A Controlled Experiment on
Children Learning Experience Through Computer Games

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Abstract

During the last years there is a trend of introducing modern technologies, such as game based learning, in the educational process. This paper aims at comparing the efficiency of game based to traditional educational methodologies. In addition to that, secondary issues such as student satisfaction and learning goal difficulty are being explored as well. Thus, a controlled experiment on elementary school students, i.e. 9-11 years old, has been conducted. The empirical results suggest that Game Base Learning can be considered as an educational approach that exhibits, at least, similar learning effectiveness to traditional learning and at the same time is more enjoyable to the students.

1. Introduction

Computer games have been used for educational purposes, since they were introduced, in the late 1960s [13]. In [8 and 10] the authors argue that games are a fundamental part of the evolving human experience and the way that we learn, providing the opportunity to practice and explore in a safe environment. Advocates of computer game-based learning argue that computer games have the potential to transform the way that students learn, motivate and engage a new generation of learners in a way that traditional education does not [12]. On the other hand, [3 and 9] oppose against using computer games in didactic approaches, because present educational software is not considered of high quality.

The aim of this paper is to investigate possible positive or negative effects of game based learning in comparison to traditional learning. More specifically, this research has explored possible differences in the effectiveness and enjoyment of traditional and game based learning. Additionally, the impact of the learning goal difficulty on both educational processes is being examined.

According to [14], there are three major types of empirical investigation that are used in order to

evaluate new techniques, methods and tools. These investigation types are surveys, case studies and formal experiments. In addition to that, experiments are appropriate to explore relationships [14], i.e. to test the existence of a correlation between two variables. Thus, in our research so as to investigate the aforementioned goals, a controlled experiment has been conducted.

Formal experiments are normally executed in environments that provide a high level of subject control. Their objective is to measure the value of one variable and control the values of all other variables at fixed levels. By such measurements the experiment provides a data set for statistical analysis. The need for experimentation in computer science has been emphasized in many studies [4, 6 and 7]. The controlled experiment of this paper has been organized according to guidelines described in [1 and 14].

In section 2 of the paper, an overview of the literature is being discussed. Additionally, in section 3, the guidelines that have been followed during the experiment preparation, execution and presentation are being described, accompanied with discussion on the experiments organization and execution. Furthermore, section 4 highlights the results that derived from data analysis, demarcated into two subsections, i.e. descriptive statistics and hypothesis testing. Finally, limitations, future work and conclusions are being presented.

2. Related Work

This section of the paper, presents a literature review on the effects of game based learning on children. According to previous work, game based learning provides various benefits concerning children education, character and socialization.

In [2], the authors suggest that computer games strengthen children self-confidence and socialization in the sense that game playing often includes sentimental missions that require mutual respect among peers. In [5], the authors attempt to introduce a model that predicts user enjoyment in educational games.

In [12], the motivation for learning that computer

games offer to children is being discussed. During the study the authors have contacted regular gamers and non-gamers, through interviews, so as to investigate the research goals. The results suggested that computer games are not motivational for all individuals, but the perception on game based learning, under certain circumstances, has been positive.

Moreover in [11] the authors performed an experiment on a sample of over one thousand students. The main aim of the research has been to evaluate the influence of educational videogames with respect to learning and motivation. The teacher reports and student observations confirmed an improvement in the motivation for learning and a positive attitude towards the technology because of the game. More specifically, high levels of attention and concentration, self-esteem increase, growth of technological faculties and enhanced collaboration between students have been observed. Thus, the authors propose the incorporation of computer games in educational plans.

3. Controlled Experiment

The controlled experiment of our research has been conducted in accordance with the guidelines described in [1 and 14]. According to the proposed methodology the steps to be followed are: experiment definition, experiment planning, experiment operation and experiment interpretation.

In the next sections, an overview of the steps followed in the formal experiment is presented.

3.1 Experiment Definition

According to the guidelines in [1] the experiment definition involves experiment motivation, purpose, object, perspective, domain and scope.

The motivation of our research is the enhancement of educational process. The purpose of the experiment is to compare game based learning with traditional learning procedure, from the perspective of the student, i.e. efficiency and enjoyment. The object of the study is a collection of e-learning games and a traditional teaching plan that aim at the same learning objectives. Finally, information on the subjects and projects, i.e. domain and scope of the experiment, are thoroughly discussed in section 3.2.2.

3.2 Experiment Planning

The planning phase of the experiment is considered to be crucial to the overall experiment success and includes aspects such as design, criteria and measurements [1]. Considering the above, in the next sections the experiments hypotheses are defined, the experiment projects and subjects are described and the methods of comparison are presented.

3.2.1 Define Hypothesis

As mentioned earlier the paper aims at performing a comparison between traditional and game based learning. Due to the study plan, three null hypotheses have been set and investigated.

Let GBEP (Game Based Educational Plan) be a learning plan that employs game playing during the educational process.
Let TEP (Traditional Educational Plan) be a learning plan that does not employ game playing during the educational process.

$H_{0(1)}$: GBEP and TEP, are equally enjoyable to students. *Alternative:* GBEP and TEP, are not equally enjoyable to students.

$H_{0(2)}$: GBEP and TEP, are equally effective concerning the learning goals of the procedures. *Alternative:* GBEP and TEP, are not equally effective concerning the learning goals of the procedures.

$H_{0(3)}$: The difficulty of the learning objectives is equally correlated to the efficiency of GBEP and the efficiency of TEP. *Alternative:* The difficulty of the learning objectives is not equally correlated to the efficiency of GBEP and the efficiency of TEP.

3.2.2 Experiment Subjects and Projects

In the experiment, two different educational plans have been used, one GBEP and one TEP. Both plans aimed at the same learning objectives (LO):

- Connection of peripheral devices to the computer tower (LO_1).
- Names and appearance of computer peripheral devices (LO_2)
- Introduction to computer science (LO_3).

The GBEP procedure involved five (5) computer games, which dealt with all learning objectives. The games have been played for two hours. Each student could freely choose playing any game, after having completed playing each game at least one time.

The TEP procedure involved two hours lecturing by a teacher. The tutor was allowed to decide the plans and the means that he would use during the courses.

After completing both procedures, data collection through knowledge testing and satisfaction questionnaires has taken place. In addition to that, data concerning students' knowledge before the learning

procedures have been collected through tests, as well.

The controlled experiment has been conducted with students from two elementary schools of Thessaloniki, whereas the number of study subjects, i.e. students, equals fifteen.

3.2.3 Methods of comparison

On the completion of the experiment a dataset with fifteen (15) rows and eleven (11) columns has been created. For every student (row of the dataset), eleven variables (columns) are recorded:

- *One variable tp which suggests the type of educational plan that the student has attended to (0=TEP and 1=GBEP).*
- *Three variables $k_{before(i)}$ that represent the percentage of the student's correct answers, before the course in questions on the learning objective i.*
- *Three variables $k_{after(i)}$ that represent the percentage of the student's correct answers, after the course, in questions concerning the learning objective i.*
- *Three variables $d_{(i)}$ that concern the level of difficulty of each learning objective, i, according to the student under study, in a 1-5 likert scale.*
- *One variable enj, in a 1-5 likert scale, that represents the enjoyment of the student during the educational process.*

In order to explore the hypothesis $H_{0(1)}$ an independent sample t-test has been performed. In the t-test the testing variable is `enj`, whereas the grouping variable is `tp`. Concerning the hypothesis $H_{0(2)}$ three paired sample t-tests have been conducted. In each test, the pair is composed of the values of the variables $k_{before(i)}$ and $k_{after(i)}$ for every learning objective i. Finally, concerning the hypothesis $H_{0(3)}$ a more complex procedure has been followed. Firstly, for each learning objective i, a Pearson Correlation x^2-test have been performed. The two variables that participate in the test are $d_{(i)}$ and the remainder of subtracting $k_{before(i)}$ from $k_{after(i)}$. The significance values of each t-test are recorded in a variable $V(i,tp)$, The investigation of the correctness of hypothesis $H_{0(3)}$ is performed through an independent sample t-test on $V(i,tp)$ and `tp`. The selection of the hypothesis testing criteria has been based on [14].

3.3 Experiment Operation

According to [14], the experiment operation phase is consisted of three steps: preparation, execution and analysis. The preparation phase of the experiment has included the knowledge testing of students before applying the two methods under study. This procedure aimed at extracting the values of variable $k_{before(i)}$ and $d_{(i)}$, for every learning objective i, as described in section 3.2.3. During the execution, the researchers have collected and validated data concerning $k_{after(i)}$ and $enj_{(i)}$, for every learning objective i.

During the analysis phase, the experimenters have performed qualitative analysis methods. Such methods are descriptive statistics, histograms and plots.

3.4 Experiment Interpretation

The interpretation of the experiment results is composed of interpretation context, extrapolation and impact [1]. The research results are presented in section 4 along with discussion on the study extrapolation and impact.

4. Empirical Results

This section of the paper, reports on the results of statistically analyzing the dataset of the experiment. The results are presented in two subsections; one concerning descriptive statistics and another concerning hypothesis testing.

4.1. Descriptive Statistics

This section of the paper exhibits the results of the descriptive statistical analysis of the dataset.

The experiment subject set has been consisted of 15 students that belonged to three different age groups:
- four, 9-years old students
- five, 10-years old students
- six ,11-years old students

The students have been divided into two categories that received courses on three learning objectives, through different educational plans. More specifically, eight children have attended a GBEP course, whereas seven students have attended a TEP course. In Figures 1-3 the difficulty of each learning objective is graphically presented.
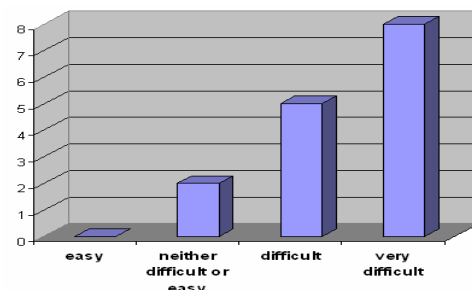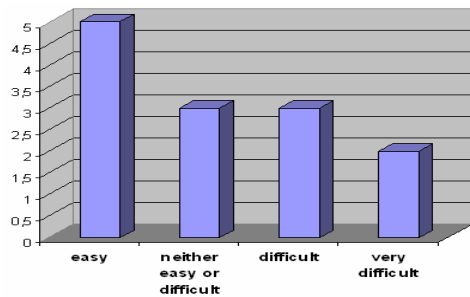

Figure 1. Difficulty of *LO$_1$*
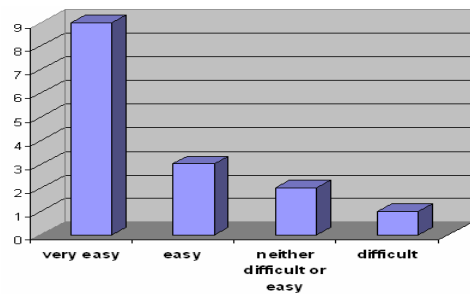
Figure 2. Difficulty of *LO$_2$*

Figure 3. Difficulty of *LO$_3$*

The bar graphs clearly suggest that the most difficult learning objective deals with computer connections, whereas the easiest one deals with general issues on computer science

4.2. Hypothesis Testing

This section of the paper aims at the presentation of results that derive from the investigation of the hypotheses which are defined in section 3.2.1.

Concerning the hypothesis $H_{0(1)}$ the results of the independent sample t-test are summarized in Table 1.

Educational Plan	Enjoyment (mean value)	Sig
GBEP	3.38	0.00
TEP	1.57	

Table 1. Educational Plan Enjoyment

The results of Table 1 suggest that the null hypothesis can be rejected and therefore, the alternative statement is confirmed. Thus, Game Based Educational Plans are more enjoyable to students than the Traditional Educational Plans.

Dealing with the hypothesis $H_{0(2)}$ the results of the paired-sample t-tests are summarized in Table 2. The data of Table 2 suggest that concerning LO_1, the efficiency of both educational plans have been statistically significant. In addition to that, in the LO_2

the GBEP did not seem to positively or negatively affected students performance, but the TEP seems to have confused the students since their performance appear to be diminished. Finally, about LO_3, the GBEP procedure seems to produce better results than the TEP procedure.

Plan	LO$_1$			LO$_2$			LO$_3$		
	before	after	sig	before	after	sig	before	after	sig
GBEP	0.01	0.11	0.02	0.52	0.53	0.78	0.30	0.51	0.00
TEP	0.01	0.12	0.01	0.57	0.40	0.03	0.38	0.42	0.48

Table 2. Educational Plan Effect

The abovementioned results are validated through the execution of an independent sample t-test The test variable is defined as the reminder of subtracting $k_{before(i)}$ from $k_{after(i)}$, and the grouping variable is tp. The results of the test are presented in Table 3.

Plan	LO$_1$		LO$_2$		LO$_3$	
	effect	sig	effect	sig	effect	sig
GBEP	0.10	0.77	0.01	0.04	0.20	0.03
TEP	0.12		-0.16		0.03	

Table 3. Educational Plan Effect - Comparative

Finally, concerning the $H_{0(3)}$ hypothesis, the results of the test are summarized in Table 4. But no safe conclusions can be drawn, since the significance of the test is above 0.05.

Educational Plan	Correlation of Effectiveness – Task Difficulty (mean value)	Sig
GBEP	0.32	0.20
TEP	0.73	

Table 4. LO difficulty – Plan Effectiveness

5. Threats to Validity – Future Work

This section of the paper deals with presenting internal and external threats to the validity of the experiment and future work.

Firstly, the small size of the subject set prevents from safely generalizing the results of the experiment to the set population. Additionally, another threat to validity is the fact that the courses have included only two hours of training. It is possible that a larger training period would show different effects on both educational processes. Finally, separate statistical analysis for each age group is expected to produce different results.

As future work, planning an experiment with a larger number of subjects is under consideration. The environment in the new experiment is planed so as to

alleviate the issues underlined in the threats to validity.

6. Conclusions

The main goal of this paper is to evaluate two different educational approaches, i.e. computer game based learning and traditional learning, in elementary school students. For this reason, an experiment has been conducted.

More specifically, the paper attempts to investigate if the two educational procedures are equally effective and enjoyable. Moreover, possible correlations between the difficulty of a learning objective and the effectiveness of each didactic method are under consideration.

The results of the experiment suggest that the game based educational plan is more enjoyable to the students in comparison to the traditional one. In addition to that, in the two out of three learning objectives the game based plan seems to be more effective. Finally, the difficulty level of the learning objectives appears to be equally correlated to the effectiveness of both educational methods.

Thus, computer game based educational plans are more likely to be a plausible solution on the problem of attracting students' interest and attention while teaching. This fact, in addition to the effectiveness of such plans, indicates that introducing game play in the classroom seems to be promising and needs further encouragement.

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