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Interactive Simulations to Physics Teaching: A Case Study in Brazilian High School

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Abstract

This paper presents the results of a study that investigated the use of simulators to improve physics teaching. The study population consisted of eight classes totaling 205 second year high school students from Brazilian public school. The research methodology adopted compares the average performance of students on tests conducted in the classroom to performance on tests conducted in the laboratory using computer simulators. The results obtained showed that students' performance on tests improved after the use of simulators. It was found that the students had more homogeneous test results when using the simulator.

Keywords: Educational simulations, students performance, physics teaching, high school.

1. Introduction

According to PISA (Program for International Student Assessment) 2009, Brazil achieved the 53rd place among 65 countries that took part of this program. Despite the fact that Brazilian students have shown improvement in mathematics, their performance in sciences was the lowest of last three editions of PISA.

The evaluation of fifteen year-old students showed that more than 50 % of Brazilian students are placed at sciences evaluation levels 0 and 1. These results have shown that knowledge and skills in this field are so limited that students can only apply them in few instances.

One of the characteristics of Brazilian education which is usually criticized is the emphasis on explaining the content using abstract modeling which is so far from students' reality. Most of high school teachers create their teaching activities based on textbooks which focus on college entrance examination, and do not practice any kind of experimentation (Schnetzler & Aragão, 1995).

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Considering physics as an example, most students consider this subject a collection of mathematical equations and codes which must be memorized and of situations that are completely absent from their daily lives.

Most of the difficulties faced by students are related to their ability to make the abstractions needed to understand physics concepts and modeling. The students' difficulties in learning negatively influence teaching, discouraging teachers in their attempts to try a different approach that would allow comprehension instead of stimulating memorization.

In order to improve teaching, it is necessary that the teachers recognize and work on students' most common difficulties in order to minimize those difficulties by varying the teaching methods. McDermott (1996) points out that most of learning problems occur because the ways in which concepts are explained to students are complex and difficult to understand.

According to Gibson (2000), the tendency is that teachers teach the way they learned. Therefore, another important issue in enhancing teaching quality is teacher training. It is necessary that teachers master not only concepts but also a repertory of different teaching approaches.

According to Novak, Mintzes and Wandersee (2000), helping sciences students to build better scientific models of nature is a very promising role for computers, especially for simulations and computer-based laboratories.

Regarding this way of thinking, Levy (2001) points that the use of simulation techniques, in particular those with interactive images, develops the imagination and thinking capacities, especially when compared to the passively watching videos or animation without any interaction.

This work presents some results of a research that investigates the use of educational simulators to enhance physics teaching. The goal of this research is to verify whether the use of these simulators enhance students' performance when compared to the traditional methods used in the classroom.

2. Methodology and Materials Used

2.1 Study Group

The research was carried out during physics classes of a public high school and lasted for one year. The population was composed of 205 high school students of eight different classrooms. The activities using simulators were developed in a computer laboratory with 16 computers. As every classroom was composed of an average of 26 students, it was necessary to divide them into two groups to allow students to develop the activities individually. Therefore, for each activity to be done, while one group was remaining in the classroom, the other was doing activities using simulators. When the activity was completed, both groups changed their places and activities. When it was not possible to take both groups to the computer room in order to practice activities with simulators, these activities were continued the following day.

2.2 Contents Selection

The selection of the learning content and the teaching approaches was carried out by the teachers. This content was part of the formal learning curriculum of the school. Despite the fact that teachers could indicate the common difficulties the students had experienced previously, they preferred each theme to be studied using simulators for two months, because this way they could have a more real and adequate scenario of the difficulties encountered in this period. In order not to modify the class dynamics too much and not to overload the team, it was decided that each activity with simulators would be carried out for two months (one quarter). The themes and quarters chosen are shown in Table 1.

Table 1. Themes of simulation according to school calendar

Academic Term	*Simulation theme*
1° Quarter	States of Matter
2° Quarter	Heat Transfer
3° Quarter	Electromagnetic Waves
4° Quarter	Light Spectrum

2.3. Development of Activities

The standard path of the work to be done includes the following steps:

a) The teacher defines the theme using the simulator.
b) The research team look for existing simulators for this theme.
c) The simulator is introduced to the teacher for his approval in terms of suitability and feasibility.
d) Teacher and research team work on the activities proposal (TG-teacher's guide) and tests (PT – performance test).
e) The activity is done using the simulator in the laboratory.
f) A student's performance evaluation is made by using the tests.
g) A general evaluation of the simulator's performance is made considering the student's interest, behavior, and attention during the activity.

In order to register the methodology and forecast its auto-sustainability for the future use of simulators in school, a document called Teacher Guide (TG) was created. This document deals with the way of using simulators, application methodology and the sequence of activities to be prepared and developed for the students.

Another document created was called Test Performance (TP). This document directs activities for the students, contains some instructions on doing them and questions that must be answered during the activities.

2.4. Performance Comparison Analysis

In order to verify whether the use of simulators enhances students' performance, the average performance on classroom tests was compared with the results of tests carried out with the use of simulators. For verifying if the performance was statistically significant, t-test was applied to each classroom using the data collected in classroom and laboratory. With the help of MINITAB® software, comparisons of average and standard deviation for the collected data were made.

3. Results

The results showed that there was an average increase of 41% in the students' performance on tests when they used simulators. The t-test confirmed that all eight classes showed significantly better performance on the tests carried out in laboratory.

Comparing standard deviations of average performance of students in classroom activities with average performance using simulators showed that the performance was more "homogeneous" on tests with simulators (lower standard deviation means less dispersion on individual grades). It was also found that the classes with the worst performance improved the most when working with simulators. The data that have allowed us to make these conclusions are presented in Table 2.

Table 2. Comparison of classroom activities and computing simulators in terms of student performance.

Classroom	***Students***	***Average (Classroon)***	***Standard Deviation (Classroon)***	***Average (Simulator)***	***Standard Deviation (Simulator)***
7	33	5,394	1,952	7,464	1,76
3	36	6,819	2,53	8,481	1,337
2	31	5,29	2,698	8,566	1,151
5	38	5,526	2,115	8,905	1,565
6	36	6,222	2,462	9,071	0,999
1	37	5,324	2,334	9,316	0,747
8	24	4,292	2,095	9,409	0,324
4	37	6,108	2,079	9,527	0,714

In order to find out the opinions on using simulators, the students were asked the following question: "What do you think about the use of learning simulators during the class?" The answers are shown in Figure 1.

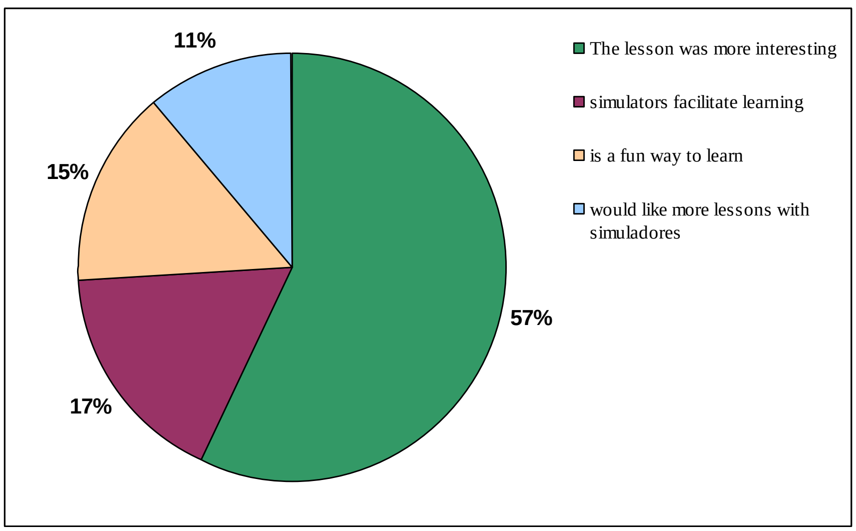

Figure 1. Students' opinions on the use of educational simulators

Teachers showed interest in this study and collaborated very actively not only when simulators were used, but also during the preparation of methodological approach and during the development of the activities. According to the teachers, the activities using simulation tools are important because they stimulate students' interest in the class content, help to contextualize knowledge, and minimize the difficulties commonly found during standard lessons.

4. Discussion

The performance on tests using simulators can be analyzed through factors such as the knowledge contextualization and students' motivation (Henning, 1998).

Learning content, when presented in classroom, tends to be apart from the real life situations where it came from. This makes the knowledge less attractive for the students. The physical, organizational, and psychological conditions of the classroom make the teaching and learning a one-way and expository process with emphasis on talking resources.

This has a negative influence on learning process, minimizing this process to mechanical rather than significant learning. As a result, students "prefer" to memorize the formulas and equations instead of understanding the processes and relations behind a determined concept. This is a very dangerous way of learning, because although students can use correct formulas or equations, they may notunderstand when or why they have to use them.

According to some authors, simulators can enhance the representation capacity and, therefore, the phenomena visualization, which is a fundamental condition for improving the process of teaching and learning (Hays, 1998; White & Frederiksen, 1998; Kali & Linn, 2008).

Alessi and Trollip (2001) state that educational simulators have many advantages compared to other teaching resources and communication media. The main advantage is the interaction with the phenomena or objects studied. This characteristic stimulates students' participation and makes learning more interesting, intrinsically motivating, and closer to the real life experience.

For comprehending the motivating impact of simulations, it is worth considering the Sperber and Wilson's (1995) relevance principle elaborated during a research conducted to comprehend how the recipients of a message recognized and interpreted a statement. According to this theory, when we interpret a message, our attention always turns to what seems more relevant and reliable. That is, the hearer interprets the speaker's words' meaning based on given evidence. This happens because the search for relevance is a primary characteristic of human cognition.

Therefore, the more relevant the "input" or motivation received by the student, the easier will be the comprehension.

In accordance with previous findings by Hung and Chen (2002), this research points out that educational simulations can be considered as one of possible solutions for knowledge contextualization in classroom. The future research will further investigate whether homogeneous student performance can be associated with knowledge contextualization provided by the simulators.

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