Serious Games in Education

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Abstract

This study investigates to what extent serious games support learning processes. We compared the abilities of two groups of high school students to answer questions on a subject that they were recently instructed on. The first group received its instructions by means of a serious game, the second group by means of a text. We discovered that the group that received its instructions via a serious game performed significantly better than the text group in solving the assignments. Surprisingly, the group that received its instructions via a text indicated that they were better motivated. Further analysis showed that clear gender differences were underlying these results: males benefitted most from instruction via a serious game, while females were better motivated by a text. From our results we conclude that serious games can be more effective in learning processes than written texts, but that they do not necessarily motivate students better than a textbook.

SERIOUS GAMES, TEXTBOOKS, EDUCATION

Introduction

The term “edutainment” refers to entertainment games that have the ability to educate players. Such games are also referred to as “serious games”. Similar to serious games are so-called “educational games”. Both types of games are focused on developing the skills and knowledge of their players. However, serious games can be distinguished from educational games in that they are designed to look more like commercial videogames than their counterparts. The educational content of serious games is implicit in the gameplay, rather than an explicit component as found in educational games (Johnson, Vihjalmsson & Marsella, 2005). Winn (2008) states that serious games play as entertainment games, but have been designed to serve a purpose beyond just entertainment.

A modicum of research has been done to investigate the effectiveness of educational games for learning processes (Bourgonjon et al., 2010; Gibbs, 1992; Kim & Chang, 2010; Lieberman, 2006; Pandey & Zimitat, 2007; Squire, 2003; Virvou et al., 2005; Zepp, 2005). The general conclusion from this research is that playing games motivates the students, and better motivated students achieve better results. In a literature search we could not find any work that had tested whether the results achieved for educational games could also be applied to serious games. As the way that knowledge is transferred with educational games differs from the way it is transferred with serious games, we cannot assume that serious games are as effective in the classroom as educational games. Therefore, the aim of the present research is to investigate how effective serious games can be in transferring knowledge compared to using textbooks.

In our research we use the serious game *E and Eve's Electrical Endeavors*, which is designed to instruct high-school students about electrical engineering. We compare the effectiveness of using this game to teach the students about transistors with a textbook that provides the same information. We are interested in which students are able to answer questions about electrical engineering more effectively, and which instruction technique motivates students the best.

In this paper we first provide background information on serious games. We then describe our experiment, discuss the achieved results, and derive our conclusions.

Serious Games

Serious games combine entertainment with knowledge transfer. They have a purpose beyond entertainment, e.g., education, training, advertising, or supporting social change (Winn, 2008). Such a combination is no guarantee for success. Brody (1993) notes that the combination of entertainment and education in computer games has produced some not-very-educational games and some not-very-entertaining learning activities.

For a long time, educators tended to ignore computer games as a source of education. Nowadays, however, the role of games in education is increasing (Squire, 2003). It is surprising that in general it is assumed that games will have a positive influence on education, but there is very little research that supports that position. One aspect of educational computer games that has been investigated are graphics. Benjamin (2010) showed that realistic graphics in a game are beneficial for the educational value of the game. He concluded that realism in educational games has a positive influence on knowledge transfer, as long as some room for imagination is being left. Bourgonjon et al. (2008) investigated the effect of games on student collaboration. He found that the games he used helped students in developing collaboration skills.

A possible reason why serious games are assumed to be beneficial for education, is that students are often motivated to play games. Svinicki (1999) showed that traditional schooling methods do not tend to motivate students. It is generally assumed that well-motivated students learn better. Winn (2008) showed that games are effective at engaging students which makes them active learners. Virvou et al. (2005) showed that certain hard-to-teach students showed improved concentration when playing an educational game. It is a small step to then assume that an educational game, which by its nature should motivate, is better at transferring knowledge than the methods used in traditional schooling. Of course, the pitfall is that a game might be a less suitable medium for transferring knowledge, leading to a motivating but ultimately less effective educational experience.

Experimental Setup

To investigate the effect of using serious games in the classroom, we ran an experiment in which we let a group of high-school students play a game that taught them electrical engineering theory. A second group of students was given a text which taught exactly the same material, using the traditional method of providing theory using a text, followed by example questions for practicing. We then compared the abilities of both groups in answering questions on transistor theory, and examined their motivation in working with the learning material. We now describe the game that we used, the participants, and the experimental procedure.

Game

The game we used is called *E and Eve's Electrical Endeavors*. It is an online serious game, that was developed by the Eindhoven University of Technology. The purpose of the game is helping players to develop skills and acquire general knowledge about electrical engineering.

The game starts with a brief introduction in which the player is shown that the playable character is trapped in electrical wires. The character has to move through the wires in order to escape. The player has to solve issues with resistances, transistors, and power shares, while moving through the wires (see Figure 1).

After every completed level the issues encountered are explained. The game consists of four chapters with ten levels each (except for the fourth chapter, which consists of only one level). In our experiment the students played only the first two chapters. In the first chapter the player is introduced to the controls and playing techniques. The second chapter teaches the player about transistors. This subject matter was completely new to the students which participated in our experiment.

Figure 1. Screenshots of *E and Eve's Electrical Endeavors*. In the top screenshot, on the lower middle of the screen the playable character is moving trough electrical wires. On the left of the screen a transistor is seen.

Participants

In our experiment 187 third-grade Dutch high-school students of two different schools participated. Both these schools were of the highest level of Dutch education (VWO). 47% of the participants were male, 53% were female. 7 participants did not indicate their gender (see Table 1). The average age of the participants was 14.6 years. 97.8% had the Dutch nationality. 78.7% indicated that they had previous gaming experience.

In each repetition of the experiment, the participants were randomly divided into two groups by either the teacher or the investigator. These groups were called the “game group”, of which the participants got to play the game, and the “text group”, of which the participants got to study the text. 97 participants (52%) were assigned to the game group, and 90 participants (48%) were assigned to the text group. Of the game group, 48 participants were male, 44 female, and 5 did not report their gender. Of the text group, 37 participants were male, 51 female, and 2 did not report their gender.

Procedure

The experiment took place in a computer room of the participants’ high school. One classroom had been reserved for this experiment. The experimental procedure followed a schedule that took one hour to complete (Table 1).

The classroom was divided into two sides. On each desk a computer with an internet connection was installed. It was not previously determined which side of the room would play the computer game and which side would read the text. After the teacher or investigator had randomly decided which side of the room would be the game group, and which side would be the text group, the investigator introduced the purpose of the research and the overall process of the experiment to the participants [introduction].

The students were then handed instructions on paper. The instructions for both versions were similarly structured, but referred to either the computer game or the text. The printed instructions of the text group were followed by the actual text and training exercises. The students started working after receiving the instructions. The game group played the computer game, and the text group read the prepared text equivalent and worked on the example exercises. None of the students had previously learned about the subject matter. They were allowed to collaborate with other students in their group during this phase [learning].

After the students had finished playing the game or studying the text, or 20 minutes had passed, the students were asked to stop working on the learning phase. They had to close down the game (game group) or hand in the text (text group), after which they received a set of 6 multiple-choice questions on transistor theory. They had 20 minutes to answer the questions. Two example questions are displayed in the Appendix [testing].

Next, the students filled out a short survey about themselves, in which they were also asked questions to gauge their motivation during the experiment. 10 minutes were available to fill out the survey [survey].

Finally, the students were asked to power down their computers and leave the room [closing].

Table 1: Schedule used for each repetition of the experiment.

phase	time limit	game group	text group
introduction	5 min.	instructions and assigning groups	
learning	20 min.	playing the game	reading the text
testing	20 min.	solving assignments	
survey	10 min.	filling out the survey	
closing	5 min.	powering down computers and leaving the room	
total	60 min.		

Results

Here follow the results that we achieved. We discuss, in sequence: (1) the effectiveness of the students in the game group and text group in answering questions on the theory; (2) the proclaimed motivation of each of the groups; (3) gender differences; and (4) the students' opinion on the use of serious games in the classroom. An alpha level of .05 was used for all statistical tests.

Acquired knowledge

To measure the relation between the total number of correctly answered questions and the group (game group or text group) a univariate analysis was conducted. The relevant means are displayed in Table 2.

This analysis resulted in an F-test of 4.12, which indicates a significant interaction between the game group and the text group in answering the questions, with a significance of 0.04. The power of this analysis is 0.52. These results indicate that the participants of the game group provide significantly more correct answers on the assignments than their counterparts of the text group.

We wanted to exclude the possibility of the game group containing more students who were doing well at physics anyway, so we correlated the students' most recent physics grade with the group that they were placed in. With the game group labeled "1" and the text group labeled "2", the correlation between group and grade was 0.013 ($p = 0.861$), i.e., no correlation.

Therefore we may conclude that the game we used is better able to transfer knowledge than the corresponding text which provides the same information. It is interesting to note that there was no significant correlation between the students' most recent physics grade and the score on our test, though there was a small trend that showed that doing well at physics increases the test score (correlation = 0.127, $p = 0.088$).

Table 2: Means Univariate Analysis between group and number of correct answers.

group	**mean**	**std.dev.**	**std.err.**
game	3.31	1.18	0.12
text	2.96	1.22	0.13
total	3.14	1.21	0.09

Motivation

The participants were asked whether they enjoyed their assigned task. This motivation factor was analyzed using a group (game or text) x motivation (rating of appreciation of the game or the text) repeated measures ANOVA. The relevant means are displayed in Table 3.

This analysis revealed a significant interaction between group and motivation: $F(1,184) = 6.40$, $p = 0.01$. The power of this analysis is 0.71. This means that the text group recalled a higher motivation for working with the text, than the game group for working with the game. This result is surprising, as games are assumed to provide higher motivation than texts.

In previous research we noted clear gender differences when computer games are used. We therefore repeated the group x motivation test for the two genders separately. For the male participants, we discovered no significant interaction between group and motivation. For the female participants, however, the analysis showed a significant interaction between group and motivation: $F(1,93) = 3.975$, $p = 0.049$. The power of this analysis is 0.51. Therefore we may conclude that the female students were better motivated by the text than by the game.

Table 3: Means Univariate Analysis between group and motivation.

group	mean	std.dev.	std.err.
game	2.82	0.83	0.09
text	3.12	0.78	0.08
total	2.97	0.82	0.06

Gender differences

We already noted gender differences for motivation. We therefore looked a bit further into gender differences. First, we correlated gender with number of correct answers on our test, and found that the males did better than the females (male = 1, female = 2, correlation = -0.303, $p < 0.001$). We also found that males claimed significantly more game experience than females ($p < 0.001$). These results are rather stereotypical, so not unexpected.

However, while the number of males in the game group was about equal to the number of females, for the text group the number of females was quite a bit higher than the number of males. As males seem to do better at physics than females, and males have more game experience, this raises the question whether the better results of the game group on our test can be explained by the ratio of males and females being askew.

We already noted that there was no correlation between last physics grade and group. But as males do better on our test than females, we decided to correlate group and number of correct answers for males and females separately.

We found that for males, there was a significant correlation between group and number of correct answers (correlation = -0.288, $p = 0.037$). This translated to the males from the game group scoring on average over half a point more on our test than the males from the text group. For the females, we found no significant correlation between group and number of correct answers (correlation = -0.055, $p = 0.596$).

We therefore conclude that the serious game that we used taught the male students the theory more effectively than the text, but that the female students gained no benefit from the game over the text. It is a well-known fact that, in general, males need different teaching methods than females. Perhaps serious games are a teaching method that works particularly well for males.

Opinion on games in the classroom

When the participants were asked whether they would like to play serious games in the classroom more often, 78.7% answered positively. This opinion stands in contrast with our conclusions on motivation.

Discussion

Our results show that serious games can be a supporting factor in learning processes, though they are not necessarily more motivating than texts. These results are contrasting to previous research conducted by Virvou (2005), Gibbs (1992) and Mujis & Reynolds (2001). Their studies show that computer games in education do motivate the students better than traditional schooling methods.

It turned out that the female participants evaluated the computer game as less motivating than the text. We offer two possible explanations for this result. Firstly, the theory concerned electrical engineering, which in The Netherlands is considered typically a male subject. It is possible that a lack of interest in the subject material had an adverse effect on the female students' opinion on the game. Secondly, in general females tend to show less interest in computer games than males.

Even though the survey showed that the participants were not better motivated by the game, the investigator who observed the participants during the experiment noticed that the game group immediately started playing the game, while the text group was not motivated to start reading the text at all. The text group had more complaints and asked more questions. Although the participants were randomly divided into the two groups, most of the students indicated that they would rather play the computer game than read the text.

This study focused on one particular serious game. The research could be extended by studying different serious games. *E and Eve's Electrical Endeavors* is a computer game concerning physics. Serious games concerning language development, training skills (for example for defense) and general knowledge should be examined as well.

In this research only short term memory has been tested. The participants immediately answered the questions after playing the game or reading the text. It would be interesting to compare the effects of a serious game with textbook learning on long term retention of knowledge.

Finally, we wish to stress that we only compared the use of a serious game with the use of a textbook. The teacher was not involved in instructing the students in this experiment. It is very much an open debate whether serious games can approach a teacher's effectiveness in transferring knowledge.

Conclusion

In this research we investigated the difference between teaching high school students electrical engineering theory by means of a serious game and by means of a text. We found that the males who acquired their knowledge through playing the game were better able to answer questions on the theory than the males who studied the text. For the females, we found no difference between using a game or a text to acquire knowledge. Somewhat surprisingly, the females who played the game professed to be less motivated than those who used the text, while the males did not seem to care either way. Whether this is the result of a lack of female interest in electrical engineering or in computer games in general is an open question. We may conclude, however, that serious games have the potential to be more effective in education than textbooks, in particular for male students.

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Appendix

These are two of the six questions that the students were to answer after playing the game or studying the text (translated from Dutch). Both questions concern Figure 2.

Q1: If the transistor is 'closed' (current flows in the right side of the diagram), what would happen if resistance R_2 decreases very much?

A. The situation remains the same, the transistor remains 'closed'.
B. The transistor will open so that the current in the right side of the diagram gets interrupted.
C. The situation depends on resistance R_3.

Q2: The transistor is 'closed', so current flows in the right side of the diagram. What will happen to the current in the right side of the diagram when resistance R_3 decreases?

A. The current in the right side will increase.
B. There will still be current in the right side, but weaker.
C. The current will no longer flow in the right side.

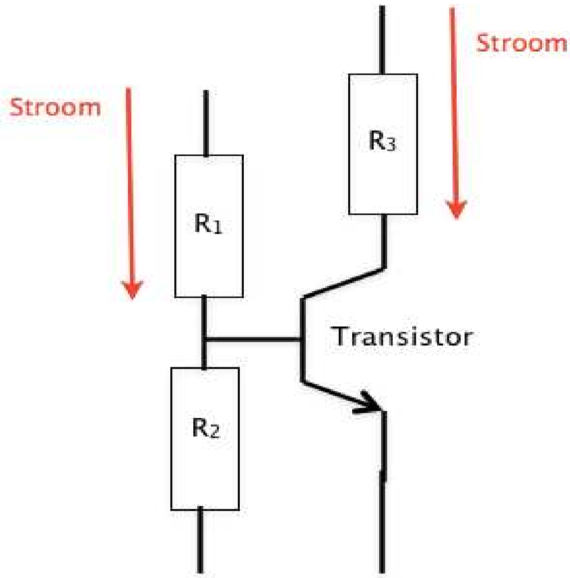

Figure 2: Schematic representation of 3 resistances and 1 transistor. The arrows indicate the flow of the current.

The answers are: Q1:B, Q2:A.

Acknowledgements

E and Eve's Electrical Endeavors can be found at `http://www.eeee.tue.nl`. A more detailed description of the research discussed in this paper is given by Stege (2011).