AN INVESTIGATION OF THE EFFECTS OF COMPUTER INSTRUCTIONAL GAMES ON STUDENT LEARNING

Lupe M. T. Gates
GOSNELLS SENIOR HIGH SCHOOL
WESTERN AUSTRALIA

Renato A. Schibeci
SCHOOL OF EDUCATION, MURDOCH UNIVERSITY
WESTERN AUSTRALIA

THE CONTEXT
Games and learning
The potential of games for learning purposes has been suggested for a long time. For example, Henson (1982) reported an account of the 19th century school teacher, Maria Montessori, who devised educational games for her pupils, basing such games on her pupils' natural environment and behaviour. Such 'natural' forms of education are reflected in the words of educators, for example Dewey (cited in Boocock & Schild 1968), who believed that children (or learners) should be directly involve in their learning.

This interest in the use of games in schools has gained impetus from the availability of computers in schools and from the large numbers of computer games that have been commercially produced.

With the increased popularity and usage of computer game software in schools, the benefits of these games on student learning has been questioned. Chaffin, Maxwell and Thomson (1982) have claimed that in comparison to other teaching methods, computer courseware which utilises gaming procedures and format is highly effective in instructing students, particularly those with low learning abilities. On the other hand, Lipsitz (1983) has argued that computer games are a commercial enterprise which have as their main aim profit-making rather than promoting an effective or innovative method for teaching students.

Do students truly learn from games? If so, what are the advantages of gaming when compared to traditional teaching methods?

Purpose
The purpose of this study is to explore some of the claims that have been made about games, particularly those relating to the use of computer games in schools. The concern of this study is the use of games as mediums of instruction: Do students truly learn from games? If so, what are the advantages of gaming when compared to traditional teaching methods?

These are complex questions. Any measure of student gain in learning through gaming is dependent on the types of games, the learning environment and, the student's ability level. To evaluate the effectiveness of games (particularly computer games) as mediums for instruction, three types of games with different educational purposes and two types of gaming environments were used.

The games
The reason for selecting three different games only is twofold. Firstly, in order to evaluate the effectiveness of games on students learning it seems essential to consider several games with different educational purposes. For example, the three games that were used in this study Concentration, Yacht Race and Number Facts have, respectively, the following educational purposes: development and enhancement of concentration skills; learning specific content knowledge through simulation; and, drill-and-practice of arithmetic facts.

The second reason for the selection of these games relates to a number of constraints in the study, including the availability of resources (for example, computers and games) and suitability for students' ability level.

An important part of this evaluation is the provision of two types of gaming environments, one in which the game participants (students) were required to play a game using the computer and the other where the students played a non-computer version (for example, with cards) of a similar game. The purpose of having these two gaming environments (computer and non-computer) was to examine which of the two would provide a gaming environment that is conducive to the learning of the specified objectives of the games.

The third variable in this study, the student, is obviously a vital part of this evaluation. The nine students who participated in the study were identified by the school's guidance officer as special education students (that is,
students with low learning abilities) and were therefore placed into a class separate from the usual class streams. Chaffin et al. (1982) have claimed that computer gaming procedures are effective in motivating students with low learning abilities to want to learn.

Types of computer games

Computer games for classroom use have sometimes been classified into two categories: arcade and non-arcade educational games; see Scriven (1987) for a more detailed taxonomy. Although significant claims have been made regarding motivational benefits of videogame formats and procedures to student learning, there is very little evidence available on the effectiveness of such formats in producing substantially better forms of learning than other, more conventional types of teaching strategies.

Non-arcade classroom computer games are commonly used in schools and teachers tend to encourage their students to use non-arcade games in preference to arcade-type games. In this study, three non-arcade games were used: a strategic game (Concentration), a simulation game (Yacht Race), and a drill-and-practice game (Number Facts).

METHODS AND PROCEDURES

The students and their teacher

The participants chosen were nine (low ability of special education) Grade 9 and 10 students (two females and seven males) and their class teacher. The class teacher was a qualified special education teacher who was responsible for the major teaching program for these students.

The purpose for involving the class teacher in the study was twofold. Firstly, classroom teachers should by fully involved and completely aware of any studies which involve their students. Secondly, the times set aside for the study were not sufficient to determine the success or the validity of the outcome for this study. In addition, it was hoped that the results of the study would be incorporated into these students' learning program after the study was completed. For these reasons, it was most desirable for the classroom teacher to be fully involved in the study.

The class teacher, at the completion of the study reported here, continued the weekly two by 50-minute periods of allowing the students to develop skills, practice number and word skills, learn concepts, and develop and practice hand and eye coordination through playing educational computer games. Thus, educational computer games have become an important part of the learning program for the nine students who participated in this study, even after the formal study was completed.

Data collection

Data on student responses to the three gaming activities were collected using comprehension activities, group discussions, and observations. Data on the class teacher responses to the gaming activities and to the students' performance and behaviour were collected through interviews and observations of the teacher's interactions with the students.

Observational data of student responses and teacher interviews were noted in written form by the first author. Although this type of written observation may be considered to have limitations, instruments such as tape-recorders may influence the participants to make responses which are unrelated to the study. Also, the use of additional instruments in the study environment was avoided in order to exclude responses (from the participants) which are not specifically the result of the influence of the game equipments (computer and non-computer equipment).

Some of the data were gathered by the class teacher, who assisted in recording the students' verbal and non-verbal responses (both during the gaming activities and during normal class periods).

The purpose of the comprehension activities was to examine whether the students have understood the objectives of the games they played. Also, these activities would provide additional information relating to the effectiveness of these non-arcade educational computer games to student learning.

Game organisation

The nine student participants were randomly placed into two groups. Group 1 students played the computer versions first and Group 2 the non-computer versions. Both groups were situated in the same classroom.

Observation and supervision of Group 1 was carried out by the class teacher while Group 2 was observed and supervised by the first author. The groups were interchanged after the 'comprehension activity' for each game. According to the implementation of the games, all nine student participants and their class teacher were given a demonstration on how to operate the computer. They were shown how to start the machines and how to load the software. The students were also tested on keyboard skills.

Students were not withdrawn from their normal class activities. Furthermore, the students were under the impression that the researcher was an extra teacher to assist their class teacher.

Study procedures

The study began on the first week of the second term of school and it continued throughout the whole term. The participants of the study were only accessible for one, 50-minute period a week. Also, only one computer was usually available; more rarely, two were available.

As indicated earlier, the students were randomly placed into two gaming groups. Initially, Group 1 played the computer version and Group 2 the non-computer version of the same game. After every two 50-minute sessions with each game, the students were given a comprehension test based on the aims and objectives of the game. In the study—session after each comprehension activity, the groups were interchanged so that all students would have the opportunity to play the computer version. Interchanging the groups also allowed the researcher to make observations of student responses to the two gaming environments (computer and non-computer environments).

With the Number Facts computer game, only two students were selected
to participate because only two computers were available for use in the study. Also, Number Facts was designed for one person playing at any one time. In addition, only two students could adequately be observed at any one time.

Table 1 gives a summary outline of the study procedures.

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Table 1 Outline of study procedures

a simulation non-arcade computer game. Two individuals or two teams can compete. Participants role play a yacht skipper and/or crew member. This simulation game is designed to help students to estimate scaled distances and to read and calculate compass bearings. A non-computer version of this game was constructed for this study. The board design was based on the screen display of the computer version.

The final game was Number Facts, a drill-and-practice non-arcade game which was specifically designed to revise the four arithmetic operations with whole numbers. From the choices provided, players in this study chose to revise all the operations except division; the 'easy' level of difficulty; ten questions from each set; expression in one or two digits; and, two of four trials in each. Answers were recorded on paper; correct responses were given when all ten questions have been attempted. A non-computer version of this game was based on four worksheets, each with 100 numerical expressions of a specific operation.

RESULTS

Concentration

A comprehension activity was used to determine whether students had understood the game's objective and to observe the recording/memorising activities of students. The activity involved 60 flashcards. The cards in each pack were individually displayed for approximately nine seconds each. The students' task was to observe each card as it was 'flashed' and endeavour to recognise any identical recurring card, hence a 'match' can be recorded. Since the value of the 'matched' cards was recorded as the score, this was a motivation for the students to observe closely the cards as they were being presented.

The results of the comprehension activity tended to support the speculation that students who record their observations using numbers and diagrams would score higher on the activity. However, the results indicated little support for the speculation that students who participated in the computer version gain higher scores on the comprehension activity.

The game environment (computer and non-computer) appears to have had little influence on the students' understanding of the game, since there were participants from both environments who recorded their observations using numbers and diagrams and who also had well-organised records and achieved high scores. However, it was noted that students in the non-computer version who scored highly and had used numbers and diagrams were those who had taken more interest in the game activity.

In general, the results of the comprehension activity showed that students who used diagrams and numbers and who had well-organised records of their observations obtained higher scores. It is interesting to note that the class teacher initially recorded her observations using words and numbers. However, she changed her method of recording from the writing of words to sketching diagrams. This she found to be much quicker.

Yacht Race

The comprehension activity for the Yacht Race game was in the form of a test. This test consists of five questions
relating to the game's objective. Question 1 tests understanding of compass directions: N, S, E, and W. Question 2 tests understanding of compass directions: NE, NW, SE, and SW. Question 3 tests understanding of scaled distances. Question 4 tests understanding of compass direction and scaled distances. Question 5 tests understanding of map reading and direction.

Each of the nine student participants was given a test sheet to complete. However, only eight test-sheets were examined (those of the eight students who participated in the Yacht Race game).

The five questions on the test sheet were assigned with possible scores of 4, 5, 4, and 8 respectively, making up the maximum score of 25.

When the students' performances are considered in groups (computer and non-computer), their overall results are very similar. This implies that both gaming environments (computer and non-computer) provided similar opportunities for the students to learn the game objective. The students from both environments achieved high scores on all the questions except Question 3.

This may be because Question 3 required a degree of abstract thinking. That is, the students were required to work out the solutions without the use of concrete aids such as rulers (which were permitted to be used during the gaming sessions). It appears that extra practice is needed in this area before these students can confidently and successfully complete this type of question.

**Number Facts**

A pre-test and a post-test was given to all of the nine participating students. Since time-on-task is an important variable with respect to the number of correct responses, it seemed appropriate to have a base-line measure (pre-test) and a comparative measure (post-test). The treatment activity was the computer version of Number Facts.

The two students answered 40 questions from each of the selected items in the Number Facts game: addition, subtraction and multiplication. Each question was displayed for 4 seconds (a total of 2 minutes 40 seconds for the 40 questions). Both students scored more highly on the post-test than the pre-test.

**SUMMARY**

The report on the three non-arcade computer games examined in this study has shown that each of the three types of games (strategic, simulation, and drill-and-practice) provided different learning opportunities and benefits for the students.

The strategic game (Concentration) provided a situation for the students to analyse a task and act in a manner consistent with prescribed rules and procedures. The simulation game (Yacht Race) provided a situation for the students to assume different roles. Finally, the drill-and-practice game (Number Facts) provided a situation for the students to test their knowledge on arithmetic facts.

The benefits of these games to the students appear to vary according to the game environment. Firstly, the computer version of the strategic game provided an environment that was less distracting for the students than the non-computer version. Second, the computer version of the drill-and-practice game provided a valid test of student performance in relation to the time spent on the task. Thirdly, the simulation game was shown to have elicited similar responses from the students, irrespective of the game version.

**DISCUSSION**

The interrelationship of three important variables (student, game and game environment) with respect to education games has been explored in this study. One of the aims of the study was to examine the effectiveness of educational computer games on student learning when compared to the non-computer version of the same educational games. In addition, consideration was given to the influence that computers may have on student responses to the games.

The results from the study must be treated cautiously; they are obviously based on a very small sample. Further, the data are more qualitative than quantitative in character. Nevertheless, the results provide some useful pointers.

**Game influence**

The results of this study indicate that the game environment is an influential variable on student responses, particularly if the game is strategic and/or drill-and-practice. However, for the simulation game the game environment appears to have had little effect with respect to student responses. Evidently, the response patterns that evolved out of the interrelationship among the three variables (student, game, and game environment) were largely dependent on the student variable. That is, students with high learning abilities may produce completely different sets of response patterns to students with low learning abilities (such as those chosen as participants in this study).

One of the claims investigated in this study was a claim made by Chaffin et al. (1982) concerning the effectiveness of educational computer games with video-game formats in teaching students with low learning abilities. These authors have suggested that educational computer games that have high motivational features (such as those with video-game formats) would cause students, especially those with low learning abilities, to want to learn. Although the computer games used in this study did not have video-game formats, these games were nevertheless representative of those to which students and teachers have ready access at the present time. Observation of student responses in this study tends to indicate that the crucial factor in encouraging the students to want to learn, is related to the type (strategic, simulation, or drill-and-practice) of educational game rather than the high motivational features of a computer game.

The kind of educational computer game which appear most appealing to the students (no surprisingly) was one which had the fewest written instructions and a minimal number of computer keys to handle. In addition, the content of the game software must be appropriate to the students' ability level and the content must be unrolled at a controllable speed for the students. This is in contrast with the claim by Chaffin et al. (1982) that low learning
ability students would benefit and are more attracted to computer games with a high response/output rate (that is, courseware with video-game format).

In analysing the computer-game-playing experiences of a group of computer players, Myers (1984) reported that being able to participate in a game provides more satisfaction for the player than being able to control the game patterns. He argued that being in control of the game patterns does not provide the same sense of cooperation between the player and the game as the participation experience (such experience requires time and effort).

In the present study, observation of student responses to the computer games supported Myers' claim. That is, the students were observed to be more motivated towards the type of computer game which permits them to react in their own time (self-paced situation).

**Educational benefits of computer games**

According to the literature, educational non-computer games are beneficial to student learning in a number of ways. Games encourage the learner to be actively involved in learning activities rather than passive involvement (Boocock & Schild 1968). Game playing reduces social distance and provides a more relaxed learning atmosphere as well as encouraging open and vigorous communication amongst participants (Bredemeier & Greenblatt 1981). Accordingly, students can learn and benefit educationally from playing games.

With respect to computer games, Myers (1984) reported that players do learn (such as concepts and skills) from playing them, though the learning is almost always specific to the games in question and have little relevance outside the game. For example, being skilful in knocking down bricks in a computer game would have little relevance to the real-life situation. Myers (1984) argued that game knowledge is different from real-world knowledge. That is, game enjoyment results from discovering connections and patterns within the game structure and manipulating these patterns in order to establish control. To use similar strategies in real-life, however, one must consider moral and practical obstacles and these obstacles may be beyond the power of the individual to manipulate in order to gain the desired control. Although there is a distinction between game knowledge and real-world knowledge, it could be argued that some game knowledge and skills could be transferable to a real-world situation. For example, problem-solving strategies that can be developed through gaming — as in war and military games — could be transferable to real-life situations — war and military combat (Vickers 1984).

The findings of the present investigation indicated that the interrelationships among the student, the game, and the game environment are complex. The patterns of responses from the student participants appeared to be unique for each type of game and game environment.

The findings from this study tend to show that educational computer games, in particular strategic type games, elicited behaviours that are conducive to learning (e.g. attentiveness and strategic though specific to the task). Further, drill-and-practice computer games are more efficient and reliable than non-computer versions in assessing time-on-task and mastery level. With simulation games, it has been suggested that the game situation and the learning content determines whether a computer or non-computer game is more effective.

In general, educational computer games are beneficial to student learning providing that the game is appropriate to the student's ability level. With students who have low learning abilities, it was observed that they responded well to computer games which allowed them (the students) to operate the games at their own pace. This is in contrast to the claim by Chaffin et al. (1982) that students with such abilities are motivated to use educational computer games which have a high response/output rate.

**Implications**

The most valuable information to be discovered in investigations of the type in this study is not non-computer games are different from computer games but how educational or instructional games can contribute uniquely to learning.

The study has shown that within the broad classification of educational games, each sub category has unique properties and elements. Also, each of these sub categories are designed for specific education purposes. For example, drill-and-practice games are designed to enhance and reinforce previously learnt knowledge and skills. Simulations are designed to allow the student to assume a new identity and experiment with different kinds of

**With students who have low learning abilities, it was observed that they responded well to computer games which allowed them (the students) to operate the games at their own pace.**

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who enjoy carefully sequenced and finite ways of learning. The in-built flexibility of the program allows other students to explore their own ideas laterally and use the task sheets as a spring board for their own creativity, demonstrating the power of this media to be a wonderful tool for whole-brain learning. The left-brain assimilation of the technical and sequential processes is a necessary part of the creative process leaving the right brain free to fly with ideas once there is technical automaticity.

Howard Gardner (1983) proposes what we see as 'intelligence' in mathematics is seen in the artist as a 'gift or talent', one of our other forms of intelligence. He maintains that we are truly complex beings made up of multiple intelligences and those of the arts are some of these intelligences. In that case there is a talent in all of us and it is the role of the teacher to find a road that each student can journey down to explore and mobilise his or her creativity.

Image generating computers and their associated technology are a truly open-ended tool for every student's journey to creativity and whole-brain learning.

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computer and non-computer games can then be designed to meet teacher and student expectations and requirements. According to Myers (1984), the best computer game designers are the best artists, those who examine broadly whatever is learned from games played in their natural environment and apply the same general qualities to computer games. Similarly the same general qualities should apply for non-computer games. These qualities should include how to feel or empathise, how to understand, and not in the strictest sense, how to know.

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