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ARTICLES

EDITORIAL

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Computer games as new media culture have become increasingly popular among young people. Today most children play different genre of games at different times depending on their age, maturity and opportunity. They seem to spend considerable amount of time not only in playing games, but also in socializing about games outside their school hours. Educators believe that game playing involves complex cognitive skills, real-time decision making, managing resources in critical situations and problem-solving.

This special issue of i-manager's Journal of Educational Technology on Educational Games for Engaged Learning brings together a set of articles each addressing the use of computer games for learning in different contexts.

Cheryl Seals, Jacqueline Hundley and Lacey Montgomery reported a game design and development course offered in a university in the United States. The authors noted that students today have grown up exposed to gaming, interactive and 3D environments. Creating a set of game design classes utilizing gaming as a teaching tool can attract and instruct students with familiar methods and environments. The paper details the development of an introductory game design class, its structure, artefacts created, and student and instructor's reflections.

In Oncology of serious games, Lakshmi Prayaga and Karen Rasmussen describe that computer games are not only used for entertainment and they have also become a useful instructional tool for acquiring knowledge. In their paper they reported how serious games can enable the player to learn a task, master a strategy or develop a skill. They argued that serious games can be used for education and training in any organization and suggest that application of serious games requires an ontology for designing high-quality materials.

Kowit Rapeepisarn, Kok Wai Wong, Chun Che Fung and Myint Swe Khine present a conceptual model to create effective educational computer games for undergraduate classroom learning. The paper investigates the appropriate computer game genre by integrating the learning conceptions from the previous researchers. They analyse the data collected from undergraduate classes and proposed a guideline for game designers to consider appropriate game genres for education purpose.

Scott Warren and Greg Jones from University of North Texas, USA put forward Yokoi's theory of lateral innovation and its applications for learning game design. In their paper they discuss how a theory of design from famed game system designer Gunpei Yokoi can be used in learning game design to deliver low-cost, engaging play for learning.

In Play, games and attitudes: student and teacher perspectives of educational games, Gerri Mongillo presented a quantitative study carried out in a North Eastern middle school to determine the influence of participation in educational games on cognition and attitudes towards learning scientific language and concepts during the game play. They have concluded that students who are not interested or reluctant to participate in the class may be encouraged to express their opinions and ideas in a more relax environment provided by the game structures in fostering cooperative learning.

Michael Evans and Feihong Wang in their paper, The overlapping worlds view: analysing identity transformation in real and virtual worlds and the effects on learning, explore the immersive virtual 3D environment of a game and determine the formation of world views by the players. Separate Worlds views and Identitical Worlds views were examined and they proposed a third option, Overlapping Worlds Views.

Finally, Hakan Tuzun and his colleagues offer an evaluation of computer games for learning about mathematical functions. In their study they evaluated the usability of game environments for teaching and learning about mathematical functions. The paper provides information about game design process, implementation and evaluation as well as reflection of the entire process.

We extend our gratitude and appreciation to all contributors for sharing their insight and understanding about the use of games in education and it is hoped that readers will benefit from these experiences.

ABOUT THE SPECIAL ISSUE EDITOR

Dr. Myint Swe Khine is currently working as an Associate Professor of Instructional Science and Technology, Emirates College for Advanced Education, United Arab Emirates. He teaches pedagogy and technology courses in undergraduate and postgraduate teacher education programmes. He has published over 100 articles and research papers in international journals.

EVALUATION OF COMPUTER GAMES FOR LEARNING ABOUT MATHEMATICAL FUNCTIONS

By

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ABSTRACT

In this study, researchers evaluated the usability of game environments for teaching and learning about mathematical functions. A 3-Dimensional multi-user computer game called as 'Quest Atlantis' has been used, and an educational game about mathematical functions has been developed in parallel to the Quest Atlantis' technical and pedagogical structure. The pedagogical aspects of the game were based on three theories of learning: experience-based learning, inquiry-based learning, and portfolio-based learning. For evaluating the effectiveness of the environment, four learners participated in the implementation in a lab environment and researchers observed and interviewed them. This paper includes information about the design process of the game world, an evaluation of its implementation, and reflections of the researchers.

Keywords: Game-based learning, Computer games, Video games, Mathematical Functions

INTRODUCTION

In recent years, learners have become the focus of education and new methods for learning have been developed and used. These initiatives have also affected the learning environments. Yalin (2000) describes the learning environment as the physical environment in which teaching and learning occur. Learning environments that engage learners may provide an entertaining experience in the learning process and as a result the achievement of learners might get better. In parallel to the development of technology, interest in computers and computer games has grown and the idea of using computer games for education has emerged. According to Garris, Ahlers, and Driskell (2002), when learners come into the circle of a game, they discover its structure and continue playing game by adopting it.

Garris, Ahlers, and Driskell (2002) describe a game as an activity that is voluntary and enjoyable, different from the real world, uncertain, and governed by rules. Instructional games are software providing students to learn content or to develop problem solving abilities (Demirel, 2003). There are some components that make a game a real game (Prensky, 2001):

1. Rules: Rules set the limitations of the games and provide different ways to achieve our objectives. If there aren't any rules, it is not a game, just an entertainment at large.

2. Goals: Goals have a major role in motivation. If there aren't any goals, players will not want to keep playing games. Through goals, users perceive that they have a responsibility, so they spend effort and time. In most games, most of the goals are apparent from the beginning like making the highest score, finishing the game, or taking the flag.

3. Feedback: Feedback provides notification of the users' progress to them. When there is a change in users' status, feedback is given. This makes the game interactive.

4. Challenge: Challenge in a game is the problem situation that players are trying to solve. Players would never feel fear or excitement without facing real challenges. This motivates them and sustains their gameplay.

5. Interaction: There are two different types of interaction, first of which is between player and computer, which could be called as feedback. The second one is the social relations forming among users while playing. It's difficult to find the content the computer games include in movies or books, because computer games provide interaction and allow players to experiment.

6. Story: Story presents what the game is about. For example, chess is a conflict game; Tetris is about recognizing the shapes and positioning them. Story can be conveyed at the beginning of the game or within the game indirectly.

While challenge and risk are components of a game for some; it is rule, strategy, competition and chance for others (Garris et al., 2002). Actually, there are four components serving for instructional objectives (Squire, 2003):

1. Challenge: The challenge of the game must be neither so easy nor so hard to accomplish. Learner should taste glory and should keep on going. Through challenge, users find problems and solve them, while satisfying their emotions through excitement, fear and enjoyment.

2. Fantasy: Computer games involve fantasies. Games take us to a dreamland from the real world. That creates interest and motivates the users. Learners can learn in a dreamland, such as learning physics theories while piloting an airplane.

3. Complexity: Games should make the players think by creating complex situations that offer them different ways to get out of it. But this complexity should not be impossible.

4. Control: A game must let players feel that they control the game, in this way players achieve enjoyment. On the contrary, so much control might end up with players losing their interest in game.

In Garris et al.'s (2002) Input-Process-Outcome Game model, the aforementioned game characteristics and instructional content are input. These go into a game circle that includes user judgments or reactions such as enjoyment or interest, user behaviors such as greater persistence or time on task, and feedback. In this process, learner discovers the game's structure and then begins to conduct inquiry. Finally, all of these lead to the achievement of training objectives and specific learning outcomes.

In the past 30 years, the time being spent for video games has increased. In the mid 80's, children were spending 4 hours a week on average at homes and in video game rooms. In early 90's, the time in video game rooms decreased, but the time being spent for video games at homes increased while the usage started to differ for gender. While girls were playing 2 hours a week on average, boys were playing 4 hours a week. In the mid 90's, girls were spending 4.5 hours a week, while boys were spending 7.1 hours. Today girls are spending 5.5 hours a week, while boys are spending 13 hours (Gentile & Anderson, 2003). Considering all of this time being spent on computer games, using computer games for learning is clearly important. Using computer games might eliminate the boredom in the learning process and make learning enjoyable for learners.

Numerous studies presented that learners generally have a difficulty in understanding mathematical functions (e.g., Barnes, 1988; Dorofeev, 1978; Gerson, 2008). Traditional method of learning and teaching mathematical functions require learners to attend materials presented along with lecture. More active methods have been called for "producing, discussing and testing the validity of mathematical statements" (Bloch, 2003). Such active methods have been evaluated recently as web-based materials (Baki & Güveli, 2008) and the use of graphical calculators (Ersoy, 2007). These studies found positive effects on learning and learner attitudes. Godwin and Sutherland (2004) pointed to the importance of collective knowledge-building and indicated that "new pedagogical practices with ICT should both harness the potential of ICT to support individual inquiry and work within this inquiry-led practice

to develop collective knowledge" (p. 150). Based on this need and the recent popularity of multi-player computer games, the purpose of this study was to evaluate the usability of a multi-user computer game for teaching and learning about mathematical functions.

1. Method

This study is an evaluative case study (Yin, 2003), and is qualitative in nature. Evaluative case studies have three distinctive features: description, explanation, and judgment (Merriam, 1998). Descriptions and researcher reflections of the case were provided in this study for an understanding of the usability of a game environment for teaching and learning about mathematical functions.

1.1. Research context and participants

The implementation occurred on January 26, 2005 at a computer laboratory in the Computer Education and Instructional Technology Department at Hacettepe University in Ankara, Turkey. Four conveniently invited learners attended the implementation. The characteristics of these participants are presented in Table 1.

1.2. Design of the game-based learning environment

Quest Atlantis educational game was used for this study. Quest Atlantis (QA, http://www.QuestAtlantis.org) is a 3-Dimensional (3-D) multi-user computer game. QA environment involves education, entertainment, and social commitments. General goal of the game is making users save Atlantis by engaging with educational tasks. QA is more than a technology. It's a virtual environment supporting learner communities all around the world. The structure of the QA, such as its narrative, virtual worlds, and rules, forms a meta-game and this context provides a base for learning activities (Tüzün, 2006).

Participant	Grade Level	Age	Gender	Prior Knowledge of Functions	Computer Competency
Participant 1	8th	14	Male	No	Computer literate
Participant 2	9th	15	Male	Yes	Computer literate
Participant 3	10th	16	Female	Yes	Computer literate
Participant 4	9th	14	Male	Yes	Computer literate

Table 1. Characteristics of participants

QA includes inquiry-based and experiential activities and portfolios for assessment. Content in QA is various such as science, geography, history, technology, health, art, economy and music. Though, there hasn't been any activity related to mathematics. This has been the first attempt of making a 3-D, multi-user game for a mathematics lesson in QA, and mathematical functions was chosen as the subject for this experiment.

For design of the 3-D game environment, another existing virtual world has been duplicated and conceptualized as the "fonksi10" world. Then necessary 3-D objects have been found and arranged. The fonksi10 virtual world included four schools, a barn, and a main building including bedrooms and a dinner room (Figure 1). The storyline immerses learners in this context as part of an imaginary vacation.

The fonksi10 virtual world includes direction signs, explanation plates, and talking avatars all around the virtual world. This is to make sure learners do not get lost and for guiding them in tasks. Avatars narrate the written texts. There are three quests in the world, which are designed like a roll of paper. They rotate in the air for taking the attention of learners. Their explanation pop-up in a new window when quests are clicked on.

Learners' progression in the game was designed in the following order:

- Interacting with the first avatar in front of the home, at the entrance of the world (Figure 2).

Figure 1. An overview of the game world. The software allows for viewing the game world (upper left), built-in web browser (right), and chat window (lower left)

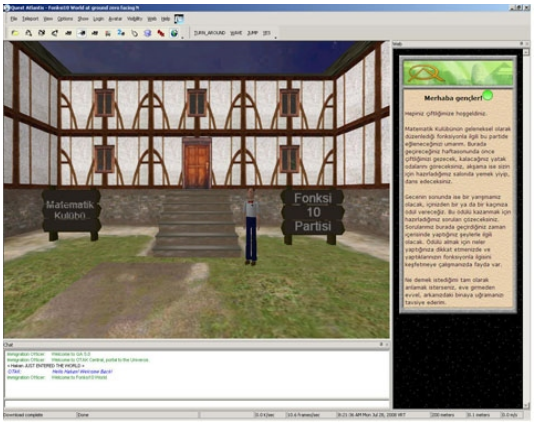

Figure 2. Entrance of the game world

- Going to barn and interacting with the avatar in front of it.
- Going inside the barn, and reading the texts on the walls and getting information about functions (Figure 3).
- Through the hints taken from avatars, going to schools and reading the boards for finding hints about function types.
- Going home and learning function types by reading the tables (Figure 4).
- Finding and solving the first quest.
- Looking around the bedrooms.
- Looking around the dinner room and eating the dinner (Figure 5).
- Finding and solving the two quests in the dinner room.

The distribution of the learners into schools, their coming together in one school, and their going to schools in couples are all based on social-constructivism (Vygotsky, 1978). These experience-based activities were designed so that learners could experience the types of functions through participatory activities. Likewise, the activities of eating in the dinner room or distribution into bedrooms served for a similar purpose. The constructivist side of these events gives answers indirectly by creating an environment which provides the learner assimilate the subject, by not leaving the learners alone, and by being there when it is needed. The pedagogical framework of the game has been based on three theories of learning: experience-based learning, inquiry-based learning, and portfolio-based learning (Tüzün, 2006).

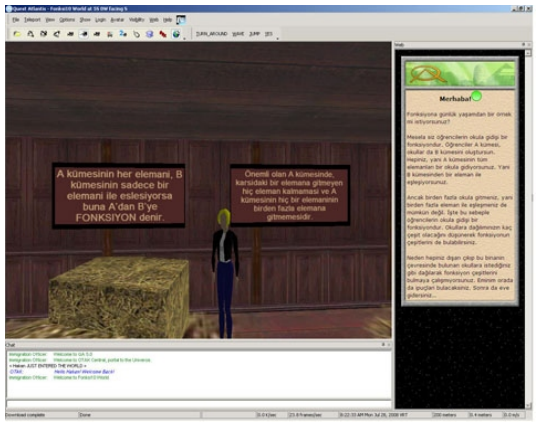

Figure 3. An avatar introduces the learner into mathematical functions

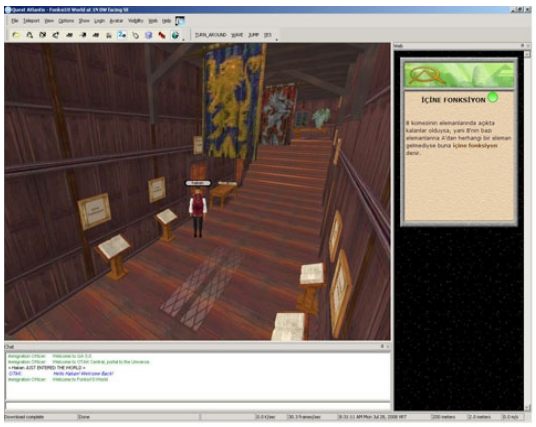

Figure 4. Learner inquiries into function types

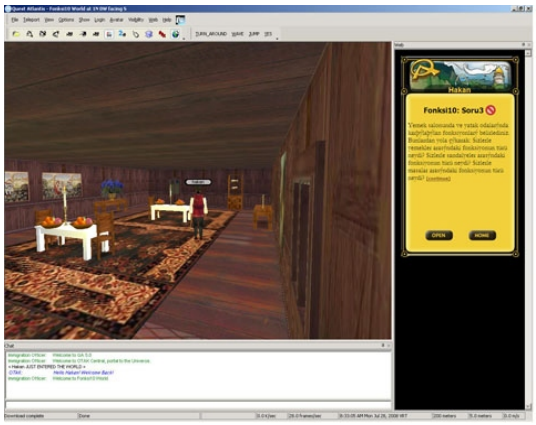

Figure 5. Learner's avatar in the dinner room. Eating fruits on the tables is one of the activities to experience the type of functions

Experience-based learning: Actually, mathematics is a difficult subject to teach in an environment like QA through experience-based learning methods. But in the

fonksi10 world, the activities are about going to school, eating and sleeping which learners do everyday. Through these daily activities, learners immerse themselves in functions without leaving the real world. They experience by living and doing.

Inquiry-based learning: In fonksi10 world, activities and hints for doing them are put around the world. Learners can find the hints by guiding their virtual characters. Hints were concealed in schools, in barn, and in the main building. Text on the reading tables, number of beds and chairs are all hints. The reading texts do not include the knowledge directly. Texts include just some information and a questioning style, which make learners think and conduct inquiry.

Portfolio-based learning: There are three instructional activities in the dinner room. Through the structure of QA, learners must answer these questions and write their reflections. Teachers can evaluate these answers and reflections through a teacher toolkit. All these give teachers an opportunity for portfolio-based assessment.

1.3. Implementation process

Before experiencing the fonksi10 world, learners were immersed in other worlds of the QA for orientation for half an hour. This orientation included:

- Information about QA and the fonksi10 world
- The reason for learners' being there
- Purpose of the study
- Directions for navigating the world, necessary keys, and how to use the chat.

After the orientation, learners were guided to the fonksi10 world. When learners entered the fonksi10 world, they couldn't understand the situation, what to do, and how to move at the beginning. They waited for the confirmation before every move. But after a couple of minutes, they adapted to the situation and started to move independently. All four learners went in every place that they must go, but a few of them confused the order. They went back for reading the texts again or for listening to the avatars. When it was thought they were lost, they were helped by giving hints. The whole implementation took an hour to complete. At the end of the implementation, the participants were interviewed.

1.4. Data sources and data analysis

All four participants were interviewed through semi-structured methods at the end of the implementation. Interview questions prompted the participants to reflect on their experience and questions were related to their general experience in the game, their learning experience, their motivation while participating in the game, and the comparison of this environment to other learning environments the participants encountered previously. Emergent issues were followed-up through additional questions. These interviews were recorded on a digital recorder and later transcribed, and resulted in 36 pages of single-spaced data.

All researchers attended the implementation and recorded their observations, feelings, and overall reflections immediately after the implementation and interviews. These observation records produced 26 pages of single-spaced data.

During the data analysis, the common themes across all observation records were identified through a content analysis and constant comparison method of grounded theory (Glaser & Strauss, 1967). The emergent themes were triangulated through the interview records. Excerpts from the interview records were used to illuminate the thematic reflections of researchers. These thematic units are presented as results in the following section.

2. Results

2.1. Design

3-D and experience-based learning environments are difficult to design. For this project, four researchers spent 30 hours each. First step was preparing the content and second was developing an appropriate environment. Both of these took so much time, effort, and creativity. It was difficult to find every 3-D object in designers' mind. One had to either design herself/himself or buy it. In addition, lots of technical difficulties were encountered in the design process.

2.2. Guidance

Learners' unfamiliarity with the environment resulted in some difficulties related to navigation or following

information, and this made them wait for researchers' confirmation before their every move. In these situations, learners were guided. This guidance was provided in the following three areas:

Guidance related to missed issues: In implementation, some learners missed reading tables or interacting with avatars. They were informed about the availability of these.

Guidance related to usability issues: At times, learners had difficulties when moving their virtual characters. Similarly, they were helped with these difficulties too.

Guidance related to challenges: They were asked questions to help them find definitions and to give them hints for questions that were not answered. They were reminded of possibilities about collaboration or their chance for revisiting the virtual places.

2.3. Difficulties in the use and implementation of technology

It is not possible to implement this project without electricity, Internet connection or computers. Even a comprehensive preparation may not work. In fact, we had to change the laboratory which was planned to use before. This caused so much technical troubles. First of all, the software had to be setup again. Then there was trouble with some computers' operating system and a speaker didn't work as a result and learners had to be replaced. Because of these differences of performance between computers, pace of learners changed and this decreased their motivation at times. Consequently, it was better to check for troubles again and again before the implementation and to have a backup plan for technical difficulties.

2.4. Implementation time

The implementation of game environments took so much time. In a traditional class environment, teachers just lecture and students listen; this does not take much time. But in the game environment, learners were experiencing and inquiring for learning; consequently this takes much longer. Longer implementation time of game-based learning environments might be an inhibitor factor for using them in formal school contexts.

2.5. Getting out of focus

In QA-like environments, the attraction of audio-visual objects can cause the learners get away from the actual focus. For example, learners might interact with objects unrelated to the subject matter when looking for hints in the world. Because of this, learners might miss the hints, have difficulties with tackling game tasks, and as a result their motivation might decrease. So it is appropriate to pay attention to this matter when designing and implementing this kind of learning environments.

2.6. Entertainment

Learners clearly enjoy learning with games. Interviews exposed that learners had fun while learning the mathematical functions through a game. The following excerpt reveals this matter:

Q: Would you like to learn functions in this way, instead of school?

A: Yes.

Q: Why?

A: Because, that's more enjoyable.

Q: Enjoyable? Could you please tell which things make this environment enjoyable?

A: It's on a computer, we progress at our own pace, there are graphics and it's colorful, that's why.

Q: I see. Alright, then could you please tell me the most three that you liked?

A: When I click on the book on the table I can get information, when I click on the avatars they narrate the information along with the text, and the quality of graphics and the environment around me.

2.7. Games are effective for learning

Games are appropriate for instructional objectives. All four learners have ended all game activities willingly. Through their answers in interviews and in the game, it was apparent that they increased their experience related to mathematical functions:

Q: How do you describe learning?

A: If I could remember what I've seen before, this means I've learned.

Q: Do you think you learned mathematical functions now?

A: Yes, I do.

Q: Would you like to learn in this way, instead of school?

A: Yes, I would.

Q: Why?

C: It would be easily remembered.

2.8. Experience-Based Learning

It is known fact that lessons would be better if we give examples from learners' lives, prepare concrete learning environments, and provide learning based on experience. This could be easy for social and applied sciences, but it is harder to do in mathematics. In this study this approach has been used. Mathematical functions was chosen which was not easy to teach concretely. Learners' answers in interviews showed that, the design has provided an experience-based learning environment. One of them said the factor which made him enjoy the environment was the realistic structure of it. Another said he liked the examples and it was easier to keep the topic in mind with these kinds of examples.

2.9. Inquiry-Based Learning

It has been observed that learners liked finding hints and answering quests by using these hints. Clearly, learners enjoyed inquiry-based learning. It has been observed that learners completed the first two quests willingly but not the third one. The reason for this could be that the questions of the third quest were similar to other quests and there were more questions in the third quest. It could be better putting in fewer questions in the quests while reducing the redundancy.

2.10. High Motivation

During the implementation, it was observed that learners kept on answering questions by themselves without getting tired, and learning without blocking others. Sometimes, they forgot that this was a lesson. A learner implied this the following way:

Q: Which factors keep you going in the activities?

A: First of all, the questions. You must learn for replying to these questions and you must continue to activities for learning. I think that environment was better with these questions.

Q: What do you mean with questions?

A: Hum, there were three [quests].

Q: You say that guidance was good?

A: Yes.

Q: What are the other factors that made you continue?

A: It was not boring.

Q: Why it wasn't boring?

A: Because it was different. It was a new environment that was different from the real world.

2.11. Self-paced learning

In environments like QA, learners learn at their pace and are independent from each other. Learners can go back and review the content if they want. The possibility to review the material and self-paced learning increases their engagement for sustaining their participation. A learner indicated the following about the environment:

Q: What are the differences between the environments in school and here?

A: In school, teachers just lecture. We don't have to use our minds. Here we must spend effort. We must think like, what I have to do now or where I have to go? We must think hard.

Q: Anything else?

A: It's enjoyable, I can do willingly.

Q: You say this environment is more enjoyable? Why do you think so?

A: Because, you do it only by yourself. I don't like learning in a very crowded environment.

Another learner indicated:

Q: What are the differences between the environments in school and here?

A: First of all, this environment is hands-on, it is easy to learn. School environment is boring, teachers always stand by you. Here it is better and more enjoyable. I think it would be more effective.

Q: You told that it was a hands-on environment. Why do you think so?

A: You move around by yourself, you see everything and recognize. Because of all these, it's more enjoyable.

Q: Alright, you said teachers were boring, why do you think so?

A: It changes from teacher to teacher. For example in exams, you beware of teachers.

Q: I see. Are there any more differences between these environments?

A: Class is crowded, but here you are alone. It's quieter; you can concentrate on more easily. You can go back and review if you want; it's hands-on, because it's hands-on.

2.12. Collaboration

In this study, collaboration had two dimensions. First, there was a competitive situation and it was observed that learners didn't want to collaborate. But on the other side, environmental structure was suitable for helping one another. They could communicate by using the chat tool. A learner found the answer of a question that he couldn't solve in that way. This prevented the disappointment of that learner and was an add-on to the social process of learning. It also increased the satisfaction of the helper. In the interview the helper indicated that:

Q: Which factors did you like when learning in this environment?

A: First of all, chatting with other students was so good. Seeing others' characters in this environment was enjoyable. Moving to right, left, forward, backward, and moving in unusual ways without limitations was good.

Q: What did you talk about when you were chatting?

A: There was a friend; he asked me which example I gave for one- to-one function and I told. Before that, he asked me what I was doing and I told I was going to dinner room for replying to the quests. Then they followed me.

3. Discussion and Conclusion

It has been observed that the game environment could be effectively utilized for learning about mathematical functions. The effective utilization was fueled by experience-based activities, completing these activities through inquiry, high motivation during the activities, opportunities for self-paced learning, and collaboration affordances. The entertainment opportunities also provided value-added to the learning process.

However, some issues related to using game-based environments for learning need to be considered. The case revealed that building these kinds of environments require extensive resources in terms of time and money. In addition, adoption of these kinds of learning environments by learners takes time and requires an orientation. Technical difficulties might arise that can hinder the usability of the learning environment. When compared to traditional learning environments, using these kinds of environments require more time. Learners in these environments might follow personally meaningful but off-target activities by being carried away by the attractiveness of the environment.

This study was conducted with limitations. For example, learners were put together conveniently in an experimental laboratory condition. The study can be replicated in natural classrooms having a unique culture and history under real world conditions. Another limitation was related to the topic chosen. It was difficult to generalize the findings to all discipline of mathematics since only the topic of mathematical functions was covered in the game environment. For that reason, results and conclusions need to be interpreted while considering these limitations.

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