INTEGRATING ICT WITH EDUCATION: USING COMPUTER GAMES TO ENHANCE LEARNING MATHEMATICS AT UNDERGRADUATE LEVEL

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Abstract
Integration of ICT in the education sector is a desired trend globally. Where it has been adopted, it contributes significantly to increased access to education for all (EFA). This research seeks to look into ways in which computer games as ICT tools can be used to enhance and promote quality teaching and learning; particularly in creating and sustaining interest in the teaching and learning of Functions, a topic taught in mathematics courses such as Discrete Mathematics, Real Analysis and Calculus, among others. At Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Kenya, the topic is introduced to students of Mathematics and those of Computer Science in first year Discrete Mathematics. A computer game was developed using Full Professional Adobe Acrobat 9 Pro. The game is designed in five levels in line with the progression of functions subject content. A minimum score of 60% for each level was built in the game to ensure the player has a good grip of the content for a certain level before moving on to the next level, thus contributing to guided revision of the level with fun. After game development, it was availed to ten first year Bachelor of Science in Mathematics students taking discreet Mathematics course at the Taita Taveta Campus of JKUAT. The students were in their second semester academic year 2009/2010. Analysis of end of the semester examinations results show that students who played the game had better performance than their counterparts who had not. Recommendations for further work as advancement of this research is development of a more advanced game in terms of adaptation of the game for use in teaching and learning other Mathematics topics considered to be boring, or difficulty or both and ultimately for purposes of promoting universal quality of university teaching.

Key words: ICT, educational computer games, discrete mathematics

1.0 Introduction

Play is very important to people and games are found in all peoples' culture. Games had until the end of the nineteenth century been associated with entertainment, but with the influence of John Dewey (1944), games began to play a major role in the education arena. With time, games were introduced into classrooms to support learning. In pre-school, they were used to learn numbers and alphabets. Numerous studies and research conducted have proved games to have a major educational potential. Games can also be used to motivate students as well as help them develop skills, abilities and strategies (Kirriemuir *et al.*, 2004) Over recent years, there has been a growing interest in the idea that computer games can be used to engage, challenge and motivate learners. Computer games are being used as medium of integrating ICT and education. This is due to the growing need for integration of ICT into the educational curriculum to replace the current educational models in line with current global trends and strides in ICT. There is need for educationist to shift away from the constrained environment of using the classroom model and the teacher model. In the current educational models especially in the developing and underdeveloped countries there is shortage of learning materials and teachers, which of course affects the quality of teaching and learning. ICT tools can be used to minimise these shortages thus promote access to education for all. Apart from e-learning and computer assisted learning, use of computer games in teaching approaches is one way of integrating ICT with education and therefore adding quality to the learning process. E-learning and computer assisted learning are ICT tools that have been in use for many years while computer games as ICT tools are slowly gaining popularity and especially because they are providing learning environments that are interesting and fun.

2.0 Computer Games and Education

Early studies show that game players perceive the world more clearly, are more creative problem solvers, more confident, and more social (Johnson, 2005). Computer games, coupled with desktop computers and the Internet lately, have assumed an important place in the lives of learners. New media are causing major changes in the nature of learning. There is a vast gap between the traditional way in which people learn and the way in which new generations approach information and knowledge. Nonetheless, in the formal educational setting the new media are still under-represented (Begoña, 2003).

Games play a very important role in supplementing traditional teaching methods. They provide immediate feedback to learners and provide a mechanism for instructional coaching and mentoring. Research has shown that the role of games is primarily to reinforce the understanding of presented material and to add variety in training (Kirk and Belovics, 2004).

Use of computerised games provides more benefits than traditional teaching methods. Games connect theory more closely to real life situation and add innovation, diversity and the opportunity for immediate feedback (Henry, 1997).

Research findings indicate that computer games provide a medium that engages people for long periods of time and gamers usually return to the same game many times over".

People easily acquire a lot of information during play and this process can be replicated as

part of education and learning (Kirriemuir, 2002).

In a study, Kuhn (1995) has established that gaming as a teaching strategy offers a unique method of reinforcing facts and allows for acquisition of knowledge and process skills. Gaming facilitates problem solving, and sometimes critical thinking, and can monitor results of the learners' actions. It also allows students to challenge the thinking and hypotheses of others. Research findings have identified three main reasons for gaming; fantasy, challenge and curiosity. Curiosity has been identified as the most common reason for using computer games.

Computer-based games provide a fun and motivating environment for teaching and learning in general and can be applied to teaching and learning and learning Mathematics even at undergraduate levels. Hui (2009) asserts that pupils in the 21st century are not satisfied with just being told about, but hunger to learn through questioning, discovery, construction, interaction and fun. Learning through computer games is the timely remedy for them because it engages and interacts. The traditional teaching methods for learning Mathematics do not create this environment that ensures the mastery of the subject. Results from research studies show that most students think that Mathematics is a difficult, complicated and confusing subject because it involves formulae and calculations. Others see mathematic as a boring subject which sometimes is unrelated to their real-life situations. On the other hand, conventional learning instrument for learning Mathematics such as text book, revision book, and courseware are not very effective in ensuring a mastery of the subject" (Ahmad *et al* 2008) Ahmad further argues that among the problems associated with the conventional learning instruments are:

a) *Lack of motivation*
   Most students do not study because they want to study, but more like they were asked or forced by others. They did not realise the benefits of studying due to no direct rewards or consequences from the action.

b) *Not very interesting/boring*
   Most of conventional learning instruments are just merely text and full of exercises. With linear learning models, students can only accept and digest all the inputs without being able to respond and interact fully.

c) *Little encouragement for self-learning*
   It does not provide enough stimulation for students to initiate learning on their own and restrict the students' freedom to find the answer of their inquiries and also to explore their world in their own way.

d) *Less meaningful*
   Weak relationship between what the students have learnt so far from their study and what they have experienced in their everyday life.

e) *No continuity*

It takes some time to gain enough concentration and focus on their study from conventional learning instruments. By stopping for a while, all the motivation is gone and they will need to regain focus from beginning if they wanted to continue their study.

ICT through games can be used in Mathematics to promote the spirit of inquiry originality in thinking and the willingness to do something differently. Use of computer games as an ICT tool in Mathematics enhances creation of interest in the subject, real and mathematical problem-solving abilities, perseverance, concentration, content mastery as well as visual skills all of which are vital in learning of Mathematics. This often is not achievable in the traditional classroom setting due to teacher and facilities limitation such as poor content masterly and inadequate quality and quantities of reference materials Hui (2009), indicates that if we can harness the potential of computer games in schools, pupils' mathematical ability may improve tremendously.

2.1 Using a Computer Game to Increase Interest and Understanding of the Topic of Functions

A function is a relation between two sets of objects. Functions may be seen as mappings because a function is just a rule that maps or relates an object in one set , domain (object set) to an object into another set range (image set). Thus, functions are synonymously referred to as mappings. The relation is such that it relates *each* object of the domain to *exactly* one object in the range. Two objects in the domain set may be mapped to one object in the range set and the relation still qualifies to be a function. However, if one object relates to more than one object in the range, the relation is disqualified as a function and recognised only as a relation. For example, if the domain is taken to be mother and father in a family with three children where the children are in the range, the relation *is a parent of* is not a function but if the domain and the range are interchanged, then the relation *is a child of* becomes a function from children set to parent set.

3.0 The Game

The main objective of the research was to come up with a computerised game as a learning aid for the topic of functions. The game was developed using Full Professional Acrobat Reader Version 9. Forms were designed which were the game user interface. The games' logic and control is embedded adobe java script a type of java script customised for adobe documents.

According to Mitchell and Smith (2004), the use of game-based learning can stimulate enjoyment, motivation and engagement of users, aiding recall and information retrieval, and can also encourage the development of various social and cognitive skills. As students play, they can look at the nature of the action they are following and the results yielded by the actions. Hence, learning Mathematics can be more enjoyable.

Computer games can be used to make learning of Mathematics as interesting and as fun as it can possibly be. This can be achieved by incorporating in the game real life situations

which make learning of abstract concepts easy. Computer games promote flexibility and active participation in the learning of Mathematics. Balasubramanian (2006) proposes the following guiding principles for development of educational computer games;

(i) The design of games and simulations should be sophisticated and challenging enough for students to be cognitively engaged with the game.
(ii) The content of games and simulations should be aligned with the standards and viable curriculum in schools.
(iii) The logistics and usability of the games should reflect classroom realities and time constraints in schools.
(iv) The feedback and assessments embedded in the games should embody measurable learning outcomes.

3.1 The Computer Game Structure

The computer game on functions has the following structure:

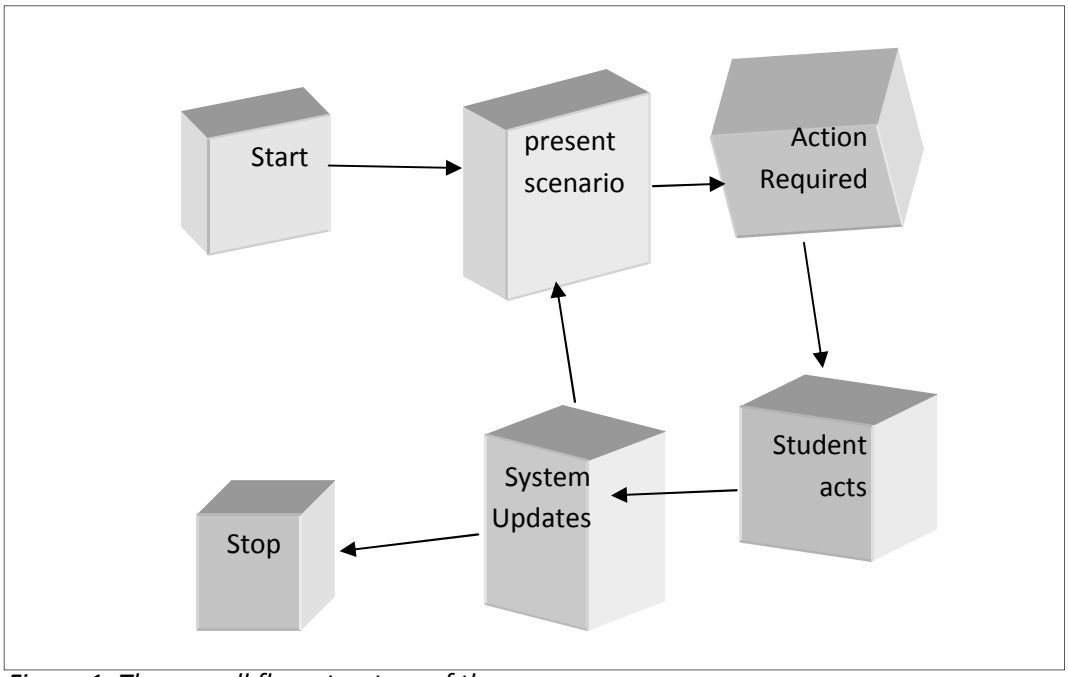
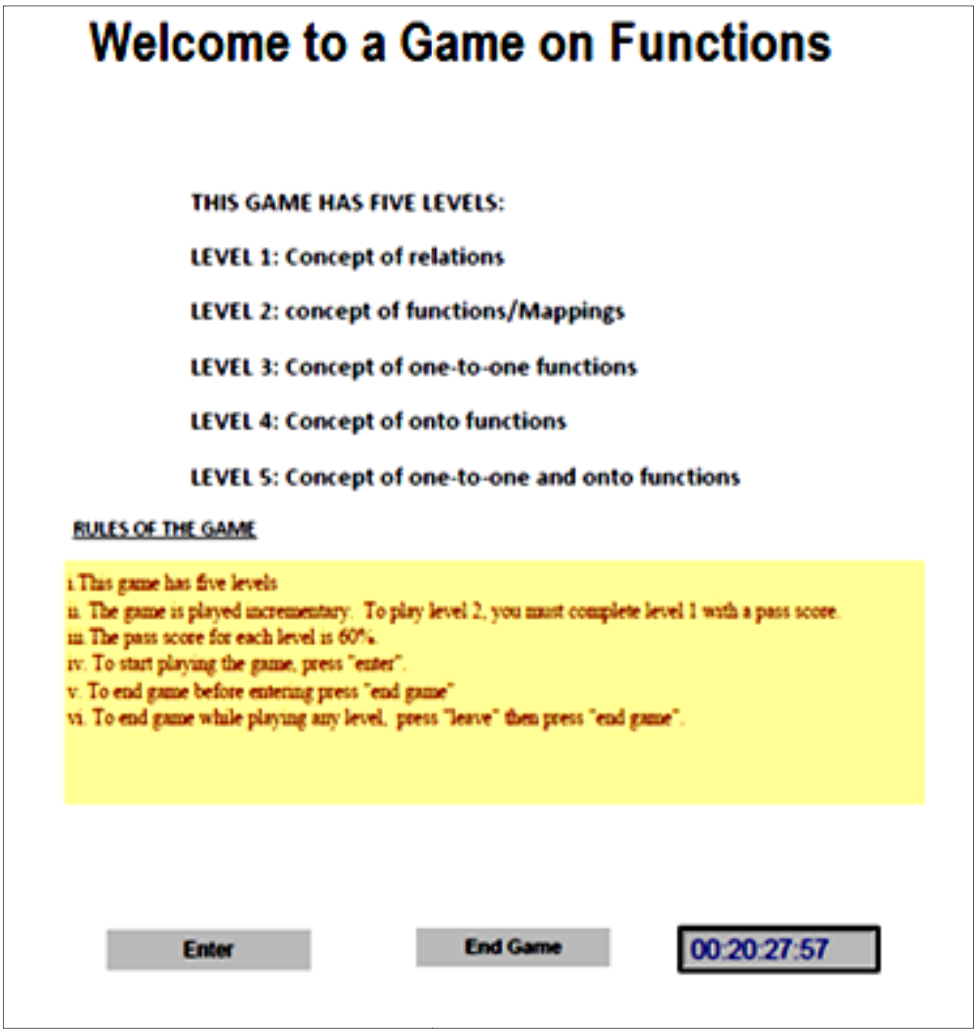


Figure 1: The overall flow structure of the game.

The main menu of the game provides instruction and rules on how to play the game. The game is divided into five levels in line with the progression of functions subject content; LEVEL 1: Concept of relations, LEVEL 2: Concept of functions, LEVEL 3: Concept of one-to-one functions, LEVEL 4: Concept of onto functions, LEVEL 5: Concept of one-to-one and onto functions. A minimum score of 60% for each level is built in the game. Screenshot 1 below is a display of the main menu showing the rules and mode of play.



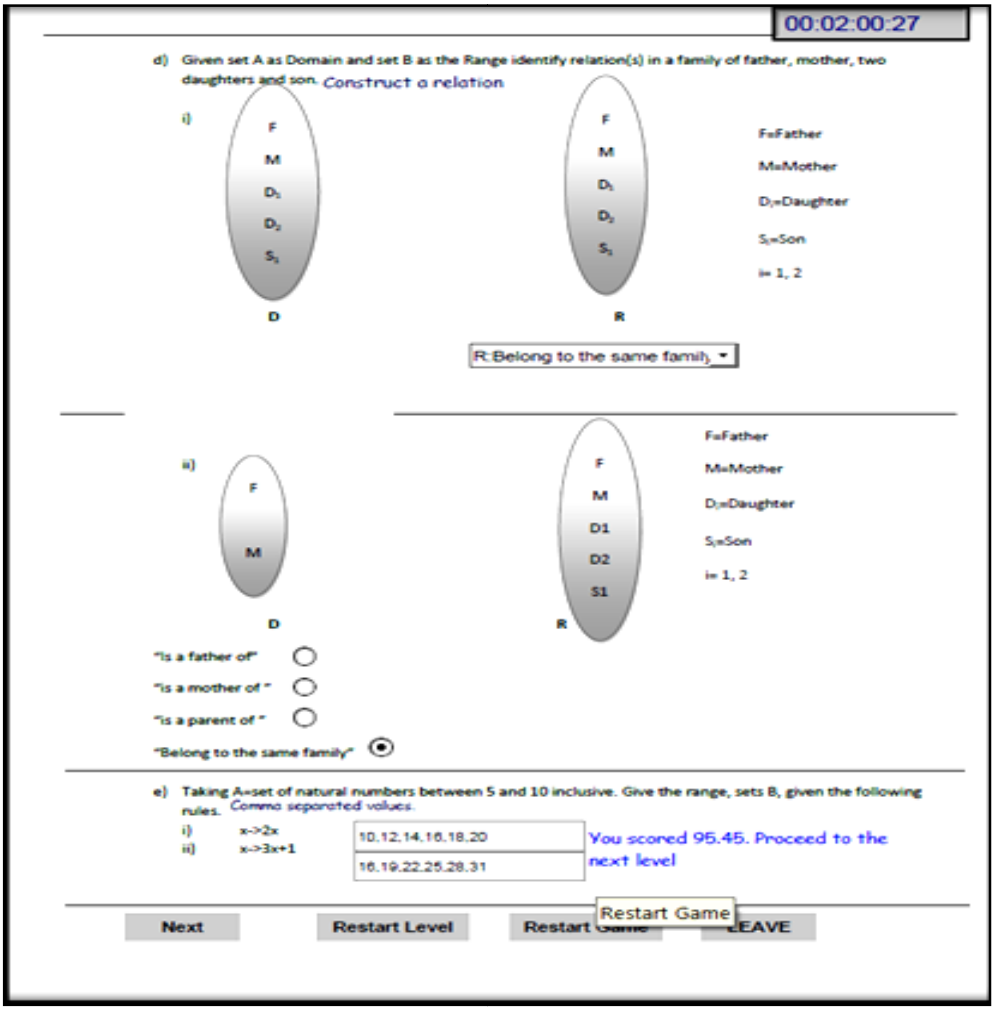
Screenshot 1: Main menu of the game

Design elements such as narrative context, rules, goals, rewards, multisensory cues, and interactivity were incorporated into the design of the computer game to stimulate desired learning outcomes.

3.2 The Students' Profile

After game development, it was availed to first year students from the Taita Taveta Campus of JKUAT taking discrete Mathematics. The course is taken in the second semester of the first year for a Bachelor of Science in Mathematics. To play the game, a student only needed basic knowledge on computer operation and to have been taught the topic. A sample of ten students randomly selected from a class of eighty students taking the course participated in the exercise.

During the session, the students showed a lot of interest in the game as they progressed from one level to another. At each level, a student had to attain the required minimum score of 60% with restriction from progressing to the next level until this threshold was met, as displayed on Screenshot 2.



Screenshot 2: Level 1 of the game

All the ten students voluntarily persisted at any failed level until admission to the next level. In addition nine students replayed the game to enhance their final mean score and increase the completion speed.

4.0 Research Findings and Results

The computerised game had two main aims, the first being to demonstrate the effectiveness of the game to arouse and sustain interest in the learning of functions through provision of an environment full of challenges, fantasy and curiosity and the second being to

assist the students to revise the topic of functions. It was designed starting with human relations and activities (functions).

Due to the interactive and stimulating nature of the computer game, it was observed that during play, the game was able to arouse and sustain interest in the players. This was observed through the frequency, and the enthusiasm with which the students attempted the game. Nine of the ten students attempted the game twice.

The computerised game was designed to create a motivating environment by using real life examples. This provided a different environment to learning of functions from the traditional way. It was also designed to make learning an enjoyable experience for the students. All the ten students, it was observed, were actively engaged in the game throughout the play session with no signs of being bored or distracted, a common occurrence in the traditional Mathematics learning environment.

The students were motivated by successful progression from one level to another which only occurred on achieving a minimum score of 60%. Achievement of the pass mark created a challenge which the students were determined to overcome by scoring the required minimum score or much higher in order to complete the game. Those who did not achieve this minimum score attempted the level until the minimum score was achieved. This promoted the subject content level of knowledge and thus increased understanding of the concepts taught. Time taken to play the game was another motivating factor. Even though the game did not disqualify a player who took too long to play, the game results show how long one took to play the game. All the ten students played the game in a shorter time during their second attempt than in their first attempt as shown in figure 1.The time taken to play the game decreased with each subsequent attempt. This may be attributed to students' acquisition of higher knowledge on the subject content through repeated interraction with the game and also to familiarization with the game playing. This is depicted in Figure 1.

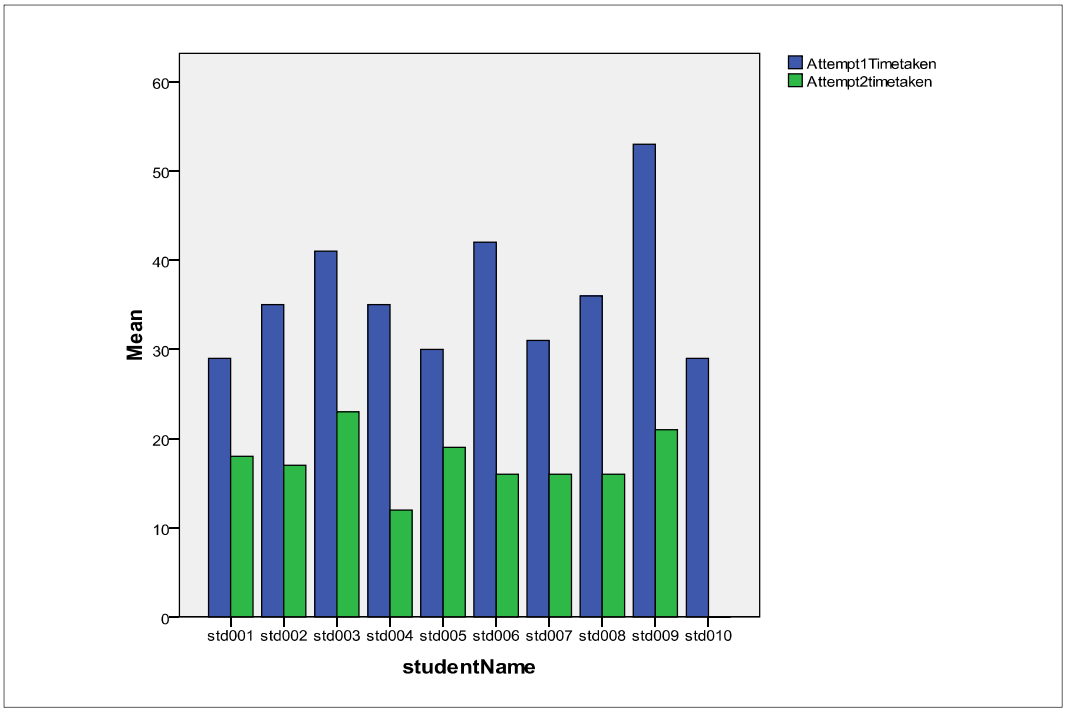


Figure 1: Chronological attempts versus chronological time taken

Nine of the ten students made two attempts at playing the game in a record time of approximately one hour 15 minutes. The number of attempts the students made was voluntary. Out of those who played the game twice, 60% of the students either scored higher in their second attempt or maintained their previous scores, while the remaining 40% scored slightly lower in their second attempt though time taken to play the game drastically reduced to more than half the time taken in the first attempt. Their lower scores were attributed to the high speed at which they completed the game during the second attempt, thus allowing for errors. This is shown in Figure 2.

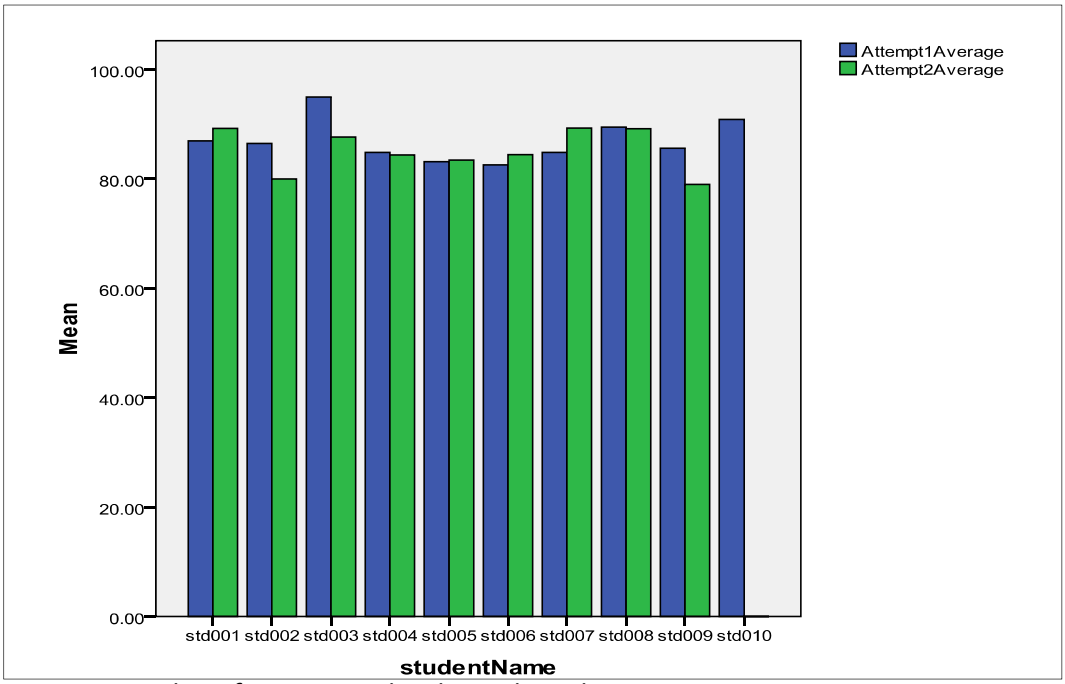


Figure 2: Number of attempts taken by each student

The computer game created a motivating and an enabling environment for students to use the game for revision purposes. Most students admitted having gained more knowledge because the game presented concepts learnt in class using real life examples of human relations and activities. This is shown below in Table 1.

Table 1: Comments from the players after game play

Student	**Comments**	**Student**	**Comments**
Std001	Interesting game for learning how to solve Functions in Discrete Mathematics.	Std002	Has helped in having a deep understanding of relations and functions
Std003	Fun and educative	Std004	The game has a lot of fun and the same time making one to think critically and fast.
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 educative and helps in good understanding of the functions.

Std007	It's fun and educative more Mathematics games should be provided	Std008	The game is interesting to play and quite educative for learning purposes.
Std009	The game is very good. It has made me master functions and differentiate between functions and relations.	Std0010	A very interactive way of educating students in terms of showing/expressing skills learnt in class. Helps one understand better.

5.0 Results Analysis for End of Semester Exams

At the end of the second semester, the students sat for their end of semester examinations for the 2009/2010 academic year. The performance of the ten students who had played the game was compared to a control group of ten students who had not played the game. This comparison was made on questions from the topic of functions covered by the game and other questions not related to functions and not covered by the game. The results are displayed in Figures 3 and 4. On analysing their results, it was found that students who played the game had better performance in questions related to functions than their counterparts who had not (these were ten randomly picked students who had not played the computer game). The analysis is shown in Figure 3.

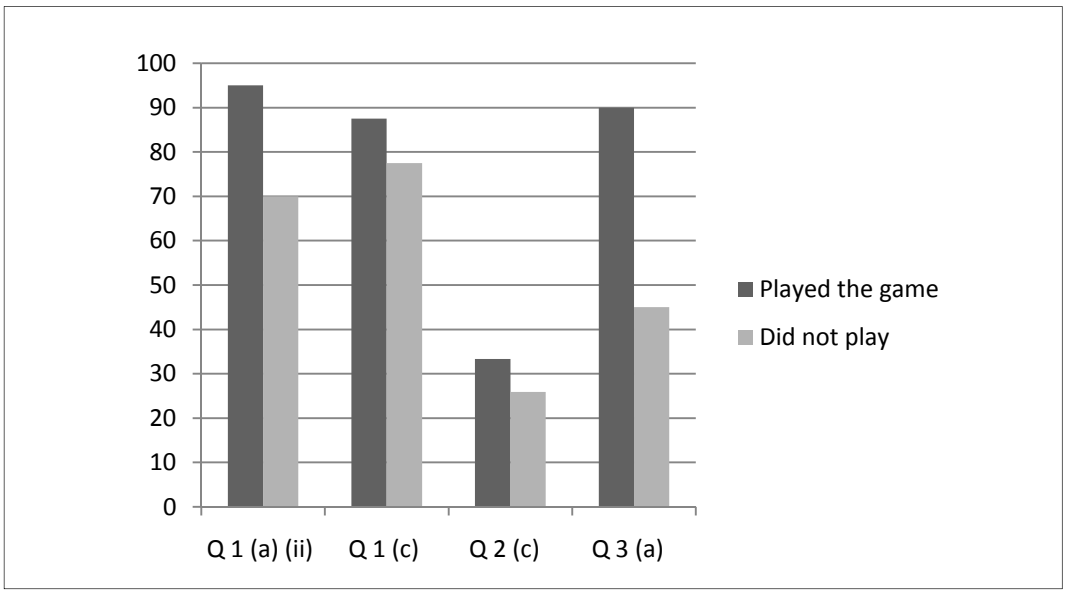


Figure 3: *Average percentage score per question for each group of ten students*

Further analysis showed that students who had not played the game performed better in question 3 which was a question not related to functions as shown in Figure 4.

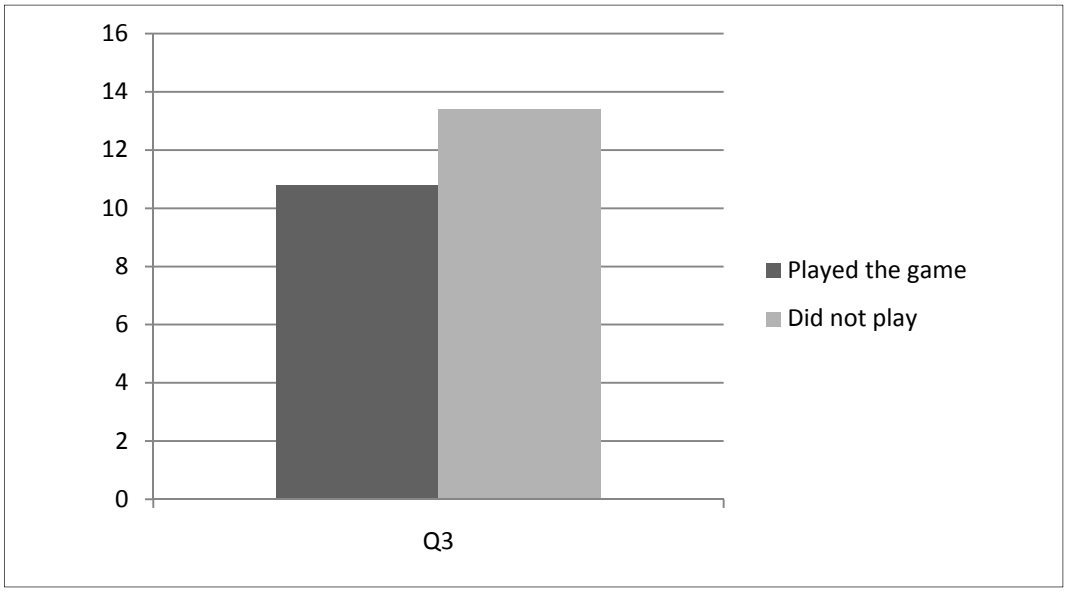


Figure 4: Mean score for all questions not related to functions

6.0 Conclusion

The results for the ten students who played the functions computer game indicate that computer game use in teaching and learning as a revision tool is a probable tool for increasing interest and knowledge levels in the topic of functions. This may be seen from the end of semester performance of students who played the game. This may be attributed to longer interactive time spent with the topic as the game progresses and also the challenge posed by the pass mark which forces the student to restudy the concepts before attempting again.

7.0 Recommendations

Recommendations for further work as advancement of this research is development of a more advanced game in terms of higher threshold for inter level progression by player and adaptation of the game for use in teaching and learning other Mathematics topics considered to be boring, or difficult or both and to ultimately for purposes of promoting universal quality of university teaching.

References

Ahmad W., Afza B. S. and Mohd H Latif (2009). Role-Playing Game-Based Learning in Mathematics. Computer & Information Sciences Department 2 EE Department, University Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia

Balasubramanian N. and Brent G. Wilson (2006). Games and Simulations**.** Retrieved from http://site.aace.org/pubs/foresite/GamesAndSimulations1.pdf

Begoña Gros (2003, July 7). The Impact of Impact of Digital Games in Education , volume 8, number. Retrieved from http://firstmonday.org/issues/issue8_7/gros/index.html

Chang Suo Hui (2009). Learning Mathematics through Computer Games Retrieved from http://atcm.mathandtech.org/EP2009/papers_full/2812009_17199.pdf

Dewey, J. (1944). Democracy and Education (DE). New York: The Free Press.

Henry J.M. (1997, September-October). Gaming: a Teaching Strategy to Enhance Adult Learning, **28**(5), pp 231-4.

Johnson S. (2005). Everything Bad is Good For You**.** New York: Riverhead Books.
Kirriemuir J. and McFarlane A. (2004). Literature Review in Games and Learning**:** Futurelab Series Report 8

Kirriemuir J. (2002, February). Video Gaming, Education and Digital Learning Technologies; Relevance and Opportunities**.** D-Lib Magazine.

Kirk J. and Belovics R. (2004). An Intro to Online Training Games, Learning circuits: American Society for Training and Development. Alexandria.

Kuhn M. A. (1995 Janaury-February). Gaming: A technique that adds Spice to Learning? *Journal of Continuing Education in Nursing*, **26** (1), pp 35-9.

Mitchell, A., & Savill-Smith, C. (2004). The Use of Computer and Video Games for Learning: A Review of Literature**.** London: Learning and Skills Development Agency.

Shreve, J. (2005). Let the Games begin. Edutopia. 28-31. Retrieved from http://www.edutopia.org/magazine/ed1article.php?id=art_1268&issue=apr_05