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The effects of computer games on primary school students' achievement and motivation in geography learning

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ABSTRACT

The implementation of a computer game for learning about geography by primary school students is the focus of this article. Researchers designed and developed a three-dimensional educational computer game. Twenty four students in fourth and fifth grades in a private school in Ankara, Turkey learnt about world continents and countries through this game for three weeks. The effects of the game environment on students' achievement and motivation and related implementation issues were examined through both quantitative and qualitative methods. An analysis of pre and post achievement tests showed that students made significant learning gains by participating in the game-based learning environment. When comparing their motivations while learning in the game-based learning environment and in their traditional school environment, it was found that students demonstrated statistically significant higher intrinsic motivations and statistically significant lower extrinsic motivations learning in the game-based environment. In addition, they had decreased focus on getting grades and they were more independent while participating in the game-based activities. These positive effects on learning and motivation, and the positive attitudes of students and teachers suggest that computer games can be used as an ICT tool in formal learning environments to support students in effective geography learning.

1. Introduction

Geography's study area is "the world and all that is in it" (Fitzpatrick, 1993, p. 156). Economical, political, scientific, and military impacts of geography have become crucial in our daily lives as the world has become a global village in the 21st century. Interpreting ordinary issues in this era requires a solid understanding of geographic issues ranging from economy such as the argument between the USA and China over their trade deficits to politics such as the involvement of NATO in the European missile defense system, and from science such as the discovery of new animal species around the world to military such as conflicts in the Middle East. Interest in teaching and learning about geography is declining on the contrary, and as a result the society encompasses a large number of geographically illiterate citizens (McNail, 1987).

2. Related literature

In response to the decreasing interest towards geography, instructors, academicians, and practitioners have investigated about how students should learn about this subject matter. Castleford and Robinson (1998) observed the lecture as being the principal mode of teaching by geography instructors. On the other hand, many studies have pointed to the changing student characteristics in the new era, and indicated the need for a shift to a new pedagogy (Fitzpatrick, 1993; Hill & Solem, 1999; McNail, 1987). In these learning contexts the characteristics of the new pedagogy are articulated though authenticity. This authenticity sees learners deal with issues of local and global significance, using real-world data, and building on personal interests, while taking responsibility for their own learning, and the instructors' roles shift to one of facilitation (Castleford & Robinson, 1998; Lemberg & Stoltman, 1999; McNail, 1987). Although, the employment of Information and Communication Technology (ICT) rich learning environments in geography can support the implementation of new ped-

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agogy, it is emphasized that ICTs would not help with geography education if only content was transferred to these technologies, and further that implementation of ICTs should exemplify sound educational pedagogies (McNail, 1987; Sancho, 2004).

ICT tools that geography educators can utilize include office applications (word processing, spreadsheet, presentation, and database), graphics and multimedia packages, authoring and communication tools, and reference libraries (Fitzpatrick, 1993; Shepherd, 1985). Recent innovative ICT tools are the Internet, geographic information systems (GISs), global positioning systems (GPSs), remote sensing, and computer games and simulations. Although use of GISs seems to be the most popular among these ICT tools within the last decade, computer games have emerged as a new frontier for geography education. In one example, Adams (1998) utilized SimCity 2000, a Commercial-Off-The-Shelf (COTS) game, in an undergraduate introductory urban geography class. The game was used to represent to students the very complex set of issues faced by urban planners. Students initially constructed a functional city with buildings, roads, power plants, and zones. The city was used to observe three different experimental scenarios. Challenges faced by students in each scenario provided an opportunity for reflection on urban processes. The results showed that one third of students acquired an appreciation for urban government, urban planners, or the difficulty with managing urban funds. Among nine other projects in the semester, students rated the one-week implementation of the game as their most favorite. It was concluded that the use of SimCity 2000 enhanced the introductory urban geography curriculum learning, despite its short implementation time.

Researchers have also integrated three-dimensional (3D) environments into their game designs for geography learning capitalizing on the popularity of these environments within computer games. As an example, Virvou, Katsionis, and Manos (2005) designed VR-ENGAGE computer game for teaching geography to fourth grade students. The purpose of the game was to navigate through a virtual environment while answering questions related to geography. Students collected points when their answers were correct. If not, students were provided teaching–learning dialogues with virtual agents to negotiate the answer. The educational effectiveness of VR-ENGAGE game and another educational software without game characteristics were compared. Results showed that while the game was motivational and educationally effective when compared to educational software without game characteristics, poor performing students benefited the most from the game environment while the performance of good performing students did not deteriorate. It was concluded that computer games could promote motivation, especially for at-risk students or for students with motivational problems.

Apart from these field studies, much of the literature on the use of computer games in geography learning is anecdotal and is based on the implicit belief in the effectiveness of computer games, in keeping with more general findings for ICT use in geography education (Castleford & Robinson, 1998; Lemberg & Stoltman, 1999). Research in this area is needed to show how geography learning can be improved by using computer games and to determine the overall impact of computer games in geography education. Aligned with this need, the purpose of this study was to examine the impact of a computer game in geography learning by primary school students. Specifically, the following questions were examined: What learning gains do students make through the game-based learning environment? what is the nature of learners' motivation in the game-based learning environment and how this motivation differs from their traditional school environment? and what are the implementation issues when a computer game is used in the geography curriculum?

3. Method

Researchers are advised that ICT impact cannot be fully understood without considering the whole educational context (Salomon, 1990). Therefore a mixed-method approach was undertaken in this study. A combination of quantitative (pre and post tests) and qualitative (observations, interviews, open-ended questions, and digital records) methods permitted a grounded understanding of the impact of computer games in geography education.

3.1. Research context and participants

The participating school was a private K-8 elementary school embedded in a state university in the center part of Turkey. At the time of the study, there were about 1240 students between the ages of seven and fourteen enrolled in the school. The average class size was 27. The school had a staff of 144 teachers and 37 support personnel. There were three computer rooms, and each was equipped with fifteen networked computers and a whiteboard. The school was part of a three-year Comenius project with seventeen schools participating from fifteen countries (http://ejournal.eduprojects.net/ipmtools10). Students in this project worked together through new technologies to learn about similarities and differences among the worlds' countries. The project required the participating schools to; (a) conduct on-site activities among local students; (b) produce artifacts reflecting information related to their school, city, country, geography, and culture, and (c) integrate these artifacts through collaborative activities among international project partners. The game implementation at this school served as part of this Comenius project, specifically functioning as one of the on-site activities among local students.

School administration selected a group of students based on their grade averages and their willingness, and called this group as the Comenius Classroom (CC). The CC voluntarily participated in the Comenius project activities after the regular school hours. The CC consisted of 24 students (12 girls and 12 boys) from fourth to fifth grades. Their English fluency was above the average, they were able to use word processing and presentation software, and utilize the Internet for research and communication. Almost all CC students had ownership of a computer at home, and many of them played computer games regularly. Social and economic status of the students' families was above average. Although CC students might have covered the subject matter in fragments through their previous courses, it was learnt from the teacher responsible for the Comenius project that they had no structured prior knowledge of the subject matter.

3.2. Design of the game-based learning environment

When present-day children were exposed to popular computer games of the past like Pong or Donkey Kong, they expressed frustration with these games (Classic video games, 2003). Possibly, the existing norms created by today's high level production in game design have impacted the attitudes of these children. Each of the top ten best-selling console video games of 2006 included a 3D immersive virtual environment (Entertainment Software Association, 2007). For that reason, it is reasonable to conclude that one of the fundamental characteristics of current computer games is the existence of a 3D immersive environment. This characteristic was therefore important for the design of the game-based learning environment.

Networked computers have been used for communication for a long time, but advancements in computer graphics and the pervasive use of the Internet have resulted in the evolution of multi-user text-based chat environments into 3D Multi-User Virtual Environments (3D MUVEs). A 3D MUVE not only increases the attractiveness of computer games but provides multiple affordances for learning that are well suited to constructivist perspective (Antonacci & Modaress, 2008). Through the use of an avatar, one's representation in the virtual environment (Damer, 1998), users are able to construct a sense of self, either natural or idealized, and share this self with others (Bers, 2001; Bessiere, Seay, & Kiesler, 2007). Additionally, these environments embrace multiple communication channels such as real-time chat, asynchronous messages, visuals, and Voice over Internet Protocol (VoIP), therefore affording collaboration, competition, sharing, and interaction among users from diverse locations. 3D MUVEs also afford the design and construction of personally meaningful places and structures, supporting the constructionist principles (Kafai, Ching, & Marshall, 1997) and allowing for creativity. Studies examining these affordances and the educational value of MUVEs in formal and informal settings have produced encouraging results, including learning gains and increased motivation (e.g., Bailey & Moar, 2003; Corbit, 2002; Dede, 2003; Osberg, 1997; Trindade, Fiolhais, & Almeida, 2002; Tuzun, 2004).

An educational computer game known as Quest Atlantis (QA) was selected for this study. The QA educational game was utilized not only for the affordances provided by its 3D environment, but also for its scalability to local and international contexts through a flexibly adaptive design. QA immerses players into a rich narrative where they are challenged to complete curricular activities called as Quests. Being more than simply a technological platform, QA is a socio-technical structure that facilitates learners in critiquing and improving themselves and the societies in which they live. A complete coverage of QA is outside the scope of this study and readers are referred to Barab, Thomas, Dodge, Carteaux, and Tuzun (2005) and Barab, Dodge, Thomas, Jackson, and Tuzun (2007) for in-depth information about the QA educational game.

QA contains many components that take time to implement in any school or after-school context. Since the implementation period for this study was limited to 3 weeks by the school administration, all components available in QA were not able to be utilized. The "Global Village" virtual world was developed in the QA universe. This world was supported with additional foci and scenarios complementing the general focus and fantasy of QA. In preparing for use of this environment the authors collaborated with the computer teacher, who was responsible from the implementation of the Comenius project at the school. A general focus was developed, a back-story was formed, and finally two-dimensional (2D) and 3D environments were developed (Fig. 1).

The back-story of the game was connected to a culturally meaningful event. The 23rd of April is the "National Sovereignty and Children's Day" in Turkey commemorating the opening of the Turkish Grand National Assembly in 1920. Since 1986, the Turkish government organizes an international children's festival on this day, during which world children present artistic performances broadcast live by the Turkish Radio and Television Corporation and participate in a special session held at the Grand National Assembly. The game environment utilized this event as a back-story, encouraging players to send the lost guest children in Turkey to their country of origin. Aligned with this narrative, the 3D part of the learning environment included seven continents, twenty country flags presenting information related to these countries, seven virtual agents representing the lost children, and twelve artifacts that were dropped by them. The 2D part included the back-story, clues reported by lost children about where they might come from, and information about continents, countries, and dropped artifacts.

After reviewing the latest educational MUVEs, Nelson and Ketelhut (2007) concluded that MUVE-based curricula could effectively support real-world inquiry practices. Aligned with this finding, the learners were required to have an active role engaging with domain-related information while designing this environment. Therefore, the design was grounded in three schools of thought on learning: experiential learning, inquiry-based learning, and collaborative learning. Based on the experiential learning framework, students would talk to the virtual agents, and gather data about continents, countries, and dropped artifacts. They would explore the Global Village through an inquiry-based learning framework, where students would compare data given by the lost children and data collected from the environment related to respective continents and countries. Then students could brainstorm which country and continent lost children might come from. Players could additionally help each other and share information in the chat window or within the physical space to foster collaborative learning.

For the submission of their matching lost children with the countries and for the collection of lost artifacts in the game environment, various design features in QA were used. The QA environment embraces an internal e-mail system called Q-mail. Players can send and receive e-mails to and from other QA players through this system just like the regular e-mail; the only difference is that the use of Q-mail is limited to within the QA environment. Access terminals were scattered around the Global Village to access the Q-mail system. The idea was that players would send their answers to the teacher through these terminals. Every QA player owns a virtual back–pack called as Q-pack. As the players collect objects from the game environment, they are sent into various pockets in the Q-pack. Players can later access their Q-pack to view, use, share, or drop these collected objects. Players would use their Q-pack to collect lost artifacts from the Global Village.

3.3. Procedures

An advanced organizer summarizing events during the implementation is presented in Table 1. The study was implemented between May 2 and May 16, 2005. The CC utilized the game environment for three weeks, an hour a day once a week. The computer teacher responsible from the Comenius project and two other teachers (a computer teacher and a science teacher) guided and supported all implementation activities. The CC group was assigned two of the three computer rooms available at the school. The computer rooms adopted a cluster layout, in which three-computer clusters were distributed around the room with an open space in the middle. This layout of computer rooms afforded collaborative work among students. Ahead of implementation, the research team installed the software required to access the game environment and created students' accounts. Students were allowed to choose any computer room and workstation during the 3-week implementation. Some students preferred to use a computer in pairs, although there was an available computer for any student.

All 24 students of the CC participated in the first week's implementation activities. These activities started by informing students about the trajectory for the next three weeks and the goal of the Global Village computer game. A regular class environment was used for this introduction so that students would not be distracted by the availability of computers and thereby would not miss important points. Students asked lots of questions out of curiosity at this phase, including if they would see each other within the game environment, how they would communicate within the game environment, talk to a lost child, find clues related to a lost child, and send lost children back to their

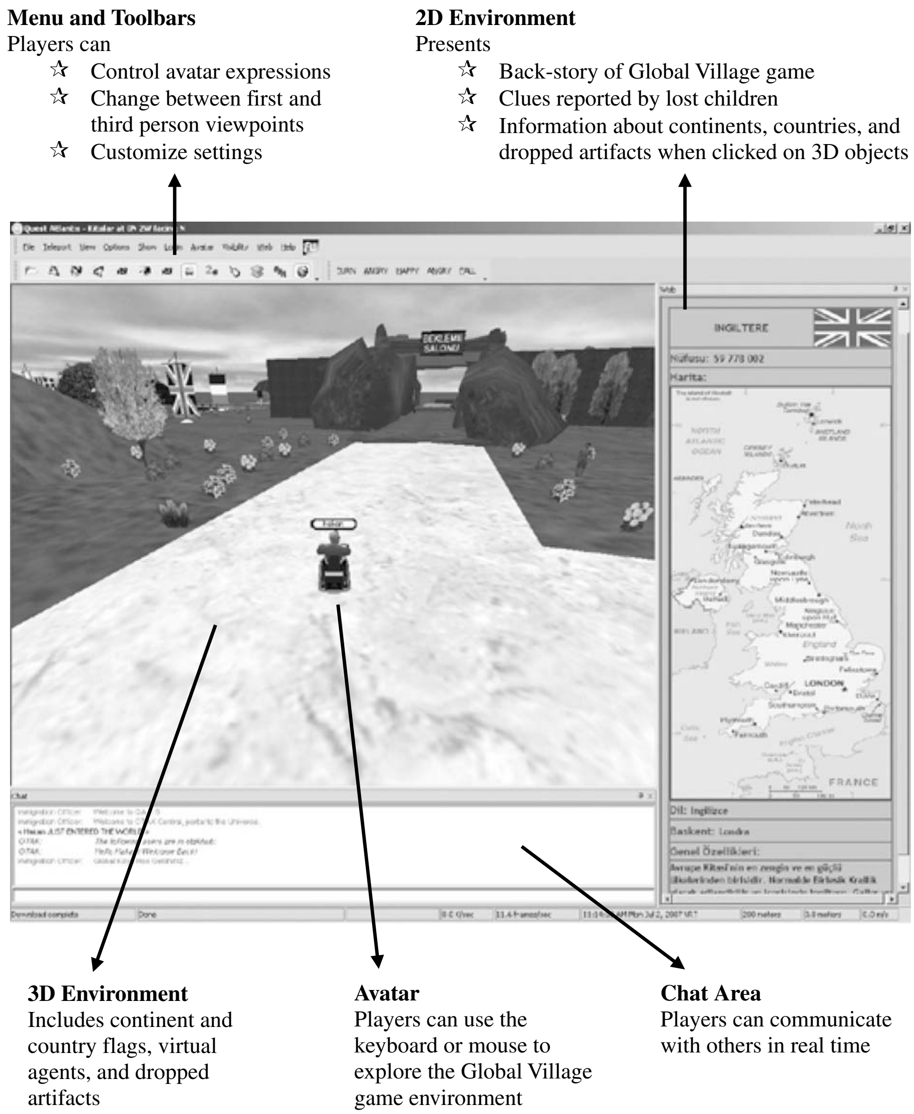

Fig. 1. 2D and 3D components of Global Village game.

Table 1
Events during the implementation

Week 1 (May 2)	Week 2 (May 9)	Week 3 (May 16)
(1) Introduction	(1) Pre achievement test	(1) Game participation (Paper-based instruments)
(2) School version of motivation scale	(2) Game participation (Paper-based instruments)	(2) Four open-ended questions
(3) The scavenger hunt orientation activity		(3) Game version of motivation scale
		(4) Post achievement test
		(5) Game participation (Paper-based instruments)
		(6) Interview with 2 players
Digital audio recordings, Digital photographs, Researchers' observation records		

country. They became impatient to experience the game environment. They were transferred into computer rooms. The scavenger hunt activity within QA was used initially to orient students to the game environment. Tasks in this paired activity included finding one's teammate in the virtual environment and then finding together two or more hidden objects scattered around. When team members found their teammates and hidden objects, they wrote down the coordinates of each. Through participating in this scavenger hunt orientation activity, players learnt to navigate within the 3D space, travel to different virtual worlds, find and use coordinates, and change avatars. All students in pairs effectively located their teammates in the virtual environment.

Seventeen CC students participated in the second week's implementation activities. On the day of the second week's implementation, there was a technical problem with the QA server delivering Web content. The 3D part of the game and static Web content were functional, but not the Web scripts that would enable the functionality of Q-mail and Q-pack. As a result, paper-based data collection instruments were developed in order to sustain the implementation. Among these paper-based instruments, one side of a paper instrument included a table with two columns: name of the lost child, and which country this child came from. The other side of the paper instrument included a table into which players could jot down collected data from the game environment about continents and countries. Another paper-based instrument was developed to simulate the collection of lost artifacts. For this purpose, one side of another paper instrument included a table with three columns: name of the lost artifact, its coordinates in 3D, and which country this artifact belonged to. Players participated in game tasks in the second week by exploring the game environment, interacting with virtual agents, collecting data, and suggesting which country a specific lost child came from.

Seventeen CC students participated in the third week's implementation activities. In this week, students continued playing the game and completing the tasks, which were the same as the week before. The students missing implementations during the second and third weeks were unavailable at the school in those days.

3.4. Data sources

Both quantitative and qualitative methods were used to collect data. The instruments for collecting quantitative data included an achievement test and a motivation scale. To measure the achievement of students, an achievement test with seventeen multiple-choice type questions was developed. All questions related to the information offered in the game environment and measured students' comprehension of knowledge and concepts associated with world continents and countries. Some sample questions from the achievement test are: "Which country the pyramids are in?" "What is the name of the ocean between America and Asia continents?" and "Which of the following is true for Antarctica?" The same achievement test was administered twice: in the second week before students started using the game-based learning environment, and at the end of the third week after students experienced the game-based learning environment.

To measure the motivation of students, a motivation scale was developed based on the work of Lepper, Corpus, and Iyengar (2005). Lepper et al.'s motivation scale was based on Harter's (1981) scale of intrinsic versus extrinsic orientation in the classroom, and modified this previous work with the assumption that intrinsic and extrinsic motivations may not be polar opposites. Therefore, the scale used provided an independent assessment of the two constructs and included seventeen items measuring intrinsic motivation and thirteen items measuring extrinsic motivation. Each of the constructs has subscales along with three dimensions: preference for challenge, curiosity, and independent mastery. The intrinsic motivation construct embraces the following subscales: desire for challenging tasks, doing tasks for personal curiosity, and desire for independent mastery. The extrinsic motivation construct embraces the following subscales: desire for easy tasks, doing tasks for pleasing the teacher or getting grades, and dependence on the teacher for guidance. When the items were translated into Turkish, some items became very similar. After eliminating the redundant items nine items were used to measure the intrinsic motivation and nine items were used to measure the extrinsic motivation. In terms of subscales, there were four items for challenge dimension, two items for curiosity dimension, and three items for independent mastery dimension within the intrinsic motivation construct. There was one item for the challenge dimension, three items for curiosity dimension, and five items for independent mastery dimension within the extrinsic motivation construct.

Two versions of the motivation scale were developed by using a five-point Likert scale (where 1 = strongly disagree and 5 = strongly agree): one for measuring motivation of students learning in their traditional school context, and the other for measuring motivation of students learning in the game-based learning context. Sample items for both versions are: "I work hard in school to get good grades," and "I worked hard in the Global Village to get a good grade". The school version of motivation scale was administered in the first week before students started using the game-based learning environment, and the game version of motivation scale was administered at the end of the third week after students experienced the game-based learning environment. While Lepper et al. found the alpha values as .90 for the intrinsic motivation construct and as .78 for the extrinsic motivation construct; the alpha values in this study for the school version were .78 for the intrinsic motivation construct and .62 for the extrinsic motivation construct, and for the game version they were .76 for the intrinsic motivation construct and .69 for the extrinsic motivation construct.

In addition to the achievement test and motivation scale, four open-ended questions were asked through a paper-based instrument to qualitatively evaluate students' learning and motivation. These questions were: "What did you learn about continents and countries while exploring the Global Village?" "How and where you may use the information you obtained?" "How did you feel while collecting information in the Global Village; was it fun or boring?" and "What would you recommend to your friends using Global Village in the future?" Students responded to these questions at the end of the third week. Paper-based instruments utilized by students during the implementations and showing their participation in the game activities also supported the assessment of students' learning.

The quantitative data were supported by a rich set of qualitative means. A digital audio recorder was used in one of the computer rooms during the implementations to record issues that could become relevant during the data analysis. Photographs were taken with a digital camera to capture the surrounds and activity in the implementations. Researchers recorded their observations immediately after implementations which resulted in a total of sixteen pages of single-spaced data. Two female players were informally interviewed at the end of the third week in relation to their experience in the game-based learning environment.

3.5. Data analysis

Thirteen students (four girls and nine boys) completed all sessions of the three-week implementation. Analysis of data was limited to these thirteen students. Data in the paper-based instruments, utilized by students during the implementations, were tabulated to record participation. A paired-samples *t*-test was conducted to compare students' learning before and after the intervention. In a similar way, a paired-samples *t*-test was carried out to compare intrinsic and extrinsic motivations of students between the school and game contexts.

The observation records were openly coded (Glaser & Strauss, 1967) by all authors. As a result 44 codes were obtained. Through axial coding (Glaser & Strauss, 1967), these codes were grouped under three categories to create parsimony for the explanation of the implementation: implementation context, the game-based learning environment, and general implementation issues. The category of "implementation context" was used to characterize the environment in the "Procedures" subsection covered previously. The other two categories are unpacked in the "Qualitative results" subsection. The responses to the four open-ended questions and interview transcripts were examined through content analysis.

4. Quantitative results

Paper-based participation data showed that out of 27 continents and countries (seven continents and twenty countries) available in the environment, students collected data about five continents or countries on average (SD = 2), while the range was between 1 and 9. In terms of matching lost children with their countries, out of 91 possible attempts that can be made by thirteen participants (13 participants $\times$ 7 lost child), a total of 71 attempts (78%) were made. Out of 71, 53 attempts (75%) correctly matched a lost child with the child's country. The average number of lost artifacts found was 6 (SD = 3), while the range was between 2 and 10.

The students made significant learning gains by participating in the game-based learning environment. The mean score for post achievement test ($M = 8.6$, SD = 2.4) was higher than the mean score for pre achievement test ($M = 6.2$, SD = 1.0), and the difference was statistically significant ($t\,(12) = 4.09$, $p < .01$).

Results of the analysis of learners' motivation are given in Table 2. The mean score for intrinsic motivation construct in the game context ($M = 31.4$, SD = 6.7) was higher than the mean score for intrinsic motivation construct in the school context ($M = 27.6$, SD = 7.2), and the difference was statistically significant ($t\,(12) = 2.21$, $p < .05$). Although the mean scores for the intrinsic dimensions of challenge, curiosity, and independent mastery in the game context were higher than the school context, the only significant difference was in the dimension of independent mastery ($t\,(12) = 2.63$, $p < .05$).

The mean score for extrinsic motivation construct in the game context ($M = 27.8$, SD = 6.0) was lower than the mean score for extrinsic motivation construct in the school context ($M = 31.7$, SD = 5.5), and the difference was statistically significant ($t\,(12) = 3.32$, $p < .01$). Although the mean scores for the extrinsic dimensions of dependence on teacher and grade in the game context were lower than the school context, and equal for easy work, the only significant difference was in the dimension of grade ($t\,(12) = 4.02$, $p < .01$).

5. Qualitative results

This section starts with an articulation of the categories "game-based learning environment" and "general implementation issues" based on observations. It then offers an analysis of responses to the four open-ended questions, followed by an analysis of the interview transcripts.

5.1. Game-based learning environment

Observations described the game-based learning environment with the following attributes: general characteristics and affordances. In terms of general characteristics, the game-environment embraced a 3D MUVE. In such an environment users were able to transport into different areas or virtual worlds, and were able to communicate with each other for various game tasks. The learning activities were presented with a general goal and sub-goals with a storyline encompassing all of these goals. These general characteristics resulted in a fun learning experience. For example, it was observed that children celebrated and congratulated each other after finding a lost child; roared, chirped, and hummed while controlling the motorcycle avatar, bird avatar, and other avatars; and expressed their enjoyment through conversations with their peers. These general characteristics seemed to generate four affordances: exploration, interaction, collaboration, and presence. The 3D MUVE afforded the exploration; the 3D MUVE, the use of avatars, and the chat tool afforded interaction; interaction and open space in the middle of the computer rooms afforded collaboration; and all game characteristics afforded a sense of presence. The comments of players in the computer rooms revealed a strong presence for players within the virtual game environment:

Follow me
This is a nice place
Where are you? I am in the house, Which of them?
I have seen you!
Let's meet at the Japanese flag
Dive into the pond

Table 2
Results of the analysis of learners' motivation

Construct Dimension (Subscale)	Mean	SD	Pairs	t	df	p
Intrinsic motivation in school context	27.6	7.2	Pair 1	−2.21	12	.048*
Intrinsic motivation in game context	31.4	6.7				
Challenge in school context	11.6	4.3	Pair 2	−1.39	12	.190
Challenge in game context	13.0	4.5				
Curiosity in school context	6.1	2.1	Pair 3	−.43	12	.673
Curiosity in game context	6.2	2.2				
Independent mastery in school context	9.9	2.1	Pair 4	−2.63	12	.022*
Independent mastery in game context	12.2	1.7				
Extrinsic motivation in school context	31.7	5.5	Pair 5	3.32	12	.006**
Extrinsic motivation in game context	27.8	6.0				
Easy work in school context	3.8	1.6	Pair 6	−.15	12	.886
Easy work in game context	3.8	1.3				
Grade in school context	9.5	1.8	Pair 7	4.02	12	.002**
Grade in game context	6.0	3.1				
Dependence on teacher in school context	18.4	4.9	Pair 8	.32	12	.753
Dependence on teacher in game context	18.0	4.3				

* $p < 0.05$.
** $p < 0.01$.

5.2. General implementation issues

Related to general implementation issues, the following issues arose: expectations of players, players' interest towards the game, and role of teachers. Players had high expectations for the game environment. Although they liked and acknowledged the 3D immersive environment of the game, they were disappointed after discovering that many of the virtual places and objects were not functional. As an example, players assumed they would do a participatory activity for matching a lost child with the child's country of origin. Similarly, they criticized the game for offering with vehicles that were not able to move.

Despite these criticisms, students played the game with great interest and enthusiasm. At the end of the second and third weeks, students needed to be ejected from the computer rooms not wanting to finish playing the game. Most of the students were unhappy when the implementation was concluded at the end of the second week, and became cheerful when reminded that the implementation would continue into the next week. It was learnt from the Comenius teacher in the third week that CC students shared their experience with their peers in the school and with their parents at home during the past week, and other students strongly desired to play the game while some of parents inquired the teacher about how to find the game. At the end of the third week, students asked for permission to continue the game following the administration of the achievement test and motivation scale. When the 3-week implementation finally came to an end, students were upset and asked if they could continue to play the game from their homes.

During the implementation of the game, many technical and non-technical problems occurred. Most frequent of these were students' forgetting their usernames and passwords in the second and third weeks, and computers crashing or freezing at times. The support given by teachers and researchers in terms of eliminating these problems however ensured a continuous experience for students. Teachers participated in the implementation by floating among the students with their support and management duties. The management duties, ranging from seating students to guiding them in tasks, supported a continuous and productive experience.

5.3. Responses to the four open-ended questions

In relation to the four open-ended questions, in response to the question "What did you learn about continents and countries while exploring the Global Village?" students indicated that they became familiar with miscellaneous facts related to continents and countries covered in the game. This factual knowledge included the shape of countries, places of interest in them, population and language of countries, and other cultural characteristics. In response to the question "How and where you may use the information you obtained?" students indicated this information could be helpful in their daily lives and in the exams. They pointed out that the information they learnt would be useful when visiting those countries. In addition, they indicated their intention to share these facts with other people. In response to the question "How did you feel while collecting information in the Global Village, was it fun or boring?" all students rated exploring the Global Village as a fun activity. In addition, chatting and interacting with other people through the virtual environment were rated as fun activities by two students. Four students rated collecting information as boring. In response to the question "What would you recommend to your friends using Global Village in the future?" students' recommendations fell under three categories: goal of the game, strategies that can be followed, and usability issues. In terms of the goal; they suggested the goal was to guide the lost children, collect information, and answer the questions. In terms of strategies; they suggested chatting, cooperating, and not competing with other players in the environment, separating to find more information collectively, exploring the virtual environment carefully by looking for interesting objects, and utilizing time efficiently. In terms of usability issues; they recommended not to go through tight places where their avatars got stuck, and not pressing many keyboard keys at once since this made the computer crash.

5.4. Analysis of the interviews

Findings from the interviews supported the above findings. Interviewees indicated that learning in the game-based environment was fun because they were exploring and chatting. They responded optimistically when asked if they would like to learn other topics in a similar environment, and pointed to the experience aspect of learning through this environment. For example, an interviewee suggested the topics of space and planets could be studied in such a game environment by traveling through a virtual solar system in a spaceship.

6. Discussion and implications

The main purpose of this research study was to examine primary school students' achievement and motivation in geography learning through an educational computer game, and to understand the implementation issues. In line with previous studies (e.g., Adams, 1998; Virvou et al., 2005) this study showed that computer games can be utilized in formal learning environments to support students in learning about geography. Students achieved statistically significant learning gains when learning about world continents and countries through the Global Village game.

After examining studies in the literature, Lepper, Sethi, Dialdin, and Drake (1997) concluded that students' intrinsic motivation at schools and their interests in subjects decreased with age and school, specifically third through ninth grades. They explained this systematic decrease in intrinsic motivation with the extreme use of extrinsic rewards such as grades, with the increased decontextualization of learning in schools as the grade level increases, and with school environments becoming more controlling and authoritative as students seek for greater independence. In addition to significant learning outcomes, the game environment in this study impacted the motivation of students in a direction desired by most educators and parents. When compared to the traditional school environment, students showed statistically significant higher intrinsic motivations and statistically significant lower extrinsic motivations while learning through the game-based learning environment. Moreover, they had a decreased focus on getting grades and were more independent while participating in game-based activities. Such a positive motivational direction might be the result of the independent participation of students in game activities that offered exploration, interaction, and collaboration affordances, and anchored them in meaningful real-world events.

Exploration, interaction, collaboration, and immersion in computer games may provide rich opportunities for geography learning. In a classic article by Pattison (1964), the field of geography is classified into four divisions: spatial, area studies, man-land inquires, and earth science studies. Related to the initial two divisions, the affordances of exploration, interaction, and immersion can provide rich environments to learn about the spatial characteristics such as distance, form, direction, and position, as well as the characteristics of a place. The game-based learning environment designed and implemented in this study stands closer to these two divisions. The third division of man-land elaborates on the relationship between humankind and the nature. The collaboration affordances of game-based learning environments allow us to design environments showing the complexity of interactions between nature and social systems. As an example, QA includes such an environment called the Black Rhino Game Reserve. Situated in Africa and based on authentic events, learners explore a virtual game reserve to experience the complexities associated with the use of land by multiple actors including native locals, farmers, ranchers, conservationists, poachers, dealers, and government officials. The fourth division of earth science studies is based on concrete knowledge such as the atmosphere surrounding the earth or waters of the earth. Again through the affordances of exploration, interaction, and immersion we can simulate environments suitable for studying topics in the earth science division.

In parallel to increased autonomy of students in their learning, teachers seemed to have transformed roles in these game-based learning environments. Since students participated in the learning activities almost independent of the teacher and in a self-paced mode, the role of the teachers became guide and manager rather than lecturer. The most frequently reported aspect of rich learning environments is the flexibility they provide to students in terms of studying at their own pace (Mayer, 2001). Another natural implication of this transformation is the rich interaction and collaboration opportunities forming among students both in-game and within the physical environment.

Even if everything is perfect in technology implementations, there can still be problems originating from technology (Smaldino, Russell, Heinich, & Molenda, 2005). This study proved that in rich technology implementations, designs should be flexible enough in order to compensate for implementation problems originating from infrastructure, hardware, or software. If such flexibility exists, measures can be taken in practice to generate temporary or permanent solutions about implementation problems. Related to the computer game in this study, there was such an implementation problem due to a problematic server in the second week of implementation. As a result, some features were not available. Since these were the main activities within the game as part of a bigger goal, their unavailability could have prevented the meaningful experience intended by the designers. The just-in-time conceptualization, design, and development of paper-based tools for the main activities overcame these problems and supported a seamless learning experience. Although the features were functional the next week, former paper-based designs were followed to sustain a consistency of game experience. This flexibility in designs in the face of problems suggests two requirements: good documentations from designers and support staff cultivated with awareness of possible problems in designs involving rich technologies. Designers should speculate about potential implementation problems and solutions to these at the same time they deal with the design endeavor, and convey these to their users as part of their documentation. In turn, support staff can go through the documentation ahead of implementation, become acquainted about potential problems and solutions, and even brainstorm problems and solutions that may be unforeseen by designers.

According to Jones (1998), aesthetic elements in designs do not provide motivation or learning if they are put merely with the aim of visual pleasure; they must have some intentions. If the elements have no functionality, they can create dissatisfaction among students. The Global Village game included some 3D objects such as a plane without any functionality. Many students assumed the plane was functional and thought their task was to help lost children catch this plane. Although the players were displeased with this situation, the aesthetic involvement of objects did not seem to disrupt motivation of players in this three-week short-term game implementation. However, some studies (e.g., Tuzun, 2006) show that longer term game implementations require attention to this matter. Overall, computer games involving MUVEs should be designed and developed with interactive features; the objects and artifacts in game's MUVE should have both purpose and functionality.

7. Future work

A common problem with learning at schools is the limited time frame devoted for learning in different subject areas. This was visible in this study with the participating group at the school only able to utilize the game-based learning environment for an hour a week. The members of the group naturally were not able to go through all the content available in the game environment in the limited time frame, but they were extremely willing to continue their participation. This willingness was also backed up by the optimism of their parents. In an era where average child devotes almost six hours to media use daily, an hour of which for playing computer games (Roberts & Foehr, 2008), it is commonsense to harness this enthusiasm of children towards computer games for learning. Therefore, the following out-of-school experience could follow the game implementation at the school:

> In her room at home, Melissa was continuing to explore the Global Village game. She had collected information about one fourth of the continents and countries in the game environment while at the school, and she was planning to visit the remaining ones in her spare time and match the remaining lost game characters with their countries. She had heard that her Comenius project teacher was going to attend a meeting for the project in Italy. For that reason, she decided to learn more about this country. While directing her avatar to the flag of Italy, she came across with Adem, another student from her class. Although Adem did not own a computer at home, he was able to play the game at a club he attended after school. Therefore, although children were separated throughout the city after school, they were still able to come together in a shared game-based learning community. After being aware of each other's avatar, they remembered that they did not have time at school to customize it. They took time to tailor the gender, skin color, hair style, and costume of their avatars. This was quite fun. Adem decided to accompany Melissa when she shared her intention of learning about Italy. As opposed to the implementation at the school, the Web scripts in the Global Village game were now functional, enabling them to use Q-mail to communicate with others and Q-pack to collect lost artifacts from the environment. After collaboratively collecting data about Italy, they utilized Q-mail to send their reports to the system. Their responses would be evaluated by one of tens of volunteer peers, who were given reviewer status after attaining a credible level of experience. Afterwards, Melissa and Adem traveled to the entrance world of Quest Atlantis, met Flora joining the environment from Italy, and exchanged details about their cultures.

Dede (2003) predicts that MUVEs will be one of the complementary interfaces that people will learn with in the upcoming decades. Collins (2006) perceives passion as being a prerequisite for learning and proffers how children can follow their passion for learning about different subject matters in MUVE-based environments. Both scholars present futuristic scenarios in which learning happens through MUVEs. A part of the vision behind these scenarios is the elimination of the dichotomy between school and home activities, and the dichotomy between learning and entertainment. Results of this study present empirical support for the vision of these forward thinkers, while the possibility of the scenario conveyed in the previous paragraph suggests that this vision is actually viable today. As computer games with 3D MUVEs become more pervasive in children's lives, it becomes extremely important to understand the effects of these experiences on children's identities and development, and organizational, political, and cultural obstacles (Dede, 2002) to using these advanced technologies for learning. Future studies could address these issues while reducing the limitations of this study by selecting participants with diverse computer and Internet literacy, willingness, familiarity with computer games, and socio-economic status.

8. Conclusion

As understanding geography becomes more and more crucial in our daily lives, innovative ICTs need to be harnessed in geography education. This study showed that computer games can be used as an ICT in formal learning environments to support students in geography learning and increase their motivation while making learning fun. In addition to gains in learning and motivation, it was confirmed that computer games embrace the characteristics of the new pedagogy in terms of providing authentic and relevant learning environments and increasing learners' autonomy. It was further found that the affordances of exploration, interaction, collaboration, and immersion in computer games may provide rich opportunities for geography learning. The efforts of future instructors, academicians, and practitioners using and researching this frontier will further enhance our understanding of the impacts of computer games in geography education.

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