. By 2014, a gamified service for consumer goods marketing and client retention will be as significant as Facebook, eBay, or Amazon, with more than 70% of Global 2000 companies having at least one gamified app. More than half of businesses that manage innovation processes will gamify their processes by 2015, according to predictions. As stated, gamification is an important component of an application since it ensures the efficacy of its use [5].

2.3 Comparison of Applications

Fishy Math, a matching and math-based educational game. Beautiful schools of fish of all hues may be seen deep in the ocean. In addition to fish, there are jellyfish, starfish, and even sea animals to match. Your goal is to use your finger or mouse to grab these marine animals, run through them, and connect them. Enjoy the bonus part, when you will encounter a slew of falling gems to match for additional points. Between each round of this entertaining online game, brush up on your arithmetic abilities. Math skills are taught from kindergarten through eighth grade. Math skills range from addition, subtraction, and counting through algebra, geometry, and graphing at all levels. You will be able to play the matching game again if you have answered 5 questions correctly [6].

Table 1: Application comparison

Application	Description
Fishy Math 	Users need to answer 5 Algebra direct questions correctly and then users will match the same type of fish in that ocean by drag the same type of fish with another fish. By that score will count on how much users can match the fish at one time.
Treasure Diving: Solving One-Step Equations (Mixed Operations) 	There are a few characters that users can choose. A chosen character will race until the finish line but in a way to the finish line, users have to answer a few Algebra direct questions and multiple-choice answers provided in the bubble. Users can pass the obstacle by clicking the correct bubble.
Solving Basic Algebraic Equations: Basketball Edition 	Users answer a few Algebra direct questions with three (3) multiple-choice answers. Users need to click the correct answer and then the character that is Penelope can shoot a ball to score in basketball.

Treasure Diving, solving One-Step Equations (Mixed Operations); In this entertaining math race, children showed their algebra abilities. Treasure Diving: Solving One-Step Equations (Mixed Operations) is a sixth-grade learning game in which players race their character to the undersea finish line while mastering one-variable equations involving addition, subtraction, multiplication, and division [7].

Solving Basic Algebraic Equations: Basketball Edition, by solving fundamental algebraic equations, users may join Penelope as she dribbles, shoots, and scores her way across the court. Working

on a variety of operations, from addition to division, users get familiar with algebra and begin to comprehend expressions and equations [8].

Several notable similarities exist in all three applications. The first is that users can use these applications on personal computers because these applications are web-based. The second has a musical background that can interest the users. The third is an attractive graphic design and the use of colors that are appropriate for the target user for each application. And the last is, the way users answer Algebra equation questions by clicking on the answer options that have been provided. Table 1 below shows a comparison of the three applications.

3. Methodology

The GDLC technique was used in the development of this game, which consists of six stages: initiation, pre-production, production, testing, beta, and release. The Game Development Life Cycle (GDLC) is a set of guidelines that regulate the game development process. This technique follows the creation of a game from beginning to end. Where it starts with the formation of the game's idea and concept and ends with the marketing of the game [9].

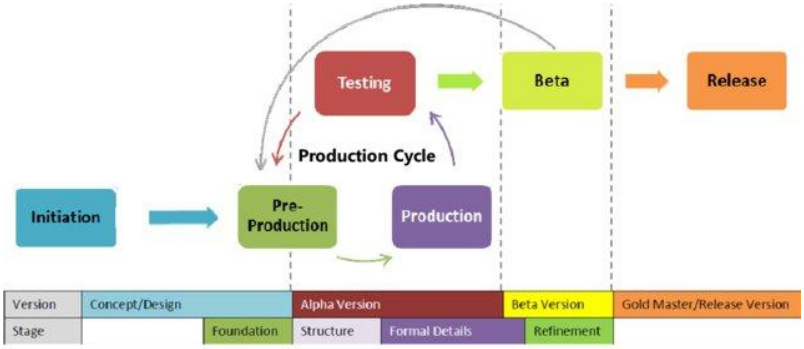


Figure 1: GDLC Methodology [10]

3.1 Initiation Phase

The first step in developing a game is to come up with an idea and material for the game that wants to produce. There are various phases to examine in this stage, including the type of game created in the adventure genre with 3D graphics, determining the game's aim is to offer knowledge about algebra, and determining if the game is run on personal computer devices. Other than that, developers have targeted form one and two students as the main users. To find out the problem and identify the deeper background of the problem, the developer conducted an interview with a mathematics teacher at Sekolah Menengah Kebangsaan Tun Syed Nasir Ismail, Ms. Fadhirah Mohammed. This interview is more about the learning environment and the content of the mathematics subject. Several questions were asked related to teaching aids, problems often faced by mathematics teachers during teaching and learning, topics that are most difficult to understand by students, and challenges often faced by teachers while teaching mathematics subjects form one and two. Table 2 and 3 showfunction requirement and non-functional requirements.

Table 2: Function requirement

Function Requirment	Description
Exercise Module	● At this module, users can see Algebra direct questions and answer all questions. ● After users answer all question, users can know their score.
Adventure Module	● At this module, users can control the character (view).

Table 2: (continued)

Function Requirment	Description
	• Users need to find book to answer Algebra problem solving questions. • After user found all the books, user need to search a key to unlock second and third places.

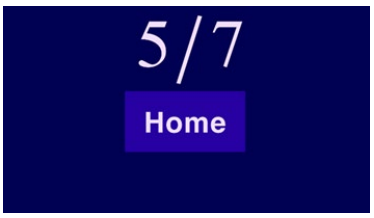
Table 3: Non-functional requirement

Non-functional Requirement	Description
Implementation	This application can display the modules or functions required by the user.
Performance	This application takes five seconds to open.
Availability	This application does not require an internet network to work.
Compatibility	This application can work on Windows 10 systems and above.
Usability	The app works entirely in English.

Table 4: Storyboard

Mainpage

Practise Module



Practise Score

Level Selection


Level 1


Level 2


Level 3

3.2 Pre-production

The development process would have to undergo the pre-production process before the actual production phase starts. The pre-production process is where the game design will be created. The specifics of the game idea, the game genres, character, game physics, game features, and several other aspects will be used in the game design.

The storyboard concept will also be shown in the process. Storyboard for games can help organize actions and experiences that need to be developed. Adobe Photoshop is used to create a game storyboard. In this step, the flowchart, the navigation system, and the material framework are also provided to support the design process.

In table 4, storyboard and design implementation. The storyboard was the earliest step in develops the application. Design implementation was based on the storyboard that has been illustrated but for level 1, level 2, and level 3, the developer changes the place from outdoor to another indoor places.

3.3 Production Phase

After the pre-production process has been done and the design of the game has been finalized, the development of the game will begin the production phase. There will be 2 sub-phases engaged in the development of the game, which is asset planning and scripting.

The storyboard from the previous process will be used to coordinate the design of the graphic assets. Adobe Photoshop would be used to draw assets for the proposed game, as the game uses 2D characters. Half of the assets in Algebra Adventure were created by a developer using Blender such as bed, bedside table, closets, lamps, book, and key while the other half was downloaded from the Unity Assets Store and CGTrader.

The game objects will need scripts, and the debugging of scripts will take a bit of time when an error happens. This process is also known to be more complicated than the other stages. For this phase, Microsoft Visual Studio 2019. The scrip that was used in Algebra Adventure was item pick up, scene switch, quiz manager, life in levels 2 and 3, and many more. Table 5 shows the application interfaces.

Table 5: Application Interface and description

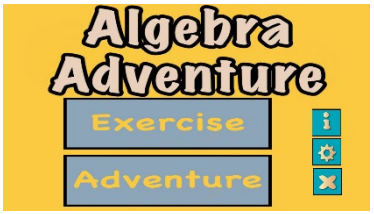
Application Interface	Description
	• Start Interface • This interface display the module in this application
	• Mainpage Interface • This interface contain 5 buttons that navigate to differents interface.

Table 5: (continued)

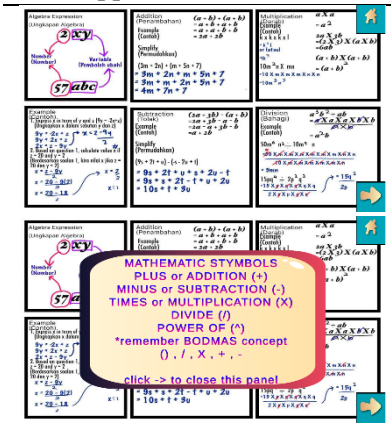
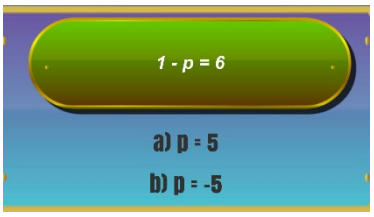
Application Interface	Description
	• Info Interface • This interface contains a few steps of answering questions and symbols of operations that use in this application. • Home button will navigate interface to mainpage. • Next button to open extra panel for info.
	• Setting Interface • Users can control audio volume. • This interface display user manual.
 	• Exercise Interface • This interface contain 10 questions of direct Algebra. • The buttons will turn to green if the answer selection is correct while red of wrong.
 	• Places Interface • This interface contain 3 buttons (places) that navigate to differents interface (places). •

Table 5: (continued)

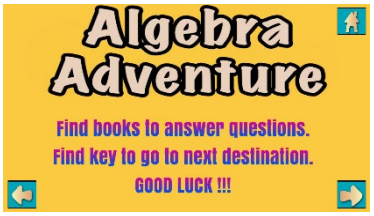
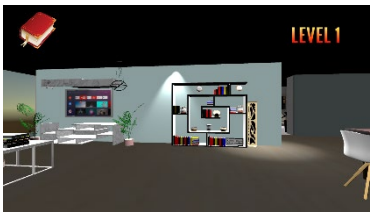
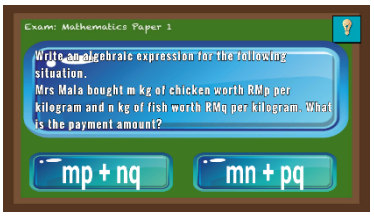
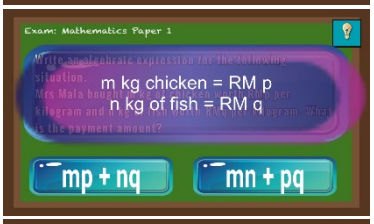
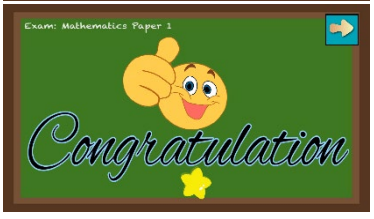
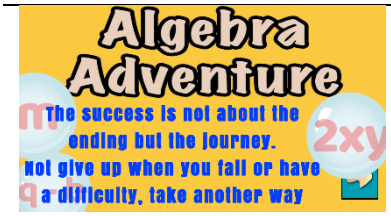
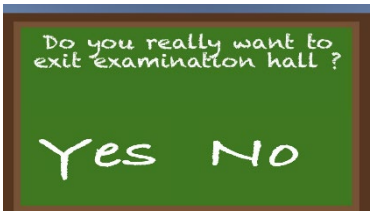
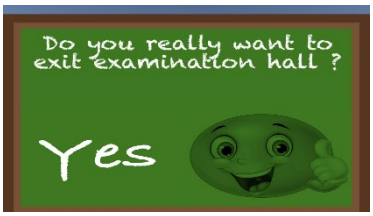
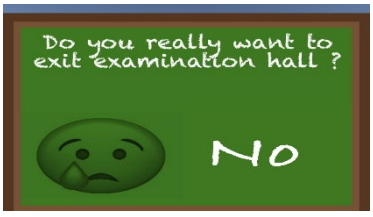
Application Interface	Description
	
	• Instruction 01 Interface • This interface display an instruction for first place.
	• First place Interface
	• Questions 01, 02, 03 Interface • This interface contain Algebra problem solving questions after users get book in every places
	
	• Success Interface • This interface displayed after users success to get all books and key. •
	• Second places Interface

Table 5: (continued)

Application Interface	Description
	• Third place Interface
	• Fails Interface • This interface displayed after users fail to get all books and key.
	• Ending Interface • Next button navigate to main page
	
	• Close Interface • If user click button no, application will navigate to homepage. • If user click button yes, application will be close.
	

3.4 Testing Phase

In this phase, two sub-phases were Alpha testing and Beta testing. For Alpha testing, the prototype of the game was tested by the developer, but for Beta testing, the expert, and students of forms one and two tested the prototype. The Black box testing method is also used for Algebra Adventure.

3.5 Beta Testing

Beta testing is a step for third-party or external testing. Beta testing will be conducted to find the final bugs left out in Alpha testing. This process would also help to collect input and advice from third-party testers. The Algebra Adventure application will be reviewed by target users that are form 1 and 2 students from Sekolah Menengah Kebangsaan Tun Syed Nasir Ismail to assess and evaluate the user's approval of this application. Due to the results of this test, it will be determined whether to proceed to the next phase, which is the release phase or to relocate to the pre-production phase.

3.6 Release Phase

The release process is the last step of the GDLC methodology model. Here, the game that has entered its final stage will eventually be published to the public. After some well-defined preparation and numerous testing by developers and end-users have been done, the application will be optimized. In other words, the application will be error and bug-free, with a refined interface from the recommendation given by the users during beta testing. The application is ready to be released to the market.

4. Results and Discussion

4.1 Data analysis on Preliminary Study

This section explains the preliminary analysis conducted at the early phase of the application development. An online survey was conducted to investigate the needs and opinions of potential users of the application.

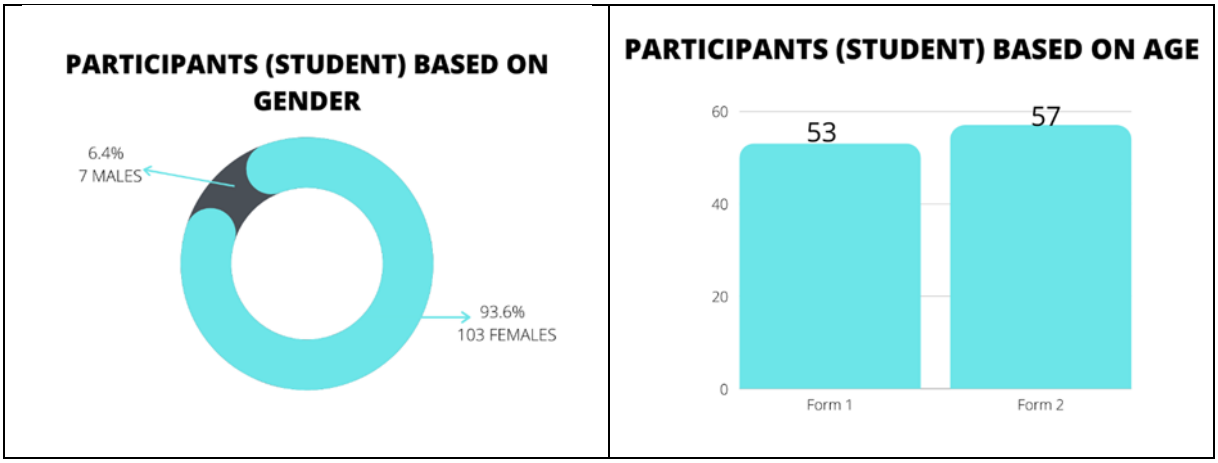


Figure 2: Gender and age distribution of participants (students)

Total numbers of 110 students from Sekolah Menengah Tun Syed Nasir participated in the online survey, while most of them are female students. Figure 2 depicts the gender and age distribution of participants (students).

The results in Table 6 represent the students' perspectives on the use of technology in learning, particularly in Algebra. Most of the students responded positively about applying technology in learning Algebra to attract students and enhance their enjoyment. Utilizing technology in the learning process offers an attraction for students to engage in the learning content compared to textbook references.

Table 6: Students' perspectives on the use of technology in learning

Questions	Yes (%)	No (%)
Have your teacher ever used an educational application that helps you to learn in a scientific subject?	37.4	62.6

Questions	SA (%)	A (%)	D (%)	SD (%)
Are existing ways of teaching scientific topics in schools sufficient for you to master the content?	24.5	36.4	19.1	20.0
You spend a large amount of time using technology.	72.7	18.2	6.4	1.8
You support the idea of creating an educational application that helps in teaching students the scientific material	56.4	18.2	13.6	11.8
Electronic educational applications are better than educational books in the learning process for you.	54.5	20.0	18.2	7.3

4.2 Black Box Testing

Black box testing, also known as Behavioral Testing, is a software testing method in which the internal structure/design/implementation of the item being tested is not known to the tester. These tests can be functional or non-functional, though usually functional [11]. Table 7 shows the summary of black-box test results for the navigation button.

Table 7: Black box result

Testing (Buttons)	Expected Result	Actual Results	Corrective action
EXERCISE	Navigate to exercise module	Success	None
ADVENTURE	Navigate to adventure module	Success	None
Setting symbol	Navigate to setting interface	Success	None
"i"	Navigate to info interface	Success	None
"X"	Navigate to close interface	Success	None
House	Navigate to first places	Success	None
Coffee	Navigate to second places	Success	None
Graduation cap	Navigate to third places	Success	None
Back	Navigate to previous interface	Success	None
Replay	Replay the places or questions	Success	None

Table 7: (continued)

Testing (Buttons)	Expected Result	Actual Results	Corrective action
Next	Navigate to next interface	Success	None
Home	Navigate to mainpage	Success	None

4.3 User Acceptance Testing

To make sure this app works well, testing and evaluation has been done. This test was done using Google Form and some questions were asked in the questionnaire. Testing and evaluation is done by involving the target users after the application is completed. In addition, this testing is done to ensure that the application has met the requirements and needs of users. This test was conducted by 10 individuals of different classes. Table 8 shows the results of the respondents' feedback calculated using the Likert scale. Figure 3 is a percentage of the respondents' feedback.

Table 8: Respondents' feedback

Feedback	Yes (%)	No (%)
This application is very useful for you	90	10
The mission in this app so hard to play	30	70
The questions in exercise module is so difficult to solve	20	80
The questions in adventure module so difficult to answer	30	70

Figure 3: Respondents' feedback

Based on the percentage diagram of the Likert scale, it can be concluded that the highest frequency in the graph of Statement 1 (This application is very useful for you) the average respondent stated in Statement 1 is yes 9 people with a percentage of 90%. While in statements 2 and 4 (The mission in this app is so hard to play and the questions in the adventure module so difficult to answer), the average

respondent stated in the statement is yes 3 people with a percentage of 30%. And for statement 3 (The questions in the exercise module are so difficult to solve), 2 people (20%) think yes for that statement.

Based on the testers' feedback, it is proven that "Algebra Adventure" can help them to learn Algebra in a different atmosphere than usual, learning in the classroom. Therefore, the function of gamification is very necessary for learning in the century of modernization to attract users to learn and gamification should be inserted in every learning application so that the application is not boring for the young users..

5. Conclusion

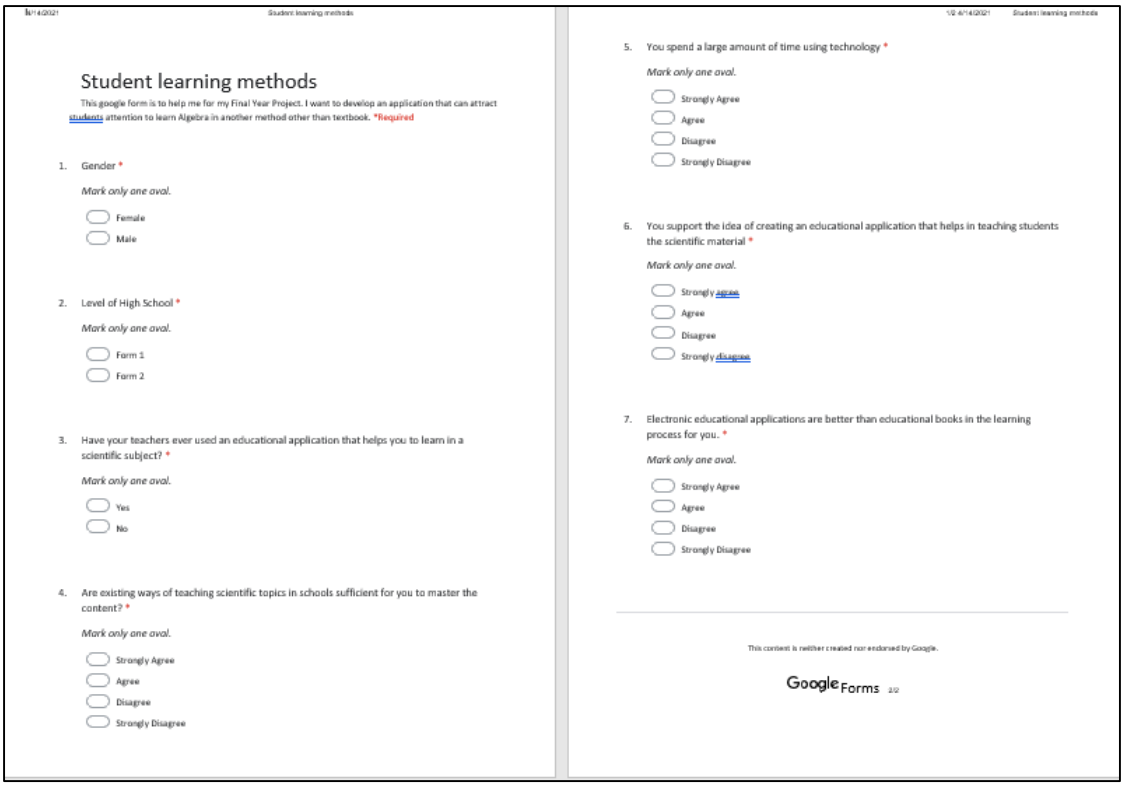
The 3D game "Algebra Adventure" was created as an educational game to provide information about Algebra. The process of making the game "Algebra Adventure" uses the GDLC method (Game Development Life Cycle) which has stages, namely Initiation, Pre-Production, Production, Testing, Beta, and Release.

The development of the "Algebra Adventure" application began after researching some materials such as the background of the problem and interviewing one of the teachers at Sekolah Menengah Kebangsaan Tun Syed Nasir Ismail to find out some of the problems faced by the students. After that, the storyboard is sketched to know the application flow. Then, application development continues by designing and downloading assets and scripts that will be used in the application animation functionality. The testing phase uses the black box method performed by the developer after the completion of the production phase. After that, continue to get feedback from potential targets from Sekolah Menengah Tun Syed Nasir Ismail who think that this application can help them in learning the topic of Algebra. And finally, this application can be marketed on the Internet.

Acknowledgement

The authors would like to thank the Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia for its support and encouragement throughout the process of conducting this study.

Appendix A



Student learning methods

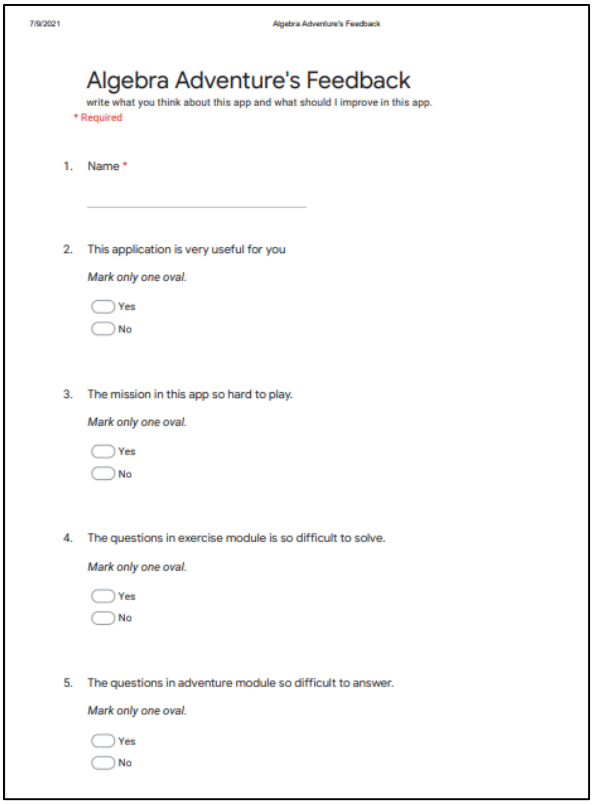
This google form is to help me for my Final Year Project. I want to develop an application that can attract students attention to learn Algebra in another method other than textbook. *Required

1. Gender *
   Mark only one oval.
   - Female
   - Male
2. Level of High School *
   Mark only one oval.
   - Form 1
   - Form 2
3. Have your teachers ever used an educational application that helps you to learn in a scientific subject? *
   Mark only one oval.
   - Yes
   - No
4. Are existing ways of teaching scientific topics in schools sufficient for you to master the content? *
   Mark only one oval.
   - Strongly Agree
   - Agree
   - Disagree
   - Strongly Disagree
5. You spend a large amount of time using technology *
   Mark only one oval.
   - Strongly Agree
   - Agree
   - Disagree
   - Strongly Disagree
6. You support the idea of creating an educational application that helps in teaching students the scientific material *
   Mark only one oval.
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree
7. Electronic educational applications are better than educational books in the learning process for you. *
   Mark only one oval.
   - Strongly Agree
   - Agree
   - Disagree
   - Strongly Disagree

This content is neither created nor endorsed by Google.

Google Forms

Figure 4: Preliminary study



Algebra Adventure's Feedback

write what you think about this app and what should I improve in this app.
* Required

1. Name *
2. This application is very useful for you
   Mark only one oval.
   - Yes
   - No
3. The mission in this app so hard to play.
   Mark only one oval.
   - Yes
   - No
4. The questions in exercise module is so difficult to solve.
   Mark only one oval.
   - Yes
   - No
5. The questions in adventure module so difficult to answer.
   Mark only one oval.
   - Yes
   - No

Figure 5: Application feedback

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