DEVELOPMENT OF A DIGITAL GAME-BASED ALGEBRAIC LEARNING SYSTEM

O. C. AGBONIFO, O. P. ONU

Abstract— Game is fun or entertainment but the application of game in the field of learning has given rise to the use of high mental skill in solving real world problems. Learning is crucial in human life and the approach and strategy to learning is also a function to human acquisition to knowledge. Game theory has been applied in various fields of knowledge and the resultant effect has promoted active engagement in learning and enhanced constructive knowledge approach of learning. Hence, this paper aims at developing a digital game-based algebraic learning system for teaching and learning simultaneous equation in institutions of learning. The game is based on chess mediated environment where a king in one kingdom is abducted by opposing kingdom and a brave knight embarks on a mission to rescue the King. The goal of the game is the art of teaching and learning algebraic concept, which provides the player with the problem solving sequences of simultaneous equations using elimination method. The rule of the game is to resolve two simultaneous equations of order 1. This is finding the values of the two unknown variables (x and y) which act as the keys needed to unlock the enemies' gate and the King's prison gate with a fraction of time allocated to each scene. The evaluation results revealed that the system is suitable to actualise the highlighted objectives.

Index Terms— Digital game, algebraic learning system, constructive knowledge, active engagement

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1 INTRODUCTION

Learning is the act or process of acquiring knowledge. Active engagement of students to learning with deep understanding of the concepts or learning materials presented to students always promote successful learning outcome. In traditional classroom setting especially K-12 class, teachers have developed several pedagogical methods that enable learning to be transferred into knowledge, promoting learning from the elementary of reinforcement to constructive-based approach. With the advent of Information Technology (IT), education in the form of teaching and learning has taken a face lift. Education is not only confined within the four walls of the institutions (close wall) but it penetrates across long distances from a specific location with the aid of computing and communication devices. Through this means, the mode of educational delivery has facilitated a more interactive way of teaching and learning. With the deployment of IT, a new way or trend of teaching and learning that attracts a form of game when learning is introduced.

Game is as old as learning but the integration of these two concepts with IT produces a combinatory effect that made gaming to be fun and through it learning is established to be attractive, attentive, motivated and constructive. The quality of game is directly related to their entertainment and is jointly related to the educational value derived. Educators and software companies validated computer games as a new way to engage students [7]. The concept of edutainment (play and fun) as a form of informal learning has been integrated into education. Gaming presents a phenomenon to support formation process, which is the process by which data about student's knowledge and skills are used to inform subsequent instruction [11]. Ash [3] said teachers can facilitate the transfer of skills by leading pre and post game discussion.

Mathematics serves as a basis for scientific and engineering inventions and discoveries. Most students are however mathphobic due to its complexity and it is often times caused by poor pedagogy techniques [1]. Silk et al [19] said teaching mathematics in a technology classroom requires more than simply using mathematics with technology but designing the lesson to focus, motivate, and highlight the mathematics in a meaningful way. In some other arguments some teachers believed that if technology is integrated into learning-teaching that the student becomes more mathematically competent, which form the basis of the good of this innovation and integration, with technology, teaching mathematics has become more effective with the belief that deep learning can be achieved and sustained through high problem design, such as seen in robotics and invariably many other high tech-like fields. Goal of which has been identified as motivation and reasoning power building. Langrall and Swafford [14] discussed that proportional reasoning is a foundational mathematics concepts that relates to a wide range of situation in everyday life and in the workspace.

According to Gee and Shaffer [10] opined that game requires the kind of cognitive that it is needed in the 21st century because the use of actual learning as the basis for assessment has not only contributed to knowledge and skills, but also prepare for future learning. With the abstract mode of think-

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ing derived when games are played, the players skills in decision-making and problem solving is developed [12], which was due to high levels of interactivity as well as highly individualised attention and feedback. Hence, this paper presents a development of digital game-based algebraic learning of simultaneous equation in institutions of learning.

2 RELATED WORK

Digital game based learning is an instructional method that incorporates educational content or learning principles into video games with the goal of engaging learners [4]. Swearingen [16] examined the interaction of students attributes with digital game play on mathematical achievement where two hundred and eighty nine grade students from a larger rural high school of the Midwest of United States participated in the study. Groff et al (2010) attested to the fact that the use of game based learning consoles in the classroom significantly increased student motivation and engagement.

Kebritchi et al.[13] presented four orientation of learning and principles such as behaviourism, cognitivism, humanism and constructivism. Felicia [8] said there are some educational benefits that are attributed to digital games which enable cognitive and major skills to be developed, which has in turn help to increase students' mathematical skills. Delacruz [6] evaluated gaming as a tool to support formative assessment; and investigate how varying the level of game scoring rules affects learning and performance in mathematics. Chen et al.[5] explained that computer games can be used as a tool to facilitate effective mathematics learning and increase motivations of students.

Yang [17] developed a digital game-based learning system for energy education called ECOPET. This was aimed to equip learners with the relevant energy conservation knowledge and measures. The instrument used in this study was questionnaires and video tapes; these were the method by which the three goals were measured. The ECOPET system was designed making use of the feedback and task complexities mechanism which is in four different phases and has a learning model designed based on the game model by Garris et al [9]. This model comprises of three operational steps which are input, process and outcomes. The input includes energy saving tips while using appliances, process guides users to transform knowledge into a consciousness of energy conservation and the outcomes promotes the learners self-awareness, learning motivation and willingness to conserve energy

Despite the major benefits that the game has added into the making the user aware of the energy conservational process and need for it, the need for further empirical studies to be done to examine the differences between the various avatars in the digital game based learning system and a need to conduct future research in a number of areas, such as enhancing the variety and suitability of the game options, adding more learning contents that are related to energy conservation education, and conducting a long-term experiment that is able to examine learning effectiveness.

Sayed et al. [15] proposed a digital game based learning for remedial mathematics students, describing the new teaching and learning approach in Malaysia. This aimed at increasing the achievement of students, considering the importance on helping students to improve their learning performance using games.

Agbonifo and Ogunmoroti [2] developed a digital Lego-based learning environment to assist the pupils in comparing fractions with like and unlike denominators to reduce the difficulty encountered by pupils when working with fractions. The platform is on a game environment that makes learning attractive for a successive learning outcome.

3 SYSTEM DESIGN

This section presents the formal description of the game, the architecture of the system, the various components, modules and the data that the system needs to satisfy the specific requirement.

3.1 Game Description

The scenario of the game is likened to a kingdom whose King was abducted by opposing kingdom, and the game begins with the mission of a brave knight who embarks on the quest to rescue the King and restore the glorious moments the kingdom has always had. The objective of the game is to take into consideration the algebraic learning concept, which provides the player with the problem solving sequences of an algebraic equation (simultaneous equation) using the elimination method. The rule of the game is to resolve a simultaneous equation of order 1. This is defined as getting the values of the two unknown variables (x and y) which acts as the keys needed to unlock the enemies' gate and the King's prison gate with a fraction of time allocated to each scene. The goal is to get familiar to the steps involved in the solving approach of the equation. Each time the player successfully completes a scene arrives at the correct step), the knight has to be empowered and scored and the snapshot of the stage is taking as the most recent checkpoint. And each time the knight fails in a scene, it returns to the most recent checkpoint and continues from there.

At the completion of each step and resolution of each variables, the correct answers are noted and the knight is awarded with the respective scores and bonuses, then the next appropriate stage is activated to allow the next line of action. There is always a procedural sketch or outline of the problem solving context which represent the progress of the gaming scenario and at the end a text file with the username as the filename is created and has the solution documented in case of user review of the solving process. The outcome can be visual-

ised mathematically to further explain the approach taken to solve the problem.

There is possible inconvenience that would be encountered in the understanding of the logic of the game with respect to the mathematical analysis. This is because each of the scenes has a goal of getting to a step in resolving the algebraic equation, and once this is achieved the player progresses to the next stage. And so the game must provide the player with the idea (hint) of what is to be encountered and needed to progress from that stage. Since there is an effective feedback mechanism that provides the player with understanding and makes the player responds appropriately with the game in order to make headway while moving around the game.

3.2 Conceptual Framework of Digital Game-Based Algebraic Learning System

The conceptual framework as shown in Fig. 1 is adapted from Yusoff et al. [18] and it focuses on student's cognitive activities such as students' motivation, engagement, learning and problem solving skills using the following features as described below:

1. Capability: It relates to the skills the students need to develop through their interaction within the learning process.
2. Intended learning outcomes: Goals students should be able to achieve successful learning outcome based on successful completion of all assigned tasks as represented with the learning outcomes. Learning outcome is closely related with the determined capabilities and game attributes which are step by step solving techniques in the algebraic solution scheme.
3. Game attributes: This includes features that aim to increase players' motivational and participatory learning as discussed as follows:
   a. Hints define the assistance is given to the students when needed.
   b. Chess learning sequence defines the level in which students can navigate on their own based on assigned activities without any guidance.
   c. Incremental learning defines that each learning outcome is achieved in incremental process through the execution of a set of activities in-line with the stage structure.
   d. Rewards involve bonuses provided to students that accomplish their goals at the end of each stage and at the end of the game there is an acknowledgement for successful learning outcome. While students that fail or close to accomplishing the goals are motivated to try more.
4. Learning activity: This is a specific set of tasks that need to be completed and each activity within the game plays an important role to the game. This includes critical thinking, chess elimination and obstacle avoidance logic.
5. Reflection: Students' reflection on their experience and an overview of their progress in the game are provided when requested. This is exemplifie through the progress bar and also the expander respectively.
6. Game achievement: This refers to the mode in which the game represent players' achievement level. These are various game stages and there is a score for each game stage as students proceed in problem solving tasks (solving of an algebraic equation) along with the solution provided in the expander and text file.

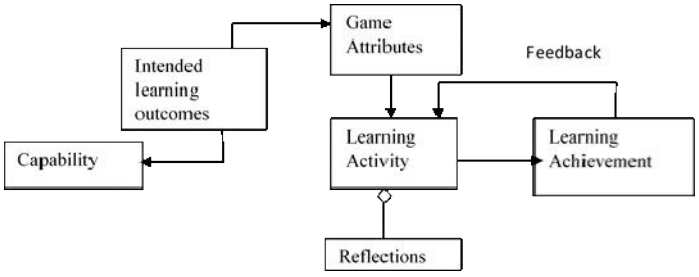

Fig. 1. Conceptual Framework of Digital Game-Based Algebraic Learning System[18]

3.3 System Flowchart

The system flowchart as shown in Fig. 2 is the flow of events and actions that are employed in the game system. At the start of the game, the system prompts the player (user) to enter the log-in details which would be subsequently used to monitor or track learning process of the user. All input to the game is made by the use of mouse and keyboard. There is a default time of 600 seconds allotted to the whole process of playing the game and if the time elapses, the game ends. The time starts counting as soon as player enters the first stage. If stage task is completed by the player and the player played correctly with respect to stage goal, the player score increases and moves to the next stage when the last stage is not true; and if otherwise (if stage task is not completed), the player is given another trial (after initial trial is set to zero and) where at each trial, the score is reduced by 50 to replay the stage until count trial is greater than three when the game would be over and returns to the start of the game. There is a flag to check if stage is the last stage or not, if stage is not the last stage then user moves to next stage but if stage is the last stage then user scores is displayed and solution process is stored in a text file with the username as the text file name, then the game ends.

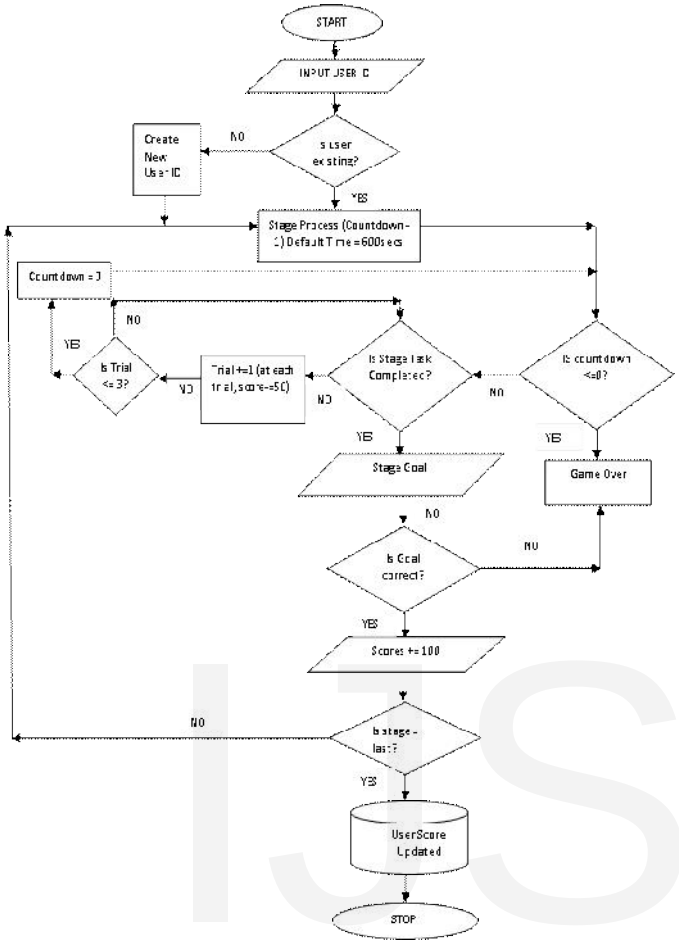

Fig. 2. Flowchart of Digital Game-Based Algebraic Learning System

3.4 System Modules

This is the design process of digital game-based algebraic learning system as it relates to the story line of playing chess game. There are seven stages involve in the problem solving process of two simultaneous equations. The game provides an interface where a player supplies log-in details viz-a-viz username and password that would subsequently use for identifying a player in the process of playing the game as shown in Fig. 3. This would be used to keep track of the player's learning engagement in the problem solving process of two simultaneous equations. The game is allocated with default time of 600 seconds for completion and the player's activities with time in the problem solving process are recorded.

Fig. 3. Home page of the Game

The Fig. 4 displays the two equations generated for the player and a popup message requesting player to enter variables to be eliminated which is either variable x or y until when player exhausts number of trial to accomplish the stage goal. The problem defined is solved according to the rule of playing chess. Whenever the player crosses the path of pieces on the chess board, the player is destroyed and failed in the quest, until the player gets to a checkpoint in the solving process when the player is able to navigate through the opponents. The player continues playing the game by substituting the value of the first variable gotten into one of the equations so as to proceed with the resolution of the second variable. To this effect, the player needs to eliminate either a BISHOP or a ROOK by the rule of the chess game to proceed to the next stage. The player has the chance of increasing game scores if the task at each stage is played successfully.

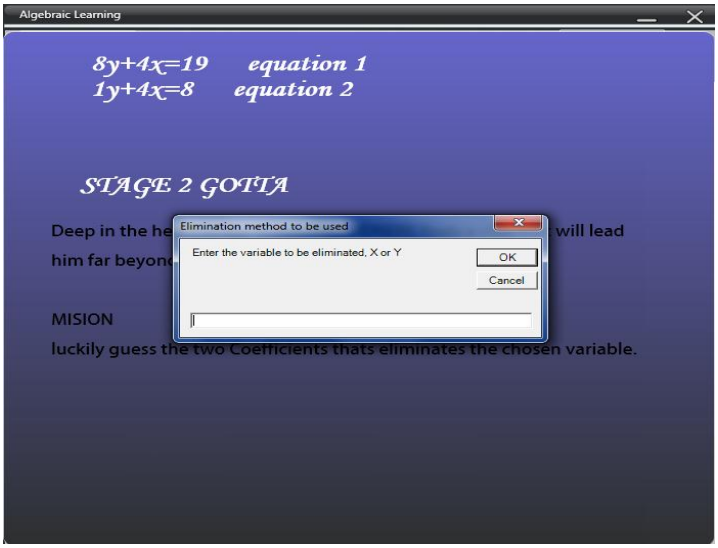

Fig. 4. The Stage at which player enters coefficient of the variables (x or y) for elimination

The player's task progress with respect to problem solving solutions is generated as displayed in Fig. 5.

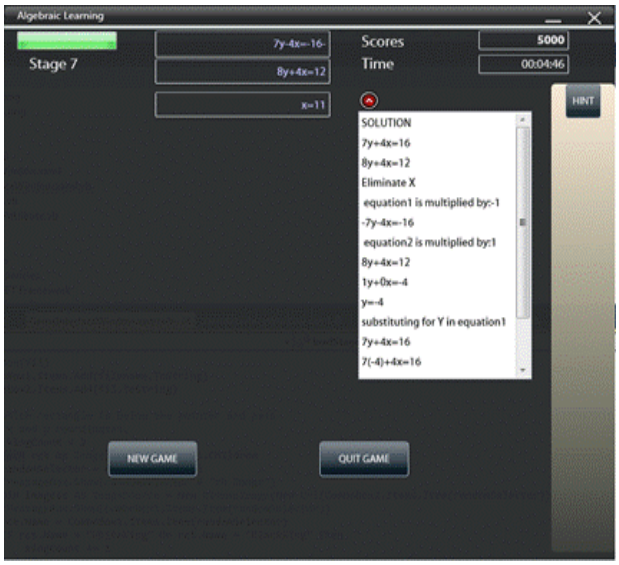

Fig. 5. Sample of a Player's Task Progress with Stepwise Solution Process

The Fig. 6 depicts the scores of random selection of twenty students of Pre-degree programme from the Federal University of Technology, Akure who actively engaged in the learning process.

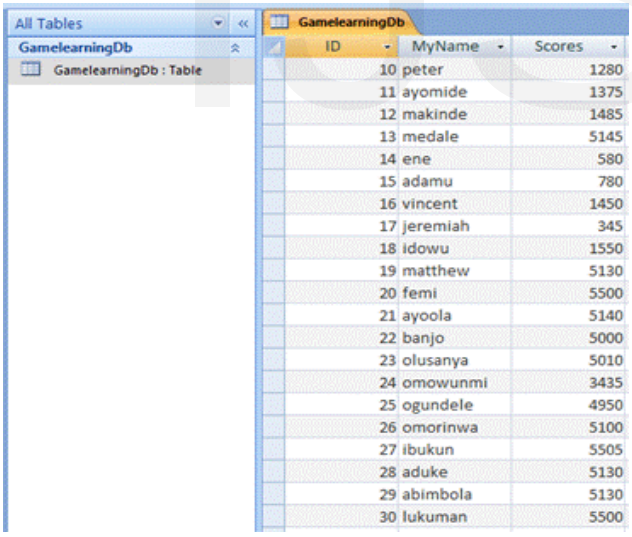

Fig. 6. Scores of Twenty Students' Generated

4. SYSTEM EVALUATION

Evaluating the importance of this game to the learning-teaching activities and skills of the student and teacher in the class room has been seen as a prospect and a new wave to the future mode of teaching and learning directed towards the students improvement in developing their skills in mathematics. The evaluation is carried out to determine the performance of the system using questionnaires with 5-point likert scale with associated linguistic terms such as Excellent (5), Good (4), Average (3), Poor (2) and Very Poor (1). The questionnaires were drawn to capture conceptual framework used in the development of the game and also based on the general standard questions in developing a universal acceptable gaming system.

The questionnaires were administered to the pre-degree students of Federal University of Technology, Akure, Nigeria for 2014/2015 academic session. The data collection was based on the number of respondentss to each question with respect to the points is shown in Table 1 and analysed using frequency distribution and weighted mean.

Table 1. Respondents' Responses to the Questionnaires relative to Linguistic Terms

Item No	Questions	Points/ Number of Respondents				
		5	4	3	2	1
A	Is game related to the task?	10	8	2	0	0
B	Is task effectively executed?	9	9	2	0	0
C	Is task objective well executed/integrated?	10	9	1	0	0
D	Is proper learning attitude motivated?	8	10	2	0	0
E	How critical is the game to the logical thinking?	14	6	0	0	0
F.	Is learning outcome closely interconnected across/along the stages?	15	5	0	0	0
G	Is assistant provided during the course of the game enough?	1	7	10	2	0
H	How easily understandable is the game without guidance?	5	7	7	1	0
I.	Is the game learning sequence objective?	5	7	8	0	0
J.	Is navigation across game virtual world explicit?	10	5	5	0	0
K	Is learning outcomes incremental?	4	10	6	0	0
L.	Is a proper attitude towards solving algebraic equations motivated?	10	10	0	0	0
M	How do you grade	12	6	2	0	0

	the critical thinking of the chess elimination method retained in the game?					
N	How do you grade the obstacle avoidance logic?	15	5	0	0	0
O	How helpful is the expander and progress bar?	12	8	0	0	0
P	How is the scoring fundamental of the game?	3	9	5	3	0
Q	How helpful is the game to your understanding of algebraic equations?	7	13	0	0	0
R	Is game challenging?	14	6	0	0	0
S	Is game user friendly?	5	6	7	2	0
T	Is game understandable?	10	8	2	0	0
U	Is game interactive?	4	6	8	2	0
V	Is game complex?	15	5	0	0	0
W	Is learning enhanced?	14	6	0	0	0

Table 2. Variables combination with respect to Framework variables

Conceptual Framework Variables	Questionnaire Variables
Capability	A,B,C,D,E,R,V
Intended Learning Outcomes and Game Attribute	F,G,H,I,J,K,T,S,U
Learning Activity	L,M,N
Reflection	O
Game Achievement	P,Q,W

The summation of the points based on the classification of the questionnaires variables into the framework variables are computed using method of percentage representation of values as in equation (1).

$$Percentage\ Point = \left(Points\ Obtained / Points\ Obtainable\right) * 100 \quad (1)$$

The percentage points are computed as shown in Table 3 which defined the significance of the variables in the underlined objectives and demonstrated the performance of the system in the art of learning two simultaneous equations.

Table 3. Percentage Points of the Respondents

Variables	Points		Percentage Points
	Obtained	Obtainable	
Capability	623	700	89%
Intended Learning Outcomes and Game attribute	712	900	79%
Learning Activity	275	300	91%
Reflection	92	100	92%
Game Achievement	253	300	84%

Based on the analysis carried out in respect to the respondents' interaction with the system, a net percentage point which explains the significance of the system to the student's constructive, behaviour, humanistic and cognitive development is shown in Table 4.

Table 4. Analytical view of the orientation theories/attributes with percentage point

Attributes	Comment	Percentage Point
Constructivism	This attribute cuts across the capability, reflection, intended learning outcomes and game attribute and achievement.	86.1%
Humanism	This was measured from the analysis of capability and intended learning outcomes and game attribute and also how the student is able to reflect on the game while interacting with it.	86.7%
Behaviourism	Was evaluated from the analysis of the Capability, learning activity, intended learning outcomes and game attribute.	86.4%
Cognitivism	Capability, intended learning outcomes, game attribute and reflection and game achievement quantifies this attribute.	86.1%

5 CONCLUSION

Algebraic has been of major challenge in the understanding of mathematics, which led to students' inability to use high order cognitive skills in problem solving processes. Hence, the system was developed to provide a medium where learning is seeing as a game or fun and in addition, students are engaged in active learning process and exploring cognitive and constructive skills to solve two simultaneous equations. The method used in evaluating the performance of the system showed that the system readily deployed and supported the four basic orientations in learning theories and attributes. However, it is recommended that the future work should focus on the algebraic expression of second order and three variables algebraic equations.

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