LEARNING PHYSICS CONCEPTS IN BASIC SCHOOL WITH COMPUTER SIMULATIONS

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ABSTRACT
We present results from the use of a computer simulation (CS) in basic school (grade 7; 12-13 years old students) to learn physics concepts (mass and weight). Our simulation was produced using Modellus. We try to understand differences in learning quality when using only CS, only experimental work, or both. We also address the influence of teacher mediation when using CS in the classroom, based on information from five teachers from four schools in Portugal. Our results show that the use of CS is not enough for effective learning of the concepts addressed in this study, in line with other studies (e.g. Yaman, Nerdel, & Bayrhuber, 2008). It is also noticeable that teacher mediation plays an important role in promoting student learning, both when using CS and hands-on experimental work. When using CS, teachers tend to expect the software to be sufficient and do not fully prepare its use in the classroom. Learning results are better when teachers assure that students understand the tasks they have to perform and the goals of such tasks. Total autonomy in the use of the CS may be counterproductive, in the sense that students may not understand the goal of the activity and engage in exploring the software in a more or less random fashion. The structure of the activity, the resources supplied to students (activity guides or other forms of guiding documents) and the balance between support and autonomy given to students during the activity are fundamental.

KEYWORDS
Computer simulation, learning physics concepts, teacher mediation

INTRODUCTION

It is in basic education[1] that many of the fundamental concepts of science are introduced. However, research results show that many students do not understand the scientific concepts of earth and space (Libarkin, Anderson, Dahl, Beilfuss, & Boone, 2005). These concepts are highly resistant to change through traditional interventions (Dahl, Anderson, & Libarkin, 2005). The concepts of weight and mass are fundamental, but are also among the least understood by students, from primary to university education (Gönen, 2008). The difficulties related to these concepts are revealed by several studies (Galili, 2001; Philips, 1991; Sequeira & Leite, 1991; Tural, Akdeniz, & Alev, 2010). After space (length, area and volume) and time, these concepts are among the fundamental physical notations, thus affecting the overall physical knowledge (Gönen, 2008).The evidence based on experimental studies suggests that we can improve learning by integrating computer simulations on topics that students find conceptually difficult (Webb, 2005). Previous studies have shown the efficiency of CS on student learning. Many of these studies focused on acquiring knowledge of specific content (Huppert, Lomask, & Lazarowitz, 2002; Trey & Khan, 2008). Some researchers also noted the success of CS to develop skills of questioning and reasoning (Chang, Chen, Lin & Sung, 2008). Other investigations reported less impressive results in the use of CS in science education. Some of them found no advantage in using simulations over traditional methods (Winn et al., 2006). Clearly, the efficacy of CS is closely linked to

[1] In Portugal, basic education consists of nine years of schooling after kindergarten (children aged 6 to 15).

the pedagogy through which they are implemented (Osborne & Dillon, 2010). Failure to take account of the pedagogy of technology use may explain some of the negative results obtained (Marshall & Young, 2006; Waight & Adb-El-Khalick, 2007).

The students' learning about the concepts of weight and mass has raised interest in research over several decades. Most of these studies have been descriptive, with the aim of cataloging alternative conceptions of students (Galili, 2001; Philips, 1991; Sequeira & Leite, 1991; Tural et al., 2010). As far as we know there are not many studies focusing on the effects of teaching strategies on students' understanding of the concepts of weight and mass. We focused the use of computer simulations as a possible contribution to the problems described, regarding the difficulties that students show in basic education when learning the concepts of weight and mass.

We intend to answer the following questions:

- Are CS combined with hands-on activities more effective, than simulations or hands-on activities alone, in promoting students' learning about the concepts of weight and mass?
- What characteristics of the teacher mediation when using CS can enhance students' learning about the concepts of weight and mass?

METHODOLOGY

Participants

Two interventions were planned, with the students, on the concepts of weight and mass. The study took place during the academic years 2009/2010 (1st intervention) and 2010/2011 (2nd intervention), in a lesson of Physical and Chemical Sciences (90 minutes). Since students were already divided into classes, it was not possible to make a random selection for the different treatments. The students were all from four schools in northern Portugal. The first intervention was developed by the teacher-researcher (pilot study), and involved the participation of 51 students from three different 7th grade classes (12-13 years old). The second intervention involved the participation of five teachers of Physical and Chemical Sciences and students from two of their classes (total of 216 students from 7th grade). Each teacher would teach two 7th grade classes (code named X and Y) at a school in the region. Before the implementation of the second intervention, all teachers invited to participate in this study were informed about its aims, and all aspects to be considered during the implementation with students in the classroom.

Study Design

Figure 1 shows the study. Before this lesson about weight and mass, students had no other lessons on the concepts of weight and mass. Based on an activity guide, consisting of three tasks designed to assess students' understanding of the concepts of weight and mass, students performed the experimental activities. In Task 1 students were asked about the relationship between weight and mass of a body. For Task 2 students were asked to explain how the weight of a body relates with the mass of the planet where it is. In Task 3, students were asked to identify the main differences between the two concepts (mass and weight). In the groups that performed hands-on activities and CS, the students tried to answer Task 1 using laboratory equipment and Task 2 using the CS.

Activities

Hands-on activities

The implementation of hands-on activities involved the use of measuring instruments (beam balances and dynamometers) and objects with different masses.

Computer simulation

The simulation used – "Weight and Mass" – was built by our team based on Modellus software (Modellus, 2000). The CS used in this study addresses the impractical space requirements typically associated with the experimental teaching of the concepts of weight and mass, which would involve measurements on other planets. The simulation, by allowing students to explore and test predictions, can also facilitate the development of students´ scientific understandings about the concepts of weight and mass (see Figure 2).

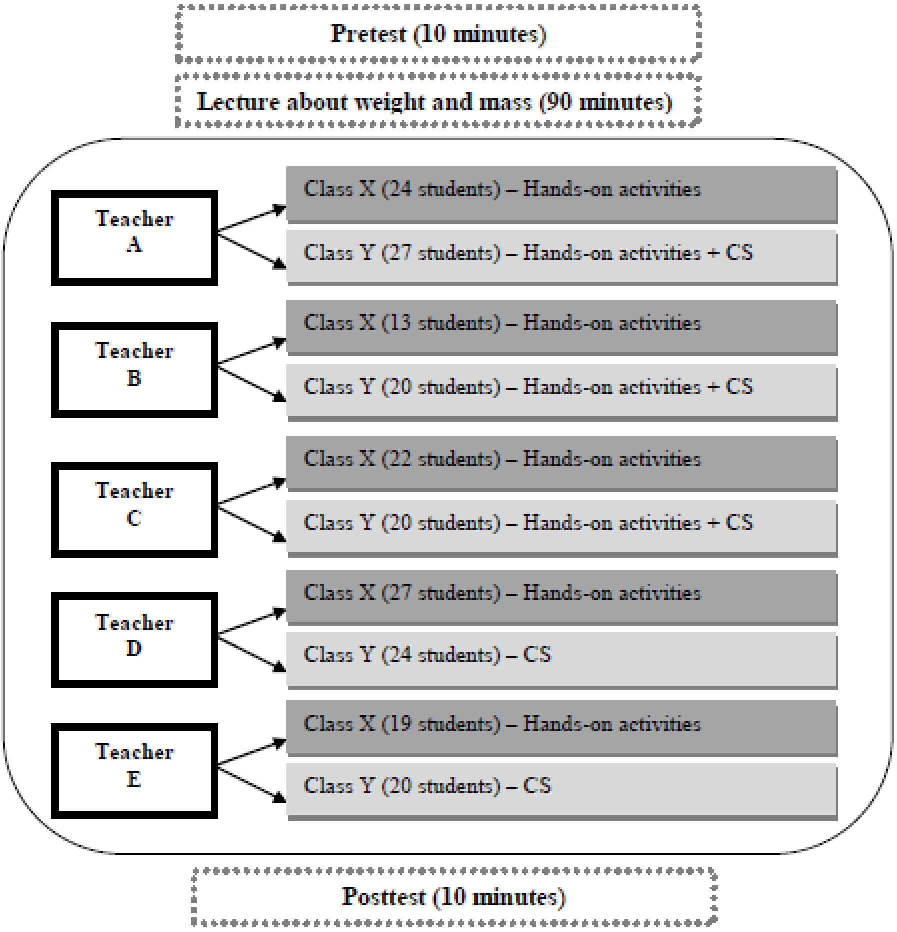

Figure 1. Study Design

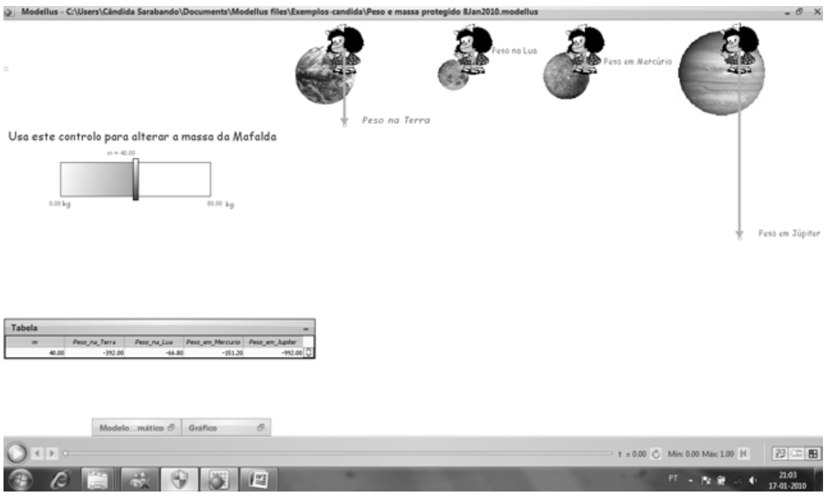

Figure 2. Screenshot of CS “Weight and Mass”

Data Collection and Analysis

Data collection about teaching was conducted through semi-structured interviews, four weeks after instruction, with teachers participating in the study, to try to gather information about how they conducted their lessons. The interviews lasted an average of 30 minutes. Based on the interviews conducted, it was concluded that three of the participating teachers (A, D and E) implemented in the classroom a methodology similar to that used in the pilot study, while the remaining teachers (B and C) implemented quite a different methodology. Thus, the results based on data from students of teachers B and C are not taken into account in the analysis of the results. To assess students' learning on the concepts of weight and mass, conceptual tests were administered: a pretest (before the educational intervention) and a posttest (after the educational intervention). The time that elapsed between the completion of the pretest and posttest ranged between 13 and 70 days. The test was developed by our research team and refined after the pilot study (first intervention). The pretest and posttest are both composed of the same three questions (see Table 1).

Table 1. Questions about weight and mass used in the tests

Question 1 - In the empty space where there is only one body, this body has (a) Mass and weight (b) Only mass (c) Only weight Because,
Question 2 – Mass and weight have (a) The same physical meaning (b) Different physical meaning Because,
Question 3 - When a body is transported from Earth to the Moon (a) its weight and its mass not change (b) its weight and its mass change (c) The weight changes and its mass does not (d) its weight stays the same and its mass changes Because,

Answers of the students that answered both tests (pretest and posttest) were analyzed according to criteria that are found in Table 2 (based on Gönen, 2008). The classification was given essentially based in the justification that students gave in each question of the test.

Table 2. Criteria used to describe the conceptual understandings

Level	Criteria
3	- Answer that includes all the components of the validated response
2	- Answer that shows some understanding of the concepts
1	- Answer incorrect or irrelevant, illogical, or a answer that is not clear, or blank answer

RESULTS

Table 3 provides a summary of pretest and posttest results. Prior to participating in their respective treatments, a large majority of students in each group respond incorrectly to the three questions.

After application of the different treatments, most students continue to show scientifically incorrect views of the concepts weight and mass. These results show that students' previous conceptions are resilient and tend to persist, as mentioned by Gönen (2008).

Figures 3, 4 and 5 present the average normalized gains (Hake, 1998), obtained for each question (see also Table 4).

Table 3. Frequencies in percentage for the three types of conceptual understanding about weight and mass (pre and posttest)

Question		**Teacher A**				**Teacher D**				**Teacher E**			
		Pre		**Pos**		**Pre**		**Pos**		**Pre**		**Pos**	
		X	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**
Q1	**3**	0	0	0	0	4	4	7	21	0	0	5	15
	2	8	7	36	30	15	21	33	25	16	5	26	15
	1	92	93	64	70	81	75	59	54	84	95	68	70
Q2	**3**	0	4	20	15	0	0	8	54	0	0	0	5
	2	12	11	32	48	7	0	44	13	5	0	5	40
	1	88	85	48	37	93	100	48	33	95	100	63	55
Q3	**3**	4	4	20	15	0	0	0	13	0	0	11	5
	2	44	11	40	63	22	25	33	33	5	20	26	60
	1	52	85	40	22	78	75	67	54	95	80	63	35

Table 4. Average normalized gains, as a percentage, obtained by students in classes X and Y

Question	**G (%)**					
	Teacher A		**Teacher D**		**Teacher E**	
	X	**Y**	**X**	**Y**	**X**	**Y**
Q1	14,6	11,5	14,6	22,0	11,4	20,5
Q2	31,9	32,7	26,9	60,4	32,4	25,0
Q3	18,9	40,8	6,2	19,0	21,6	27,8

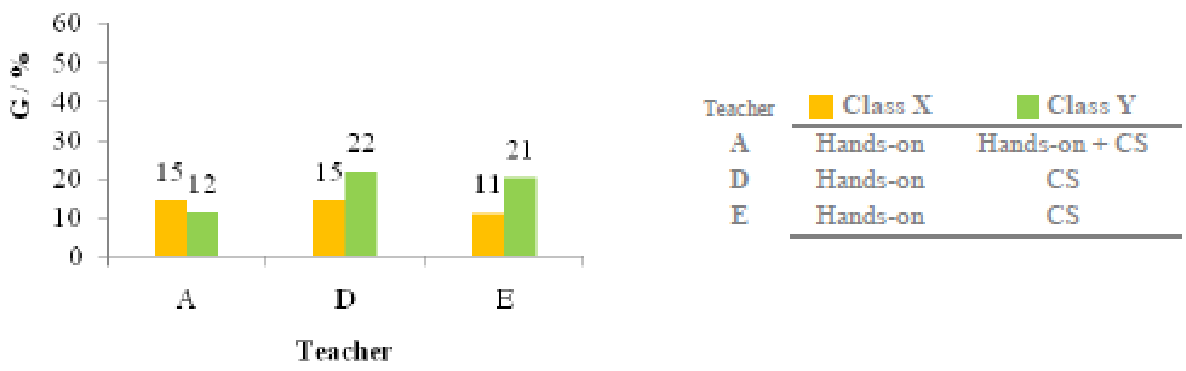

Figure 3. Graphical representation of average normalized gains obtained, in question 1, by the students of the different treatment groups: class X and class Y

From figure 3, it can be concluded that the gains from pretest to posttest, in question 1, were higher in the groups that used only the CS. This question involves some degree of abstraction, which may explain the relatively low gains. Moreover, the fact that this particular situation was not addressed directly in the CS should also be taken into account.

The gains from pretest to posttest in question 2 were approximately equal for all the students, with the exception of students of class Y of teacher D, where gains were substantially higher (see figure 4). The mediating role of the teacher cannot be forgotten here, and teacher D did performed oral and written summaries of Task 3 in the activity guide, which is partly addressed in this second question of the test.

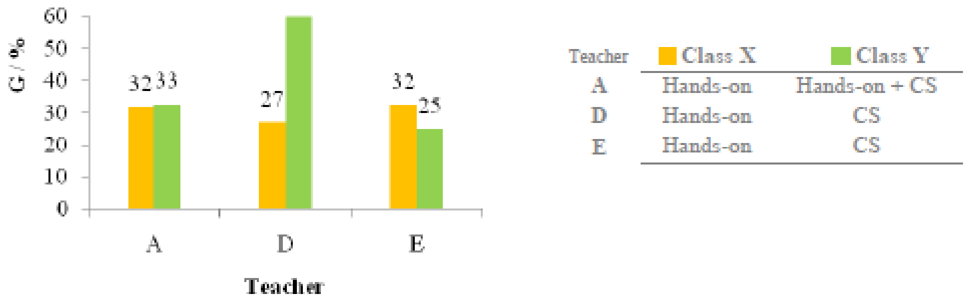

Figure 4. Graphical representation of average normalized gains obtained, in question 2, by the students of the different treatment groups: class X and class Y

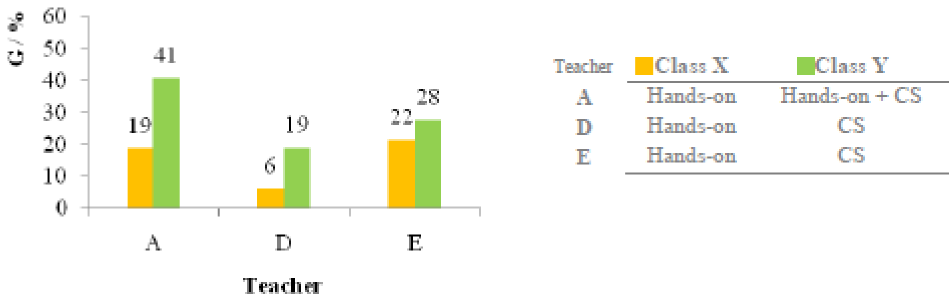

Figure 5. Graphical representation of average normalized gains obtained, in question 3, by the students of the different treatment groups: class X and class Y

With regard to question 3, the gains were higher for students who used the CS. The gains were even higher when students used the CS integrated with hands-on activities. Q1 and Q2 were more decontextualized whereas Q3 involved the exploitation of a physical situation. The physical situation selected was inferable directly from the CS. Students manipulating the CS visualize information in ways that students using laboratory equipment cannot see, like the weight vector of a body in each planet.

CONCLUSIONS

Prior to the different treatments, most students presented scientifically incorrect conceptions about the concepts of weight and mass, in agreement with the results obtained by several researchers (Galili, 2001; Gönen, 2008; Tural et al., 2010).

The different treatments were not highly effective in promoting the development of scientifically accepted conceptions about weight and mass.
In this study, teachers familiarized students with the use of the CS and provided a written guide to focus students´ attention. However, only one of the three questions of the tests (Q3) was inferable directly

from the CS. That may explain the higher gains, in this question, when students used the CS. In this case, the CS coupled with hands-on activities seems to promote even higher gains. For the two other questions, the gains obtained by students seem very dependent on what the teachers did in the classroom.

These results emphasize the close connection between the efficacy of CS and the pedagogy through which they are implemented (Osborne & Dillon, 2010).

We can then say that, despite high expectations for the CS, we can not guarantee an overall conclusion about its effectiveness, as referred by Yaman and colleagues (2008). CS provide new affordances for learning, particularly when they are based on phenomena that cannot easily be observed and explored in the real world (Webb, 2005). However, teachers have a crucial role in planning the learning experiences of their students using simulations and in promoting their learning through appropriate mediation.

Teachers participating in this study used the same resources (laboratory equipment, CS), used the same activities guide. However, they certainly guided students in different ways, leading to very different learning gains. To fully address this question we will conduct further in-depth analysis of the interviews with the teachers.

It is important to note that the present research is based essentially on three cases with a small number of participants. Thus, it would be helpful for future research to explore the benefits of using this simulation with more teachers and students. Further information about how teachers taught their lessons and more in-depth information from the students (obtained from interviews) would be very helpful to better understand the observed differences in learning.

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