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INTEGRATING ICT WITH EDUCATION: DESIGNING AN EDUCATIONAL COMPUTER GAME FOR TEACHING FUNCTIONS IN UNDERGRADUATE MATHEMATICS

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ABSTRACT

This research seeks to look into the design process that promotes the development of an educational computer game that supports teaching and learning processes. The research specifically looks at the design of an educational computer game for teaching and learning of the topic of functions. The topic is essential in the teaching and learning of Mathematics courses such as Discrete Mathematics, Real Analysis and Calculus among others at Jomo Kenyatta University of Agriculture and Technology (JKUAT) Kenya. The computer game was developed using the Basic Unified process (BUP) which is a streamlined version of the rational unified process (RUP). This is an Object Oriented methodology mostly used for small projects with few end users. Due to the few numbers of end users we used interview method of data collection to gather requirements for the computer game. A paper prototype was used to validate the requirements. Use cases were used for both analysis and design of the game while Class diagrams and activity diagrams were purely used for the design of the game. Owens' six top level design anatomy aided in the design of the computer game. The overall computer game design was based on Craw fords' computer game design sequence model. The well designed and developed game met all its user requirements and was able to facilitate the teaching and learning of Functions to Bachelor of Science in Mathematics and Computer Science students who were taking Discrete mathematics in their first year of study at JKUATs' Taita/Taveta campus. Development of heuristics for measuring interest, fun and motivation are recommendations given to aid in the evaluation of user satisfaction of educational computer games.

Keywords: *ICT, Educational Computer Games, Computer Game Design, Functions*

1. INTRODUCTION

(Klopfer et al 2009), asserts that "technology can have a reciprocal relationship with teaching. The emergence of new technologies pushes educators to understanding and leveraging these technologies for classroom use; at the same time, the on-the-ground implementation of these technologies in the classroom can (and does) directly impact how these technologies continue to take shape." How well an educational computer game is designed determines the level of success of use in the classroom setting. This research lays particular emphasis on the design of a computer game with an educational component to it. The research sought to find out whether a well designed computer game using a formal system development methodology will not only entertain the student but also support the teaching and learning of functions a topic in discreet mathematics taught to undergraduate mathematics students in Kenyan universities.

To support teaching and learning a computer game must create an appropriate mapping of education and engagement. The computer game developed followed a formal systems development methodology called Object Oriented systems development.

Objected oriented systems analysis and design approach was used for the analysis (requirements engineering) and design of the computer game. Object oriented approach views information systems as a collection of interacting

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objects that work together to accomplish tasks. Objects are things in a computer system that can respond to messages. Object oriented approaches include the rational unified processes and the basic unified process which is a streamlined version of the rational unified process. The basic unified process (BUP) was used since it is a process that focuses on practices suited to most small projects and teams.

Basic unified process method content is focused on the following disciplines: requirements engineering, architecture (analysis and design), development, testing, project management and change management.

The computerized game is developed using full professional acrobat reader version 9 and the games' logic and control is embedded through adobe java script a type of java script customised for adobe documents.

This research paper looks at the design of the computer game which in BUP is intertwined with analysis phase.

2. REQUIREMENTS ENGINEERING

Requirements engineering is a process whereby the requirements for the computer game are gathered from the users and analysed. Three lecturers from the Department of Mathematics at Jomo Kenyatta University of Agriculture and Technology (JKUAT) provided a set of problems (requirements) which translated into the computer game functionality. This was an iterative activity which included documenting the requirements the computer game was to provide, analysis of the requirements for any possible omissions, contradictions and ambiguities and review of the requirements after validation before moving to the design stage.

A paper prototype of the computerised game was generated using Microsoft word. This paper prototype simulated the user interface as it would appear to a player on a computer screen and the developer walked the users through to make sure all the requirements had been captured.

3. ANATOMY AND DESIGN OF THE DEVELOPED GAME.

This section looks into the design of the computer game for teaching and learning function from Owens' design anatomy of a computer game. According to (Owen, 2004), 'Anatomy is a study that arises from dissection'. An anatomy of the game aided in better design of the computer game. (Owen, 2004) bases anatomy on six top-level categories of game components: game aims; game location; game pieces/players; the means of making progress in the game; game language; and the time frames of games. It is on these six levels that the computer game for teaching functions is based on. The game has five levels as shown in ***fig 1*** **class diagram**

3.1 Game aims

Any computer game must have aims which should be achieved. Rules and objectives form part of the aims of a game. (Owen, 2004) recognises that in many games a strong fantasy and/or narrative are important and that in all games there is also a set of objectives that give rise to the nature of the game activity – the Gameplay'. In the developed computer game the aim of the game is to play all the five levels and achieve a minimum of 60% in each level in order to progress to the next level. A player cannot proceed to another level until he or she achieves a minimum score of 60%. ***Fig 2*** shows an UML activity diagram that was produced to design the computer game rules. **Screen shot 1.0** show the actual screen on the computer game where the game rules are displayed before the game starts.

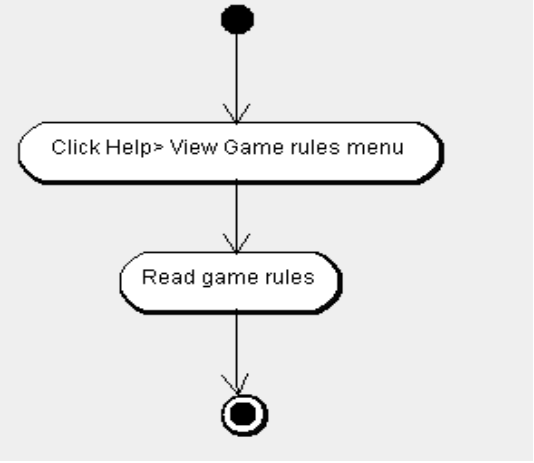

Fig 2: Game Rules activity diagram

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3.2 Location

Location is an important component in computer game play. (Owen 2004) points out that 'Games can take place in real spaces, virtual spaces and some games do not involve any particular space at all'.

Real space may be bound, unbound or augmented. Virtual spaces may include audio and visual screens, boards and mazes. In the developed computer game paper diagrams have been simulated on computer screen and interface provided where the user interacts with the game as would on paper. This is shown in **Screen Shot 2.0**

Non-location specific games can be played anywhere for example in a car, a school play ground. For computerised games it can be on any platform that is any type of operating system, hardware, online or offline, web based etc.

3.3 Game Pieces/Players

A piece means anything that is engaged in the play. It could be a simple counter, human player, a proxy item a token, a drop down menu with a list of possible answers for a quiz, a blank space that could be used to provide an answer or instruction, a blinking object etc. There is uniformity in pieces in a game. In the developed game the pieces include the player, the quiz questions and answers, blank spaces for putting down answers, drop down menus with answers and diagrams. In object Oriented design the pieces and players are represented by actors and uses cases in a use case diagram. The actors and the use cases for the computer game are shown in the two use case diagrams: ***fig 3*** **game play use case diagram** and ***fig 4*** **game control use case diagram.** The game play use case shows two actors and five use cases. While the game control use case has two actors and four use cases.

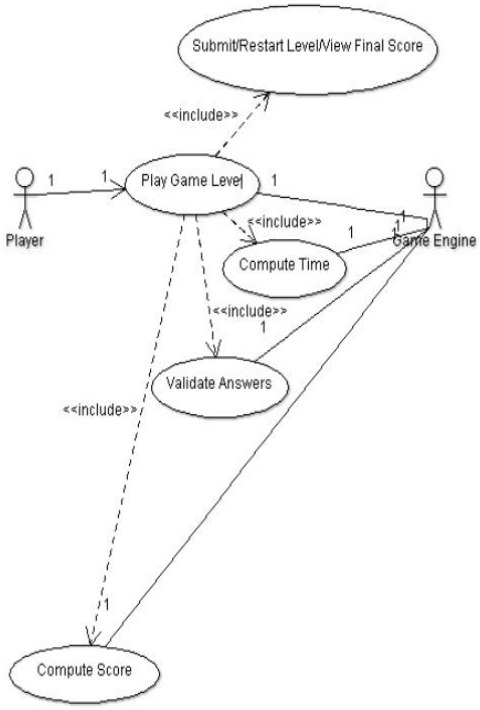

Fig 3 Play Game Use Case

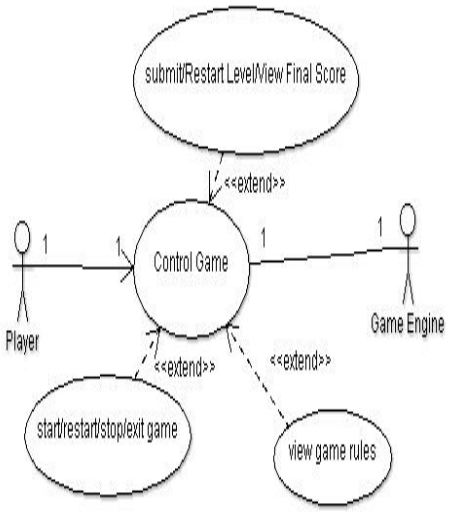

Fig 4 Game Control Use Case

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3.4 Language

A computer game should make use of language specific to the simulated physical game or activity in the case of the computer game for teaching and learning functions. The developed computer game makes use of mathematical terms used in the teaching of functions see ***screen shot 3.0*** this makes the game easier to learn and play by students taking the mathematics course since they do not have to learn new terms to play the game. This is also referred to as transfer of learning.

3.5 Time

In most computer games timing and speed are part of the gaming process. Some computer games allow a player to complete the level even when one does not play in the required time given but of course marks for time are not awarded or in some instances one is penalised for taking too long to play a game. Some computer games lock out a player out of a session once the time elapses and the level has to be replayed. In the developed computer game since it is a game that is meant to aid acquisition of knowledge the timing has been provided but that's meant for the players to see how long they have taken to play the game. Once the player completes the entire game that is all the five levels the aggregate marks for the five levels are displayed including the time taken to play the game. The timing component was designed as a use case as illustrated in ***fig 3 play game use case*** above.

3.6 Making Progress

Journeying towards the achievement of a game goal is the most important goal in any computer game. There are many factors that may influence how one progresses from one level to another. This may include according to (Owen, 2004) random elements; physical effort (with and without the support of other devices); solving puzzles; answering quiz questions; and cheating. In the developed computer games factors that affect the journeying towards the achievement of the goal include first the physical effort that is speed of typing, second level of computer literacy skills and third mastery of the subject content, those who have prior knowledge of functions were able to answer most of the questions correctly and therefore getting the required minimum score for progressing to the next level. The computer game design incorporated a definition for the subtopic for each level to aid the students in remembering the subject. The structure of the game is illustrated in ***fig 5*** **Start to Stop Activity Diagram**.

4. MODEL USED FOR THE DESIGN AND DEVELOPMENT OF THE COMPUTER GAME FOR TEACHING FUNCTIONS

From literature review that has been conducted there is a general consensus that for instructional computer games to be effective they must be designed to support instructional objectives. Proper and systematic analysis and design of computer games facilitates learning of both specific domain knowledge and concepts, and several cognitive skills like pattern recognition, decision-making and problem-solving. There are a number of models that have been developed to be used for the development of instructional computer games. This research based it computer game development on Craw fords' model. (Crawford, 1982) describes the computer game design sequence model as: choosing a goal and a topic, researching, designing, programming, play testing, and post-mortem.

5. RESEARCH FINDINGS

The research findings found out that a well designed educational computer game developed using a formal system development methodology to be successful in its use in the classroom teaching and learning of functions a topic in discreet mathematics taught to undergraduate mathematics students in Kenyan universities.

Educational computer games enhance motivation and increase students' interest in subject matter. Educational games have to be intrinsically motivating to appeal to the gamers. They should incorporate learning activity in a virtual world. (Maja et al, 2003**)** argues that for intrinsic games "Game characters have to solve a certain problem and can proceed further only after solving the problem. In this case the problem is part of the game and players are motivated to provide a solution in order to continue with the game". An example for intrinsic motivation in the computer game for teaching and learning functions is where players

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have to achieve a minimum score of 60% in order to proceed to the next level. This intrinsic motivation of computer games is making them very attractive ICT tools for teaching and learning.

The research study was able to come up with a computerised game that had an educational component to it. The developed computer game was not only entertaining but supported the teaching and learning of functions. This is supported by feedback and comments given by students who played the game see ***Table 1.0.***

The computer game was able to create an appropriate mapping of education and engagement.

6. CONCLUSION AND RECOMMENDATIONS

There are many issues that need to be addressed before the education sector can fully realise the full potential of using computer games as a way of integrating ICT with education. (Hui, 2009) states that "The greatest impetus is the tussle between commercialism and education. Most commercially-made computer games are based on some inaccurate, badly designed and often violent themes.

Particular characteristics and challenges of a computer game design raise concerns over design issues, educational aims of the game and the learning outcomes that educational designers should deal with. These challenges can only be overcome through careful design and development of the computer game. Thorough evaluation both for systems performances and whether the system meets its learning objective is needed for the computer game to realize its full potential in supporting teaching and learning.

Further studies might explore what makes computer games interesting, fun and motivating enough to support teaching and learning. Heuristics for measuring interest, fun and motivation could also be developed to aid in the evaluation of educational computer games.

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FIGURES AND TABLES

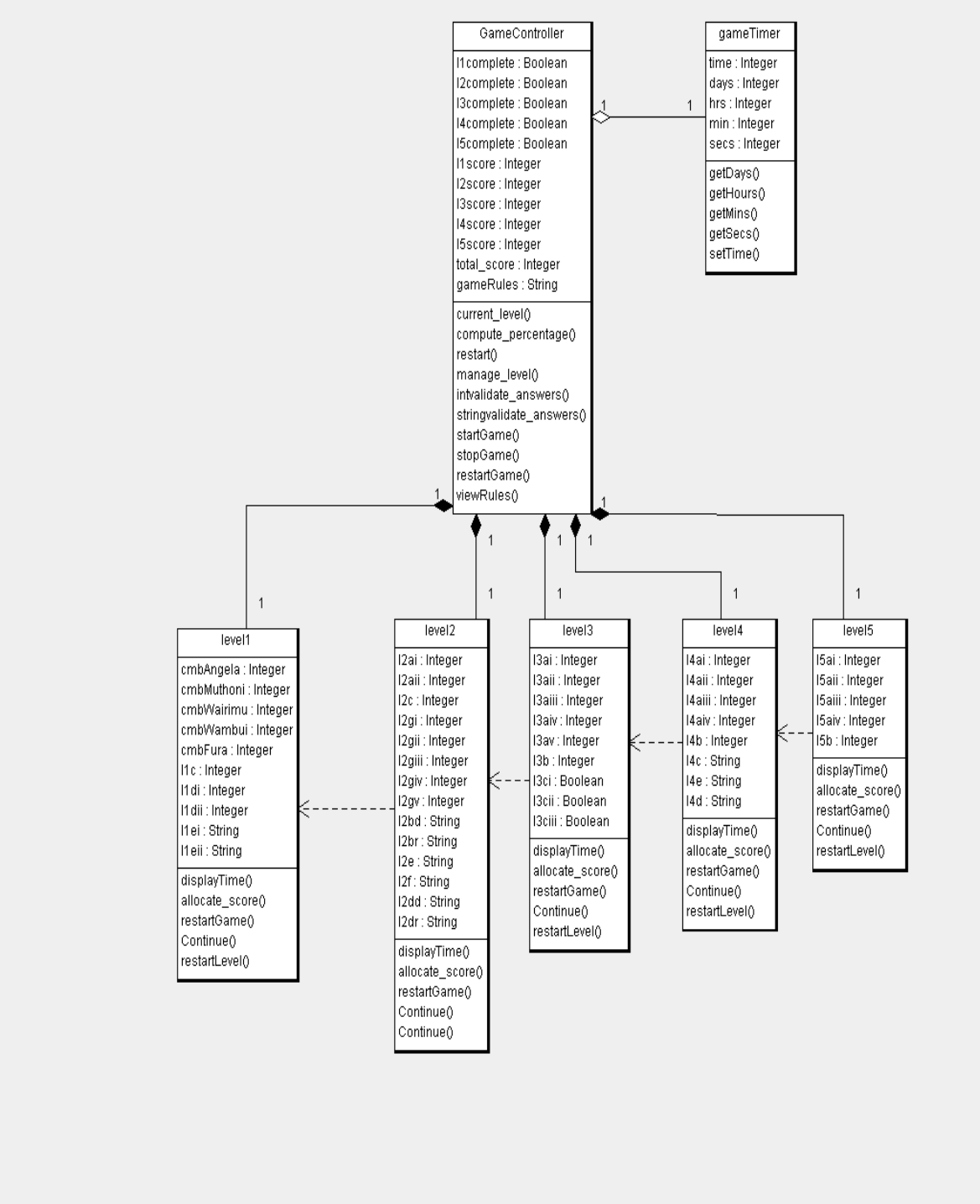

Fig 1: Class Diagram

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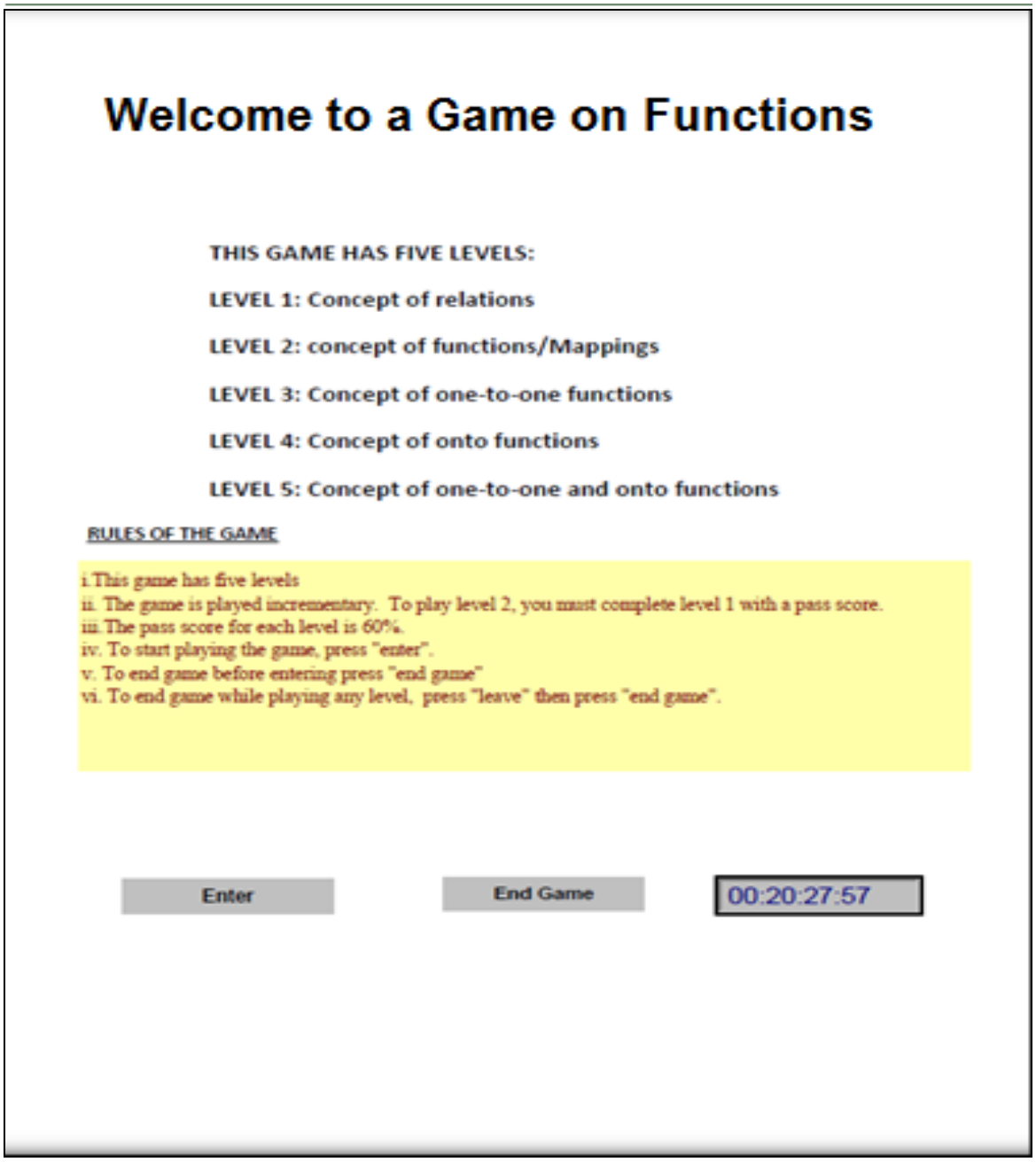

Screen Shot 1.0

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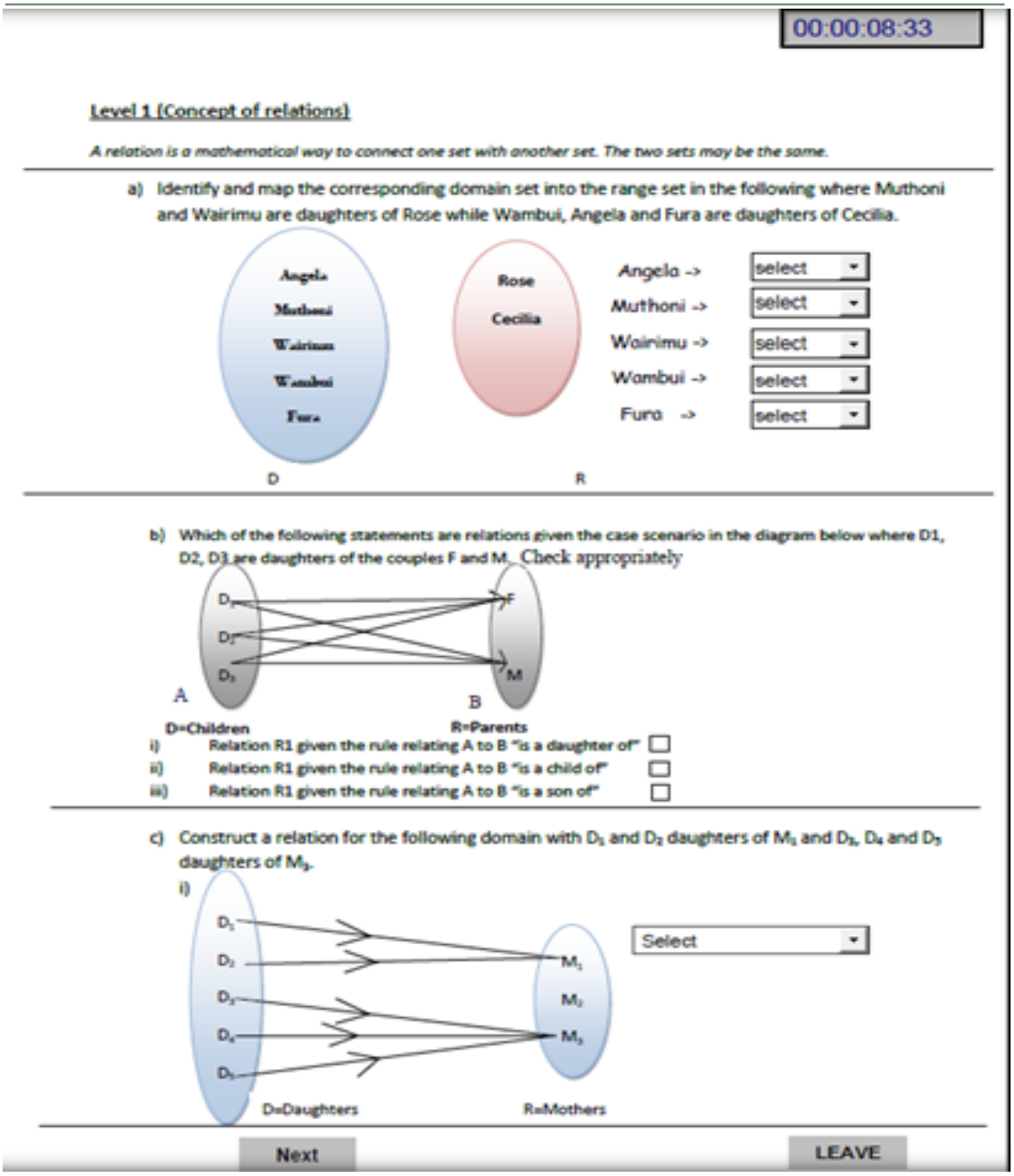

Screen Shot 2.0

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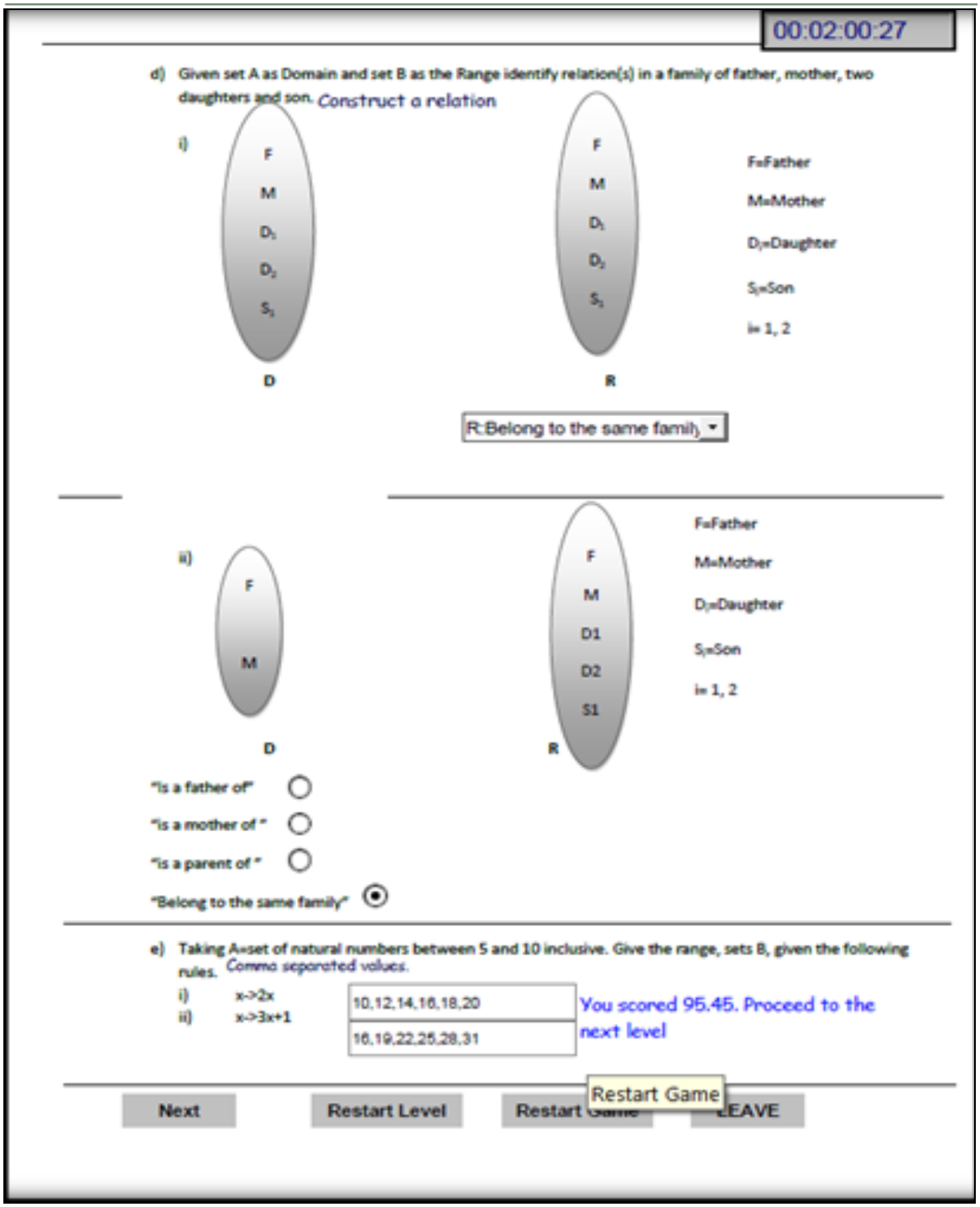

Screen shot 3.0

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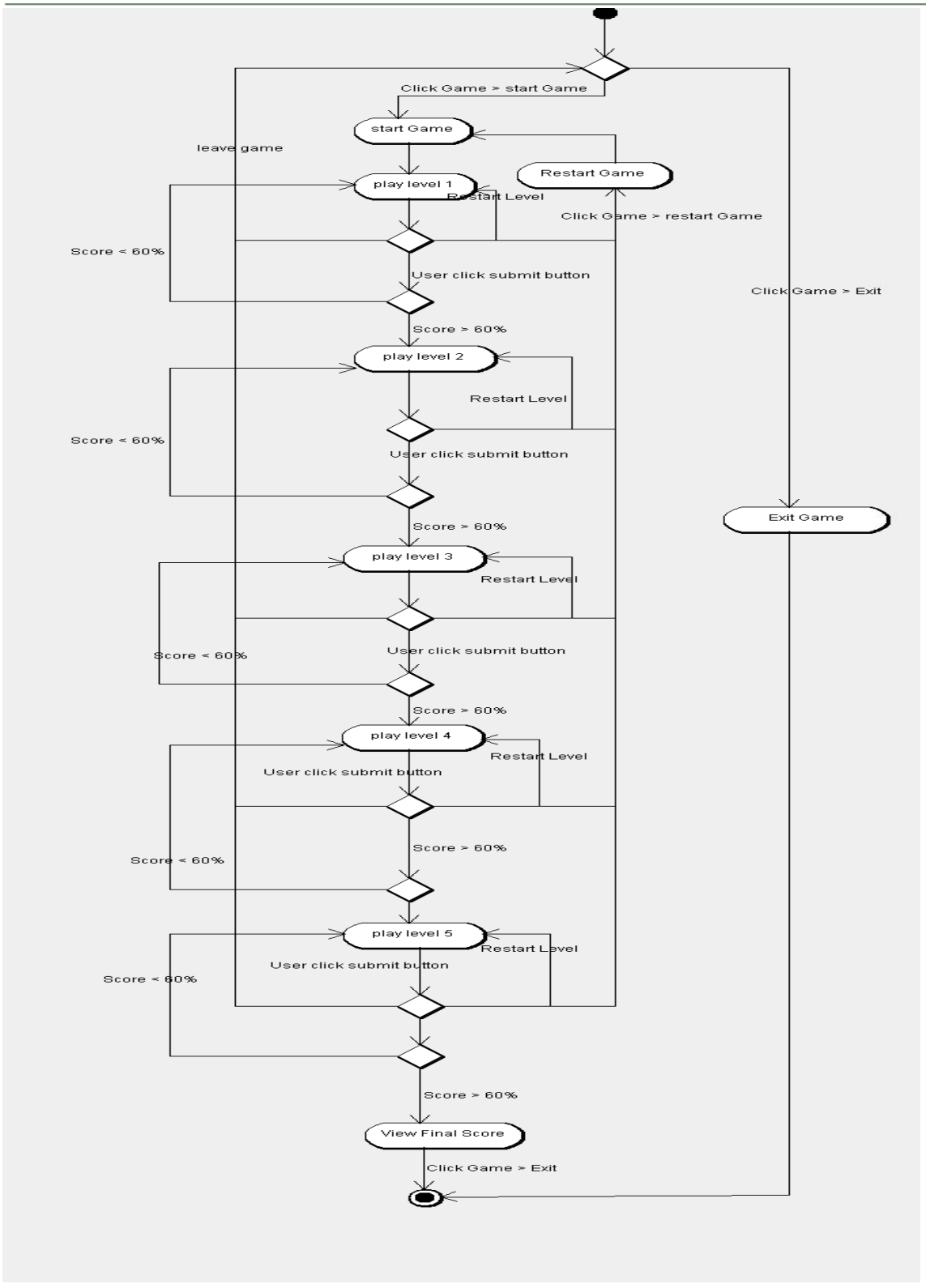

Fig 5: Start to Stop Activity Diagram

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Student	Comments	Student	Comments
Std001	Interesting game for learning how to solve Functions in Discrete Mathematics.	Std002	Has helped in h of relations and
Std003	Fun and educative	Std004	The game has a time making on
Std005	The game is so good. Actually it has made me understand functions more than what I had learnt before. It has also helped me to differentiate between one to one functions, onto functions and one to one and onto function.	Std006	The game is edu understanding o
Std007	It's fun and educative more Mathematics games should be provided	Std008	The game is int educative for le
Std009	The game is very good. It has made me master functions and differentiate between functions and relations.	Std0010	A very interacti students in term skills learnt in c better.

Table 1.0 Comments from the players after game play