British Journal of Educational Technology *Vol 30 No 4 1999* 311–321

The use of computer games as an educational tool: identification of appropriate game types and game elements

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During the past four years Alan Amory, a lecturer in Biology, has investigated the use of multimedia as a teaching resource and converted his courses from old-style lectures and practicals to constructivist-like classrooms. He also enjoys the thrill of creating software. Kevin Naicker, an Honours student at the time of this research, is interested in the use of computer technologies, especially the World Wide Web, in education. Jacky Vincent, our graphic artist, with her abounding enthusiasm and experience, enjoys designing unique virtual worlds and developing game scenarios. Claudia Adams, a zoologist and librarian, helped in the finding and organisation of the content and enjoys the creative side of plot development. Address for correspondence: Professor Alan Amory, Biological Pedagogics Research Unit, Biology Department, University of Natal, Durban, 4041, South Africa. Tel: +27-31-260 1191; fax: +27-31-260-2029; email: amory@biology.und.ac.za

Abstract

Playing games is an important part of our social and mental development. This research was initiated to identify the game type most suitable to our teaching environment and to identify game elements that students found interesting or useful within the different game types. A group of twenty students played four commercial games (SimIsle, Red Alert, Zork Nemesis and Duke Nukem 3D). Results suggest that students prefer 3D-adventure (Zork Nemesis) and strategy (Red Alert) games to the other types ("shoot-em-up", simulation) with Zork Nemesis ranked as the best. Students rated game elements such as logic, memory, visualisation and problem solving as the most important game elements. Such elements are integral to adventure games and are also required during the learning process. We present a model that links pedagogical issues with game elements. The game space contains a number of components, each encapsulates specific abstract or concrete interfaces. Understanding the relationship between educational needs and game elements will allow us to develop educational games that include visualisation and problem solving skills. Such tools could provide sufficient stimulation to engage learners in knowledge discovery, while at the same time developing new skills.

Introduction

Rieber (1996) argues that play, especially during early childhood, performs important roles in psychological, social and intellectual development; is a voluntary activity that is intrinsically motivating; involves some level of activity and often possesses

Published by Blackwell Publishers, 108 Cowley Road, Oxford, OX4 1JF, UK and 350 Main Street, Malden, MA 02148, USA.

make-believe qualities. Such attributes are similar to those contained in modern educational theories where learning should be a self-motivated and rewarding activity (Kolesnik, 1970). Blanchard and Cheska (1985) contend that play is not the opposite of work as is leisure, and appears to be a universally accepted mode of learning.

The advent of personal computers with superior graphics systems has precipitated an explosion in game software. This multimillion-pound industry produces many different kinds of games ranging from simulations through to first-person adventures. Here players are immersed into virtual worlds filled with stunning graphics, compelling, if not addictive, story-lines, sound and video. However, many question the social consequences of this form of entertainment. McKee (1992, 5) and Billen (1993, 51) argue that games affect cognitive functions, motivation and remove players from the "real world". However, games appear inherently to motivate users intrinsically by stimulating curiosity (Thomas and Macredie, 1994). This may be due to the presence of challenges and elements of fantasy (Malone 1980, 1981a, b), novelty and complexity (Carroll, 1982; Malone, 1984; Malone and Lepper, 1987; Rivers, 1990).

Learning that is fun appears to be more effective (Lepper and Cordova, 1992). Also, Quinn (1994, 1997) argues that for games to benefit educational practice and learning they need to combine fun elements with aspects of instructional design and system design that include motivational, learning and interactive components. According to Malone (1981a, b) three elements (fantasy, curiosity and challenge) contribute to the fun in games.

There appears to be a close association between play and learning. Computer games enhance learning through visualisation, experimentation, and creativity of play (Betz, 1995) and often include problems that develop critical thinking which was defined by Huntington (1984) as the analysis and evaluation of information in order to determine logical steps that lead to concrete conclusions. Visualisation, a key cognitive strategy, plays an important role in discovery and problem solving (Rieber, 1995). Sekuler and Blake (1994) stated that our sense of vision represents our most diverse source of information of the world around us. Visualisation, therefore, has tremendous value in computer games. Also, many of the problems presented in games require the manipulation of objects, or elements, in these exploratory environments and can be involved in goal formation and competition. Leutner (1993) argued that manipulation of objects stimulates learning and training while Neal (1990) proposed that goal formation and competition are inherently motivating components.

Of the many different types of games (for example, adventure, simulation, role-playing, shoot-em-up and strategy games) developed, educational researchers appear to have concentrated on two types, simulation and adventure (Quinn, 1994; Roberts, 1976; Ju and Wagner, 1997).

Before embarking on a research programme to evaluate the use of games as an educational tool it was therefore necessary to determine the game-type best suited to our environment and to investigate game elements that students found appealing. This paper reports on our initial investigations. First and second year university students played four commercial games in order for us to: discover the games type they found most enjoyable; identify game elements that contribute to the fun aspect of the games; and to evaluate student opinion relating to the use of games in education.

Materials and methods

Outline

Four games, representing different types, were played by a small group (n = 20) of first and second year biology students. Individual students completed questionnaires for each game after playing for about one hour and provided some demographic data (age, sex, ethnic group and year of study). The experiment was designed to identify the type of game that most undergraduate students would enjoy playing and to ascertain from the students those elements they found useful or interesting within each game.

Student selection

All first and second year biology students were invited to participate in the project. From these applications we selected a group of 20 students made up of an equal proportion of the different ethnic groups and an equal number of male and female students.

Game selection

Four games were selected and included Command and Conquer: Red Alert (strategy) by Westwood Studios; Duke Nukem 3D ("shoot-em-up") by 3D Realms; SimIsle (simulation) by Maxis and Zork Nemesis (adventure) by Activision. All games were played under the Microsoft Windows95 platform.

Questionnaires

Students answered a series of questions on their computer experience, how often and for what they used computers, and a series of questions for each game. The last series of questions attempted to ascertain whether the game was captivating, addictive and/or presented challenges. The questionnaire evaluated aspects related to game enjoyment (sound, graphics, type, story-line and technology), skills (logic, memory, visualisation, mathematics, reflexes and problem solving) and game play (addictive, boring, too difficult, illogical). Ranking (strongly agree, agree, disagree and definitely not) and open-ended questions were used. Questions on game enjoyment determined which elements contributed to curiosity (Thomas and Macredie, 1994), fantasy (Malone 1980, 1981a, b), novelty and complexity (Carroll, 1982; Malone, 1984; Malone and Lepper, 1987; Rivers, 1990). Visualisation and problem solving appear to be closely related to intrinsic motivation and learning (Rieber, 1995; Leutner, 1993; Neal, 1990). Other skills, such as logic, memory, mathematics and reflexes are also often required to solve complex problems. The second series of questions attempted to ascertain which of these skills students thought were required to play the games. The final set of questions on game play attempted to provide more information on each game and were used to identify the type of game preferred by our students. After playing all four games students rated them from most to least favoured game. The time spent on each game and the level, or stage reached, was also noted by each student.

Analysis

Ranking questions were calculated as the mean score out of a maximum of 4. To determine differences in responses by gender, or by race, the Kruskal-Wallis one-way Anova and Pearson's cross tabulation (SPSS) were used by grouping all the questions relating to each game (n = 80).

Results

Evaluation of commercial games by biology students

Of the 20 students who participated in this part of the project, ten were female, with an equal distribution between White, Black and Asian. The average age was 19 with most of them having very little computer experience or exposure to playing computer games. Among those that were computer-adept, most used computers for doing class assignments or for obtaining information. A minority of students did appear to spend some time playing games.

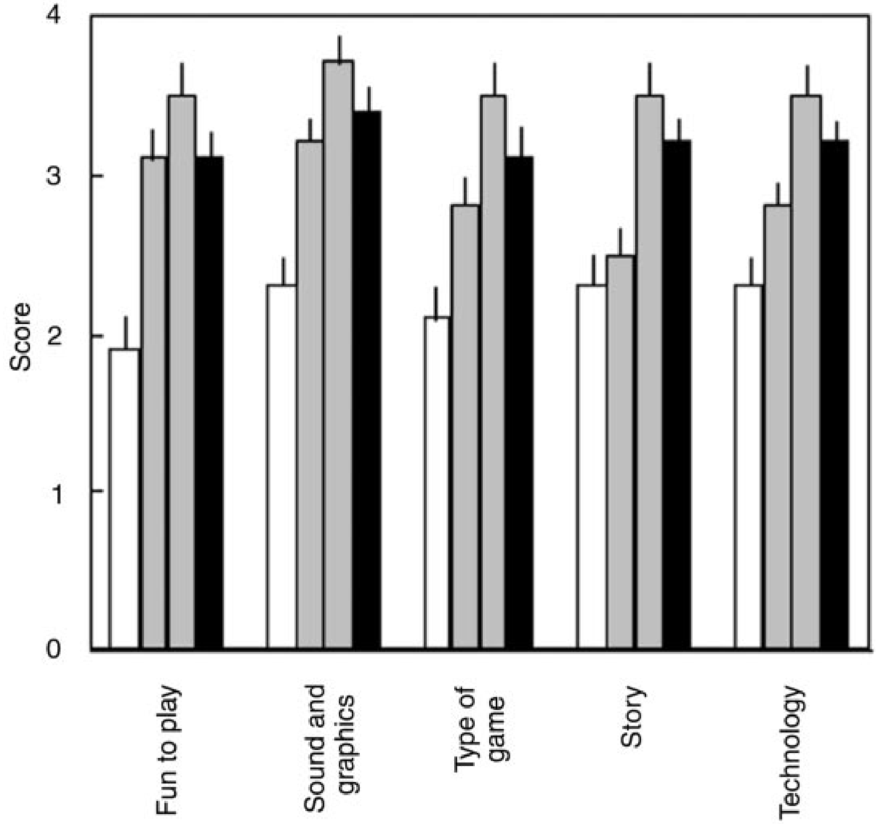
To determine the type of game elements most appreciated by the students we asked them to rate the games according to the fun aspect, sounds and graphics, type of game, game story and use of technology (see Figure 1). Zork Nemesis scored the highest in all aspects, closely followed by Red Alert (no statistical difference); SimIsle, on the other hand, was rated poorly by the students.

As a number of different skills are required to play games, students were asked to assess the importance of some skills [logic, memory, visualisation, and mathematics, reflexes and problem solving] (see Figure 2). The game that required the widest variety of skills was Zork Nemesis followed by Red Alert. Few of the games required mathematical skills, but reflexes were important in Duke Nukem. Problem solving was rated highest for Zork Nemesis and Red Alert.

Students were also asked whether the game was easy to play, addictive, too long, challenging, confusing, too difficult, illogical, difficult to play or manoeuvre and if their performance increased with continuous play (see Figure 3). Except for SimIsle, students were able to play the games successfully (see too easy and too difficult); found them addictive, challenging and not boring; were not too confused; and found that with practice their performance improved.

Generally students appeared to enjoy Zork Nemesis and Red Alert the most, and did not enjoy playing the simulation game, SimIsle. The ranking of the different games supports this conclusion (from best to worst: Zork Nemesis → Red Alert → Duke Nukem → SimIsle).

Statistical analyses of student opinions according to gender showed no differences (results not shown). It appeared that males played the games longer than did females



(Mean values; bar represents standard error; Score: 1—strongly disagree, 2—disagree, 3—agree, 4—strongly agree; n = 20).

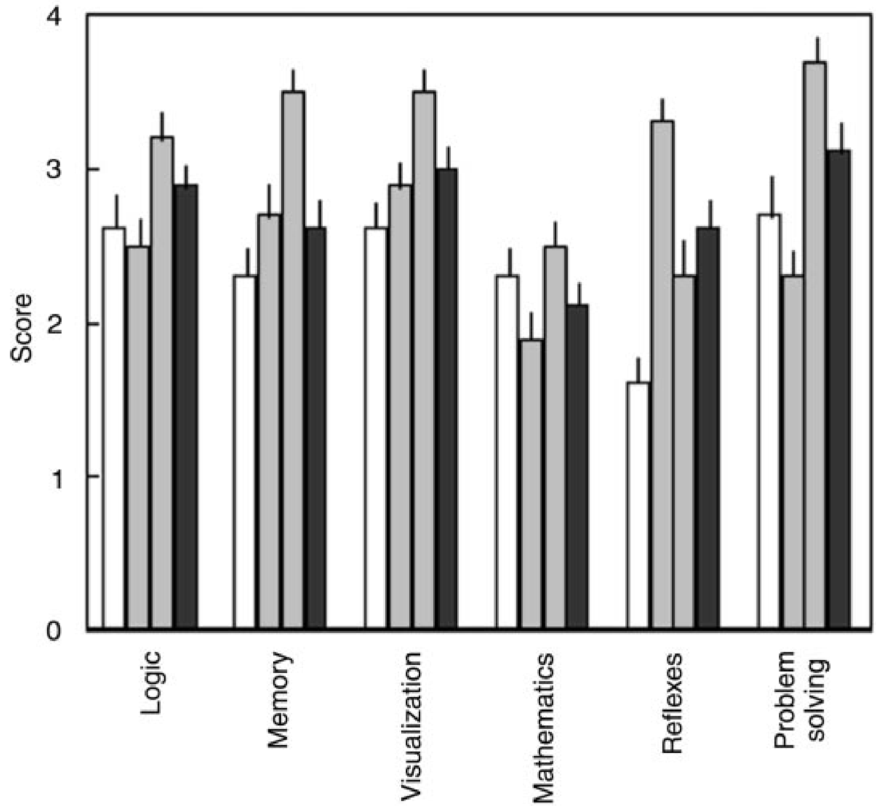
Figure 1: Student opinions related to different aspects of four commercial games

and therefore completed more of each game. The different ethnic groups did appear to respond differently to some questions as shown in Table 1. Differences were found in questions relating to how logical the games were, if they caused confusion, if they were too difficult and if they required memorisation. Also there appeared to be differences in rating the technology present in the games.

Generally students enjoyed Zork Nemesis and Red Alert the most. The game requiring the most skill was Zork Nemesis. The game least liked was SimIsle. This may in part be due to the user interface and game play (observations). There appears to be little difference between how male and female students viewed the games and the responses according to race groups were similar.

Discussion

Students were asked to rate the entertaining and educational aspects of four commercial games. They appeared to prefer adventure (Zork Nemesis) and strategy (Red

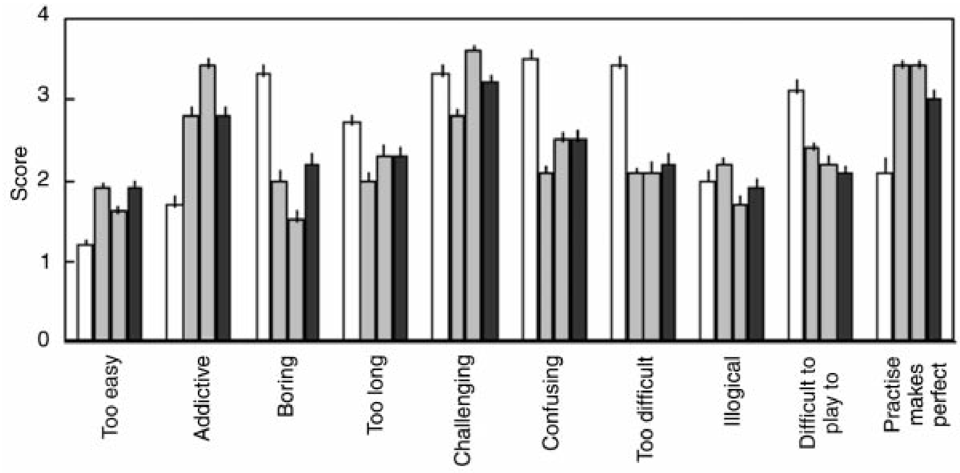


(Mean values; bar represents standard error; Score: 1—strongly disagree, 2—disagree, 3—agree, 4—strongly agree; n = 20).

Figure 2: Student opinions related to skill required to play four commercial games

Alert) games as they found them more stimulating (sound, graphics and technology scored the highest). Story lines were also deemed to be more interesting. These results support the ideas of Malone (1981a,b) and Quinn (1994) and those of Thomas and Macredie (1984) who argued that such elements promote intrinsic motivation and effective learning. Also, Myst, an adventure game, is the best-selling game of all time and strategy games, like Red Alert, were the most highly rated games by GameSpot (www.gamespot.com) in 1997.

Some students enjoyed playing Duke Nukem 3D while others reacted negatively to the violence and stereotypic characterisation in this game. SimIsle, the simulation game, was rated very poorly by the students. That may be due to the confusing interface and the lack of sufficient feedback (Norman, 1988).



(Mean values; bar represents standard error; Score: 1—strongly disagree, 2—disagree, 3—agree, 4—strongly agree; n = 20).

Figure 3: Student opinions related to game play for the four commercial games

Table 1: Analysis of answers by ethnic groups versus different game attributes

Variable	*Pearson Chi-squared value*
Game was illogical	19.66***
Game was too difficult	17.56**
Use of technology	16.99**
Game was confusing	15.86
Game required memory skills	15.04
Game required reflexes	14.02
With play performance increased	13.10

n = 80; df = 6; *** $p < 0.005$; ** $p < 0.05$ and > 0.005.

Visualisation and problem-solving skills are an integral part of adventure and strategy games. In this study, students felt that Zork Nemesis and Red Alert required such high-order thinking skills. Visualisation strategies nurture creative problem solving (Rieber, 1995). Computer simulations enhance learning through visualisation and creativity, as players are able to visualise the cause and effects of their own actions on whole systems and thereby develop intrinsic decision-making skills (Betz, 1995).

Male and female students appear to react similarly to these games (no statistical differences in responses, n = 80). Other authors (Gipson, 1997; Temple and Lips, 1989; Canada and Brusca, 1996) have argued that there are differences in attitudes between male and female students with respect to computer and technology usage.

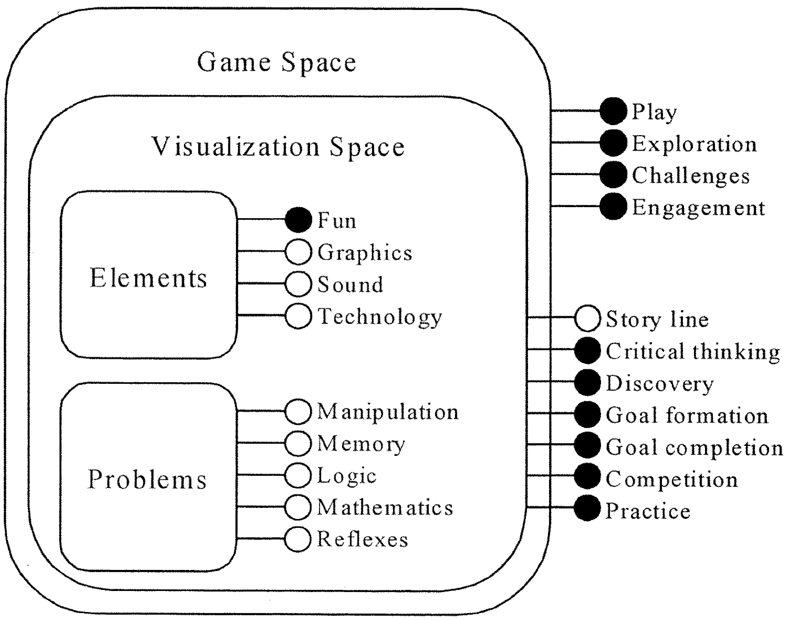
Absence of this trend in our results may be due to the small sample size and therefore not a true representation of the population.

Responses between the ethnic groups were statistically different (n = 80) and were related to questions on logic and difficulty of the games. The exact nature of the differences is unclear. Students from disadvantaged backgrounds lack cognitive, practical and psycho-social skills (Grayson, 1997). The relationship between these skills and ability to play games needs to be investigated further.

Therefore, the adventure game appears to provide the best foundation for the development of teaching resources. This is supported by the work of many authors such as Quinn (1994, 1997). However, there appears to be little information available regarding the importance of the different elements within the adventure game that could be useful to education. Students rated sounds, graphics, story line and use of technology as important. While it could be argued that all the commercial games contain cutting-edge technology, the students rated the technology in Zork Nemesis the highest. This may be due to the use of many cinematic constructs, such as the use of real actors in virtual worlds, cuts, fades, voice-overs and full-screen animations. Realistic graphics, sounds and addictive story lines appear to enhance the playability of games.

Skills required to play adventure games identified by students include logic, memory, visualisation and problem solving. Modern educational theories (Saljo, 1979; Schank and Cleary, 1995) argue that the development of such skills are fundamental to all learning.

Quinn (1994) noted that there is insufficient pedagogical support in games. In an attempt to synthesise information on educational games and our results, we present a model that attempts to create a dialectic between the pedagogical dimensions and game elements. Educational games contain different aspects, those that promote educational objectives (abstract) and those that allow for the realisation of these objectives (concrete). Therefore a game space consists of different *components* that contain discrete *interfaces* (see Figure 4). These *interfaces* are either abstract or concrete. The game space embodies all the *components* (each with their own *interfaces*) and *interfaces* that define the interactive learning environment. In this model *components* are represented by rounded squares and *interfaces* by circles linked to *components*. *Components* may either be free-standing or part of other *components*, in which case they inherit all the parent *interfaces*. Inner *components* contain concrete *interfaces* while the outer ones are more abstract. *Interfaces* are also lists from the most to least important. Therefore the *game space component* is proposed to consist of five motivational *interfaces* (play, exploration, challenges and engagement) and the *visualisation space component*. This *component* contains the story line, critical thinking, discovery, goal formation, goal completion, competition and practice *interfaces* with the *elements* and *problem components* embedded within it. The *elements component* contain those *interfaces* (fun, graphics, sound, and technology) that make up the story line, appearance and playability of the game and are related to the discovery and goal formation *interfaces* of the *visualisation space component*. The other



(●—abstract interfaces, ○—concrete interfaces).

Figure 4: Components and associated interfaces game development model

interfaces of the *visualisation space components* (critical thinking, discovery, goal formation, goal completion, competition and practice) are expressed via the manipulation, memory, logic, mathematics and reflexes *interfaces* of the *problem component*. Abstract *interfaces* therefore depict pedagogical elements and concrete *interfaces* depict game elements. Students identified the two inner-most components (*visualisation space* and *problem*) and the *story line*, *memory* and *logic interfaces* as the most important game elements. Such a model could allow for a systematic approach to the development of educational games that will allow for the easy identification of appropriate game elements underpinned by sound pedagogical arguments.

Conclusions

First and second year Biology students appear to favour 3D-adventure (Zork Nemesis) and strategy games (Red Alert) and found the simulation game SimIsle unsatisfactory. Students identified graphics, sound, story line as important aspects and perceived skills such as visualisation, logic, memory and as important skills required to play adventure games. A model that links pedagogical issues with game elements is also presented. Development of learning tools based on the adventure game could provide educators with a superior mechanism to entice learners into virtual environments where knowledge is acquired thought intrinsic motivation.

Acknowledgements
We wish to acknowledge research grants from the University of Natal Research Fund and Foundation for Research Development, and to especially thank Mr Richard Devey for his help with the statistical analyses, Dr Rob Slotow and Professor John Cooke for their expert help, and Professor Pat Berjak for careful reading of the manuscript.

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