TEACHING WITH SERIOUS GAMES: AN INTERDISCIPLINARY STUDY WITH "ELECTRIC FIELD HOCKEY"

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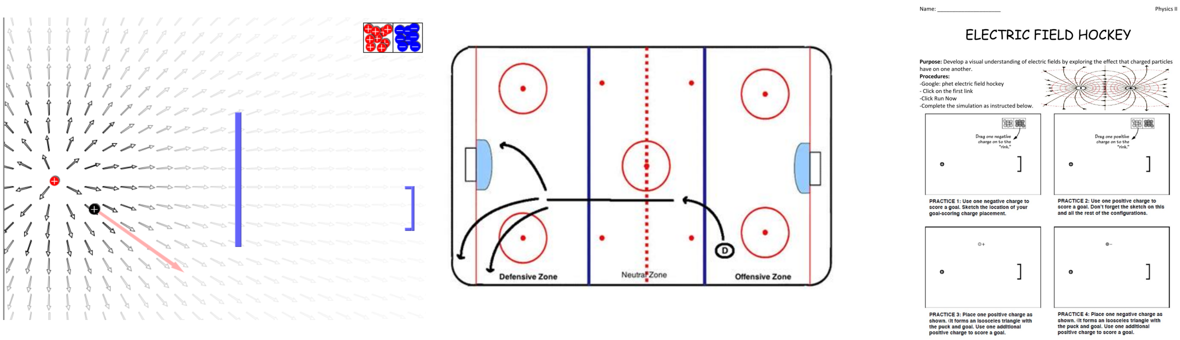
1. INTRODUCTION

Usually, Physics deal with abstract and multidimensional phenomenon that present difficulty for students to both comprehends and apply the knowledge due to students have no real-life referents. Frequently, scientists and teachers use mental imagery to "simulates" impossible physical experiences of to perform or to simulate computationally (e.g., electron diffraction experiment). Although mental imagery has won notoriety for its purpose and effectiveness in high-performance athletics, it also acts as a significant part in the structure of scientific knowledge, having significantly influenced many of today's physical theories (Clement, 2008). In fact, despite the crucial importance of experimentation in the evolution of science, it was through mental imagery that some scientists reveled their genius, using their mind as a "laboratory" and conceiving "imagined experiences", which contributed significantly to breaking new ground in the understanding of the universe. For instance, Galileo and Einstein were masters in this process and through "imagined experiences" they abstracted from real situations, going beyond the perceptions transmitted by the senses. The scientific revolution in the seventeenth century, with Galileo (who dethroned Aristotelian theory) and the revolution in the early twentieth century, with Einstein (who dethroned Newtonian theory) uses this new process of interrogating Nature to find the laws that govern the phenomena (Miller, 2000).

On education, the image has a pedagogical impact of considerable relevance. Since the emergence of personal computers in the 1980s, on education there has been a call for more playful and motivational teaching methods for students (Bork, 1981; McCloskey, 1983; McDermott, 1984). In this sense, in parallel to the growth of educational software, led off to appear educational games and, more recently, serious games. Gamification in education has gained strong interest due to the technological development of portable personal computers and mobile devices, software development with physics engines (giving realism and dynamics similar to physical computational simulations), the variety of offer digital games and the exponential growth of the video game market, among other reasons. The gamification (with simulation characteristics) gains a new status, particularly in the teaching/learning of exact sciences like Physics (Garris et al., 2002).

Sport is a crowding field, very current and dynamic in the search for techniques to improve sports performance and is an important bridge to link gamification to Physics concepts and to known phenomena. The vast publication involving Sport and Physics, and the vast proliferation of digital games on Sport using Physics engines, that give them enormous realism, reflects the interest in this interdisciplinarity. For example, *Fifa 2018* (by *EA Sports*), *PES 2018* (by *Konami*), *Out of* *the Park 18* (by *Out of the Park Developments*), *Motosport Manager* (by *Playsport Games*), just to mention some of the more recent ones.

On the other hand, although research in the field of gamification in teaching is not conclusive about its effectiveness and there are still many doubts to be resolved, it points out that it is an advantageous pedagogical medium to use with students with school failure (Adams et al., 2008; Bjælde et al., 2014). Thus, it is the objective of this work to contribute to the study of gamification in education, in particular to the teaching/learning of Physics concepts of electricity, electric charges, and electric field, using the game "Electric Field Hockey", developed by the University of Colorado (PhET, 2018). In order to facilitate a better anchoring of the concepts under study, an interdisciplinary context of learning was used in conjunction with hockey, promoting collaboration between students and teachers in the areas of Physics and Sport (Figure 1).



(a) (b) (c)

Figure 1: (a) "Electric Field Hockey"; (b) Some positions in field hockey; (c) Physics inquiry

2. METHODOLOGICAL FRAMEWORK

This study included a total of 91 students divided into two classes: one as a control group (N=32), where traditional inquiry-based learning experiences were implemented; the other plays "Electric Field Hockey" and to serve as the experimental group (N=59). Each group (control and experimental) was expected to learn the same content. In addition, 90% of these students were identified as students with serious shortcomings in major Physics and Mathematics concepts, and with a long history of absenteeism or withdrawal. Students agreed to participate in the study and were randomly assigned to the experimental or control groups. Of the 91 participants, 84 had experience playing video games and 75 had played educational games. Their average age was 22 and they play about 5 hours of video game each week. The treatment group averaged 24.3 hours of computer usage each week and the control group averaged 22.9 hours per week. The non-science background of the participants is reflected by the poor results obtained in secondary school and by the failure in the Physics discipline of the first year of higher education.

The entire study took place during 6 weeks, during the normal schedule of the planned Physics class, which was 2 classes per week, with a duration of 2 hours for each class. In total, the study lasted 22 hours, 16 of which were dedicated to the experimental part. The students belonged to the same class and had the same teacher.

The procedure was carried out according to the following phases and order:

- Preparation stage: the researchers presented the students with the objective of the study, gave a general description of the development of all the work and obtained their consent for the study. It was not previously determined which students would play the computer game and which one would follow a traditional method and none of the students had previously received instructions from their teacher on the subject matter. Students completed the background survey about their prior experience with science, computer technology, video, and educational games, and a modified pre-task evaluation Intrinsic Motivation Inventory

(IMI) to assess their attitude/feeling, motivation, and beliefs about games and Physics. Subsequently, they performed a pre-test about basic Physics concepts, created by the project researchers and reviewed by two teacher Physics to ensure that the questions were appropriate and that the questions were not confusing or misleading. The exam consisted of 20 questions with space provided for the students to describe why they chose their particular answer. The content exam was determined to have an internal consistency (Cronbach) of $\alpha = 0.75$ for the instrument, which is within an acceptable range. The constitution of the gaming and control groups was decided at random. Prior to the experimental phase, the game group was trained for about 90 minutes on how to play the game "Electric Field Hockey", both by direct and guided instruction, as well as by a user manual designed by the researcher. This stage lasted for 4 hours.

- Experimental stage: The experiment procedure takes place in a computer room of the participants' high school, that had been reserved for this experiment. On each desk, a computer with an internet connection was provided. During the study, the classroom was divided into two sides, with both groups and the same teacher. In this procedure, guided research was used with the teacher to provide the script, exploratory and material questions, and the students were responsible for determining the method of investigation, interpretation, and explanation of the resulting data. Students in both groups received written instructions, structured in a similar way, but directed specifically to the computer game (experimental group) or support text (control group). The experimental group exclusively used the game with small scenarios from saved points in the game and were asked to complete sub-goals within the game. The control group was taught through guided consultation methods, interactive exhibits, experiments, demonstrations, as well as access to complementary content materials. Both groups started working after receiving the instructions and were allowed to collaborate with each other in each of the groups in which they were inserted. During the study, a subset of students from each group, chosen at random, was chosen and interviewed. The interview was specifically designed to gain a better understanding of student performance after the pre-test. This phase lasted for 16 hours.
- Final stage: Students were asked to complete a post-test on Physics concepts, which was identical to the pre-test. We are particularly interested in understanding which students are able to answer questions about mechanics more effectively, and in a comparison of the motivational effects of both instruction methodologies. This phase lasted for 2 hours.

3. RESULTS

The statically results of evaluation of understanding of Physics concepts are in Table 1.

Table 1: performance assessment for both groups

	Pre-test	Post-test	Diff (Post-Pre)
Experimental	8.30	17.50	9.2
Control	9.45	11.7	2.25

As measured by the difference between post-pre tests, in the experimental group there was a 9 question gain on 20-question evaluation, reflecting a statistically significant gain for the game group (*t-value* = 5.3, *p-value* < 0.05). *Cohen's d* = 2.4 suggested a high practical significance.

These results indicate that students' learning in the experimental group was influenced by their interaction with the game scenario, which is in line with the reaction, comments, and observations recorded during the experimental stage.

Concerning the modified IMI used to assess participants' motivation for games, Physics, and physics in a game we obtained the following results (only the differences found are referred to):

- Motivation: Only the items related to the game experience obtained statistically significant differences (*t-value* = 4.83, *p-value* < 0.0001), showing that students found "Electric Field Hockey" more motivating to learn Physics. *Cohen's d* = 2.78 suggested a high practical significance.
- Attitude and interest: There are significant differences in various items relating to student experiences. In the experimental group students appreciated their experience significantly and were more interested in games (*t-value* = 2.99, *p-value* <0.05, *Cohen's d* = 2.67), were more interested in Physics (*t-value* = 10.23, *p-value* <.0001, *Cohen's d* = 1.98), and were more interested in learning Physics in a game environment (*t-value* = 5.12, *p-value* <.0001, *Cohen's d* = 2.32).
- Tension and perceived competence: no statistically significant difference was recorded either between the groups or between the various phases of work

4. CONCLUSIONS

This study intends to contribute to the analysis of the pedagogical potential of gamification in teaching/learning concepts of Physics, particularly with recurrent school failure students. The main result was that "Electric Field Hockey", can lead to positive learning outcomes and how the dynamism of games, goal-based nature of using game structures and the way students used visual representations within the context of the game, may be beneficial to make students think and understand conceptual phenomena, as demonstrated by the increase in test scores from pre- to post-assessment and the student interviews. However, this does not mean that the students understand the theoretical model underlying the concepts studied, or that the understanding of them persists in the medium and long-term.

5. REFERENCES

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