

# Development of Gamification Linear Algebra Application Using Storytelling

Rini Hafzah Abdul Rahim  
Faculty of Computing and Informatics  
Universiti Malaysia Sabah  
Malaysia  
rinihafzah@yahoo.com

Siti Hasnah Tanalol  
Faculty of Computing and Informatics  
Universiti Malaysia Sabah  
Malaysia  
hasnah@ums.edu.my

Rozita Ismail  
College of Computer Science and  
Information Technology, Universiti  
Tenaga Nasional, Putrajaya Campus,  
Malaysia  
irozita@uniten.edu.my

Aslina Baharum  
Faculty of Computing and Informatics  
Universiti Malaysia Sabah  
Malaysia  
aslina@ums.edu.my

Emelia Abdul Rahim  
Faculty of Business Management,  
Universiti Teknologi MARA Cawangan  
Sarawak, Kota Samarahan, Sarawak,  
Malaysia  
emeliassc255@yahoo.com

Noorsidi Aizuddin Mat Noor  
UTM CRES, Faculty of Built  
Environment and Surveying, Universiti  
Teknologi Malaysia, Johor Bahru,  
Johor, Malaysia  
noorsidi@utm.my

**Abstract**— Students often experience carelessness, lack of confidence and less motivation to learn Mathematics, thus, teaching aid tool is needed to increase student engagement to learn Linear Algebra. This mobile based proposed teaching aid tool application was developed to change teaching and learning process to become more interesting, fun and motivated. The application development process was based on the design of the study initiated using storytelling gamification with the implementation of three main phases; Pedagogy Phase, Design Phase and Evaluation Phase. The three main phases were divided into smaller components to facilitate the process of achieving the goals set by each phase. This study used the syllabus from Polytechnic Malaysia with the focus group of students in semester three (Mechanical Engineering) and semester four (Electrical Engineering). The Evaluation Phase was divided into two main tests which are the Preliminary Test and Final Test. This research used mixed method of the combination of quantitative, by using survey, and qualitative, by using Electroencephalogram (EEG).

**Keywords**—gamification, linear algebra, storytelling, EEG, teaching

## I. INTRODUCTION

Gamification Linear Algebra is one of the initiatives to implement gamification for the purpose of teaching and learning process for Mathematics Linear Algebra to be more interesting, fun and motivated. The development process is based on the design of the study initiated with the analysis process, followed by the implementation of three main phases which are Pedagogy Phase, Design Phase and Evaluation Phase.

## II. RELATED WORK

Storytelling is one of the approaches outlined for the success of gamification in education [1], as gamification gives freedom to fail, rapid feedback and progress in learning. Storytelling can also help make gamification unique from others because it has its own goals and storylines [2], for example, solving the main goal of learning by rewarding gamification as an encouragement to complete the assignment given.

There are some recent studies that use the storytelling approach in gamification. The first gamification is Ato's

Adventure: A journey through space and time, for students aged three to seven years to train students for graphomotor skills [3]. The second gamification is RefugeeScout, which is created using a narration to educate visitors or tourists who want to learn about German culture [4]. By using pictorial storytelling strategies, users are encouraged and motivated to use this app as they are keen to know and learn the cultures and costumes found in German. The third gamification is Apollo that combines an interactive approach, narration and 3D visuals for learning Physics [5]. Storytelling is used to say that Apollo space has experienced a breakthrough and loss of contact with Earth. The computer must be repaired, and to do this, the player acting as the Pilot must help contact Earth. The pilot must help in determining the parameters needed to send the message, and the computer assigns Physics tasks to be completed and the video is used to show the explanation. From this three gamification, it can be seen that storytelling can be used to convey events in the form of words, sounds or images used as entertainment tools, cultural preservation, tools for applying moral values and education.

## III. METHODOLOGY

The research methodology used in this study was adaptation [6], and it was adopted by the study conducted by [7]. The model used is the Three-Stage Thinking Model, where this model connects the Pedagogical Phase, Design Phase and Evaluation Phase. At Pedagogical Phase, some things were taken as the Curriculum Objectives to be achieved, the Goal of Goals to be achieved, existing skills of the students and the Knowledge Improvement of the students. After completing all the processes in the Pedagogical Phase, Design Phase and Evaluation Phase needed to be implemented. At the Design Phase, emphasis was given to the Design of Gamified Designs, the Design of the Gamified Assignment and the Gamification Interface Design. After completing all the processes for Design Phase, further Evaluation Phase can be implemented where this phase is divided into two stages: Preliminary Test and Final Test. The performance evaluation and achievement efficacy process were developed in terms of Experience, Mechanics, Rewards, Goals and Social Factors. Figure 1 shows the research methodology framework.

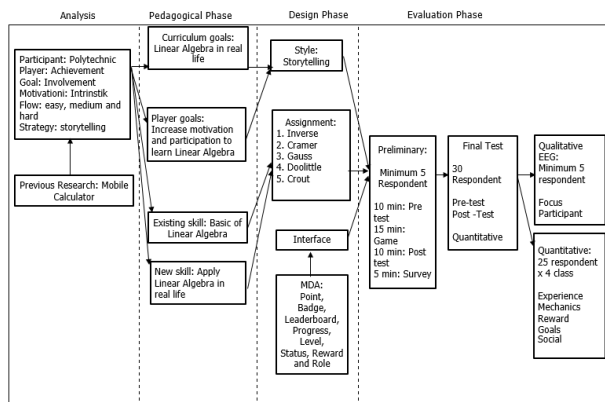


Figure 1. Research methodology framework

Figure 1 shows the methodology for the purpose of this study. It starts with the Analysis Process and is followed by three main phases, the Pedagogical Phase, the Design Phase and the Evaluation Phase. Each phase has several processes that need to be implemented to ensure that the developed gamification prototype achieves the objectives.

The analysis process acquired all basic information such as participants, players, goals, motivations, flow concepts and gamification strategies. Second is the Pedagogical Phase where it obtains information on pedagogical approaches that are curriculum goals, game goals, existing skills and new skills. Third is the Design Phase where it aims to implement the design process based on the gamification style information, gamification task and gamut interface. Fourth is the Evaluation Phase where it focuses on the gamification testing process consisting of preliminary test and the final test using mixed method; Quantitative (survey) and Qualitative (Electroencephalogram).

Participants targeted as prototype users were Polytechnic Malaysia students who were Mechanical Engineering students in semester three and Electrical Engineering students in semester four. This is because, the topic of the prototype development scope was focused on the syllabus for solving simultaneous linear equation problems by using Inverse and Cramer's Rule that the students have learned in DBM1013 Engineering Mathematics 1 and solving simultaneous linear equation by using the Gaussian, LU Doolittle and LU Crout method that the students have learned in DBM3013 Mechanical Engineering Mathematics and DBM3023 Electrical Engineering Mathematics. The type of player targeted was Achievement category [8]. The type of game goal was targeted to increase players' involvement. The type of motivation aimed to encourage player by using intrinsic motivation [9]. The concept of target prototype player flow was an easy, medium and hard flow concept [10]. The targeted strategy was using storytelling strategy [11]. The storyline for the prototype was developed to give the player the choice to become King or Queen of Kings for Kingdom of Linear Algebra. The player must help the King or Queen of Kings to solve five problems faced by the people and after the King or Queen of Kings solved the problems faced by the player, and will be awarded with the appointment of the King or Queen of the King for the Linear Algebra of the Kingdom.

#### IV. PEDAGOGICAL PHASE

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prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

#### V. PEDAGOGICAL PHASE

The main focus was to get information for curriculum goals, player goals, existing skills and new skills. The curriculum goals for DBM1013 were to practice mathematical knowledge and skills in different mathematical problem for solving simultaneous linear equations using Inverse method and Cramer's Rule up to three variables and curriculum goals for DBM3013 and DBM3023 to practice mathematical knowledge and skills in different mathematical problem for solving simultaneous linear equations using Gaussian, Doolittle and Crout. The two main pedagogical phase goals were to increase students' motivation to learn Linear Algebra and to increase students' involvement in learning Linear Algebra.

The syllabus and curriculum learned at Polytechnic is a continuation of what has been learned by students on Linear Algebra from Secondary School which was students' existing skills. Meanwhile, for the new skills, the researchers took the initiative by diversifying the use of Linear Algebra in real life activities that are relevant to the learning that they wanted to convey. Since there are five methods of Linear Algebra equations simultaneously, the researchers used five daily activities that can be attributed to the simultaneous use of equations. The approach was used to control the traffic in the roundabout for Inverse method of calculation, the combination of three ingredients to produce fire was used for Cramer's Rule's method of calculation, the process of transmitting and receiving computer data for the Gaussian method of calculation, the process of electricity supply flow for a three-lamp (blue, red and green) for the LU Doolittle calculation method and the air flow process in vehicle engine for the LU Crout calculation method.

#### VI. DESIGN PHASE

The main focus of this phase was to get information for prototype style, assignment and interface. The style of learning chosen was storytelling. The style enabled the presentation of learning and story presentation to be delivered to players and students more effectively. In addition, the style of storytelling can attract students to learn [12].

Assignments were divided into two categories, which are Tutorial and Quiz. Upon completion of the assignment, the player will be awarded with the category of King or Queen that is compatible with the player's achievement in solving the questions given.

Storyboard is very important for the purpose of designing prototype interface and storyboard as shown in Figure 2.

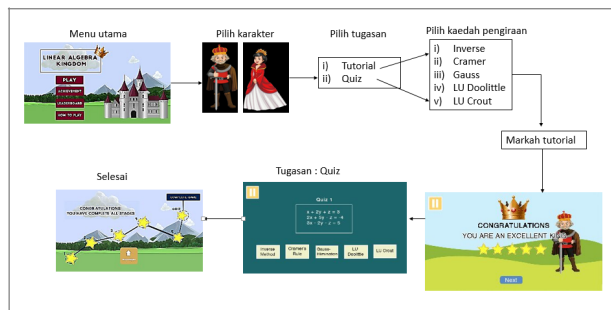


Figure 2. Storyboard for Gamification Linear Algebra

Figure 2 shows a storyboard example for the introduction of Linear Algebraic prototyping prototype. In this introductory storyboard, there are five calculation methods for the Algebra Linear by using Inverse, Cramer's Rule, Gaussian, LU Crout and LU Doolittle. In addition, five situations were used for the use of Linear Algebra equations in real life such as traffic control in roundabout, a combination of three ingredients to produce fires, transmitting and receiving data for networks, electrical distribution of a circuit that has three different bulbs and air distribution to enable a working engine. Figure 3 shows storytelling for Inverse calculation.

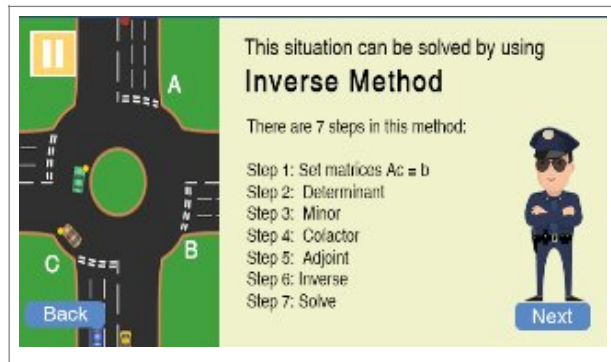


Figure 3. Storytelling for Inverse calculation

Figure 3 shows the storyboard of the calculation by using the Inverse Method. For Inverse calculations there are seven steps, which are  $Ac = b$ , determinant, minor, cofactor, adjoint, inverse and solve.

## VII. PROTOTYPE DEVELOPMENT

The process of development of Linear Algebra prototype was implemented by selecting appropriate, stable software and had various reference sources and guides to facilitate the development process of gamification. There was various gamification software available in the market, however, the software selected to develop this prototype used the Unity 2017. This is because this software met all the features as well as ease to include graphics and sound. In addition, this software was able to produce gamification for various platforms such as android, iOS, tablets and computers. In addition, Photoshop CS6 software was used for graphic and C# for programming language. Figure 4 shows introduction interface for Kingdom Linear Algebra.



Figure 4. Introduction page for Kingdom Linear Algebra

Figure 4 shows the introduction interface for Kingdom Linear Algebra. Before starting the game, players were given the options to play two characters, either as King or as Queen of the Kings for the Kingdom Linear Algebra. The player acting as a King or Queen of the King was given the situation of the problems faced by the people. There were five problems which are:

- i. Police personnel who face difficulties in controlling traffic on the circle by applying Inverse calculation method.
- ii. Researchers who face the problem of solving the production of fire using three materials namely air, heat and oil by applying the method of calculating Cramer's Rule.
- iii. Officers having problems managing the receipt and transmission of data for the use of three equipment namely laptops, tablets and smartphones by applying the Gauss-Elimination calculation method.
- iv. The electrician who faces the problem of distributing electricity to an electric circuit and then turns on three blue, red and green lights by applying LU Doolittle's calculation method.
- v. Mechanics that deal with the problem of distributing air for a vehicle engine to function perfectly by distributing air to three engine components by applying LU Crout's calculation method.

The chosen character of the King or the Queen of Kings should assist the police, researchers, officers, technicians and mechanics in solving the problems they faced by solving tutor questions for each of the five levels provided. That was the first stage of the Inverse method of calculation, the second level of the Cramer's Rule calculation, the level three for Gauss calculation, the fourth level for calculus LU Doolittle and the fifth level for LU Crout calculation.

## VIII. CONTENT VALIDATION

Content Validation was implemented to ensure that the content was based on the syllabus set for Polytechnic Malaysia topic four of DBM1013 Engineering Mathematics 1 and topic two of DBM3013 Mechanical Engineering Mathematics and DBM3023 Electrical Engineering Mathematics. Four lecturers in Mathematics, Science and Computer Department, Polytechnics Kota Kinabalu were selected for Content Validation. They comprised of the first Lecturer, Mr. Fuad Omar as the Head of Mathematics Course. The second lecturer is Mr. Helley Helen as Lecturer for DBM3013 Mechanical Engineering Mathematics. The third lecturer is Mrs. Masni Binti Tasmin as Lecturer

Coordinator DBM3013 Mechanical Engineering Mathematics and DBM3023 Electrical Engineering Mathematics and the fourth lecturer is Mrs. Najwa Shahida Binti Mohamad as lecturer for DBM3023 Mathematics of Electrical Engineering. Table 1 shows the feedback received.

Table 1. Kingdom Linear Algebra Content Validation

No.	Item	L1	L2	L3	L4
1.	Selected topic	√	√	√	√
2.	Content meets syllabus	√	√	√	√
3.	Gamification learning approach appropriate.	√	√	√	√
4.	Suitable content layout.	√	√	√	√
5.	Font size suitable.	√	X	X	√
6.	Voice clear and suitable.	√	X	X	√
7.	Gamification approach is compatible with learning.	√	√	√	√
8.	The approach of the gamification (obstacles, lives, eyes, stars and badges) is appropriate.	√	√	√	√
9.	Assignment is appropriate.	√	√	√	√
10.	The order of the questions in the subtopics and the level of learning is appropriate.	√	√	√	√

Table 1 shows the results of the Content Verification feedback for Linear Algebra prototype by four lecturers showing that there were 10 items evaluated in terms of topic selection, content matching syllabus, suitability of gamification approach, content layout, writing size, sound, gamification learning suitability, the use of gamification element, the number of questions and the order of questions used. The feedback shows that the majority of evaluators agreed with the developed prototype and the improvisation needed to be implemented for the aspect of the font size used and the use of more effective voice to produce more exciting and fun gamification learning.

## IX. EVALUATION PHASE

The phase is divided into two main testing stages which are Preliminary Test and Final Test. A pilot test was conducted to make the initial test and prepare before the Final Test. During Preliminary Testing, some things needed to be scrutinized and noted to ensure that the process for making improvements can be implemented so that the same problem did not arise during the Final Test.

Preliminary Test was conducted with a minimum of five respondents where the time distribution would be for the first 10 minutes to answer the pre-test question, the second 15 minutes to test the prototype of Algebra Linear gamification learning, the third 10 minutes to answer the post-test and 5 minutes to answer survey questions.

The final test was conducted with a minimum of 30 students for four classes at selected Polytechnic. The Final Test requires students to answer pre-test, post-test, and survey questions. The survey evaluated aspects of

experience, mechanical system, reward, goals and social, while EEG tests were conducted to assess the focus and involvement of the students. Students were divided into two groups of 25 students to answer quantitative survey while five students used EEG tools. For the time distribution, the first 10 minutes were allocated to answer the pre-test question, the second 15 minutes to test the prototype of Algebra Linear gamification learning, the third 10 minutes to answer the post-test and 5 minutes to answer survey questions. The target of five students for EEG test was dependent on the number of EEG testing tools available during the test. The flow chart for the Evaluation Phase is shown in Figure 5.

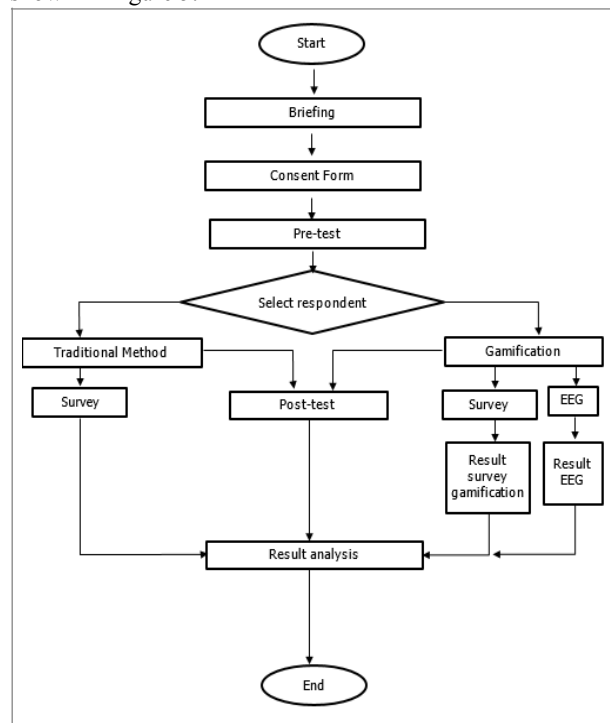


Figure 5. Flow chart for the Evaluation Phase

Figure 5 shows the flow chart for Evaluation Phase for the gamification Linear Algebra. The procedure starts with the briefing, the respondents filling in the consent form, pre-test, respondent selection, post-test questions, responding to surveys and EEG tools. And the last stage, the result analysis to get the result of the research.

## X. CONCLUSION

The analysis process, the Pedagogical Phase and the Design Phase of the study are an important phase before the Implementation Phase and Evaluation Phase. This is because during the analysis process, all the initial information is collected and scrutinized besides the findings from the previous study, the use of Inverse and Cramer Smartphone Calculators at Kota Kinabalu Polytechnic. In addition, during the Pedagogical Phase, all information related to the curriculum, game goals, existing skills and new skills are collected and subsequently reviewed for the next phase. The next phase is the Design Phase, where during this phase all information regarding the style, task and interface is examined to achieve the stated objectives. With detailed and planned design and research, the process of generating Linear Algebra Gamification prototypes can be implemented more optimally and efficiently.

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