Curriculum Integration in the Teaching of Physics to First Year Engineering Students

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Abstract - **Educational Research (ER) has been pointing out the need to consider new approaches to teaching and learning, particularly in Higher Education (HE). Given the challenges of our societies today many studies refer that there are important competences that must be developed by HE students, beyond the academic knowledge. Among these, and in particular in the filed of science, we can highlight the following ones: questioning, group work, problem solving, communication and technology (ICT) abilities and openness for life long learning.**

It is also well known that the numbers of failure in physics courses in HE is a problem that teachers are facing nowadays, namely in Portugal. Indeed current research in science education indicates that the levels of interaction between teachers and learners in formal instructional settings are often very low and also that students often say that physics is boring and has no interest because it deals only with formulas and academic settings with no relevance for real world life.

In this study we analyse the effect that curriculum integration had in changing the physics classroom environment and the learning process of future civil engineers. An integrator curricular component ("The Physics Elevator Project") has been used in order to combine a real word problem with all the course contents and the development of students competences in active learning environment.

This study has been carried out in a HE Institution in Portugal ("Instituto Superior de Engenharia do Porto"/ISEP) with first year students of an introductory physics course for civil engineers and in the first semester of the school year 2006/2007.

Besides the discussion of the theoretical framework in which the study was based we also bring to this paper the results of the implemented strategy. These suggest the educational relevance of the strategy, both for the students and the teachers involved.

Index Terms - Curriculum Integration, Higher Education, Physics for future Engineers, Real Word Problem, Teaching and Learning.

INTRODUCTION

Over the last years, Educational Research (ER) in general, and in the particular in the field of Higher Education (HE), has challenged our view in what concerns the teaching and learning process in the traditional instruction. The main findings in the area of Physics Education in HE can be summarized in the following three points:

- for many engineering students traditional instruction in physics is not working since students do not see the importance of physics and do not acquire conceptual understanding [1-4];
- students are not "blank slates." Student's experiences and cognitive attitudes can affect what they learn. Many student experiences and beliefs are not compatible with what we want them to learn [5, 6];
- research-based curricula should be developed to improve student learning by helping students to change their common sense and conceptual beliefs through active engagement [7].

The research-based curricula often require changes in teaching style so learning can be achieved effectively. Taking into account what research has been pointed out, it has been implemented in our study a variety of strategies/tools, namely conceptual questions, group projects, reading tasks, assignments with tutorial review, blended-learning, problems solving and a platform of e-learning. These strategies and tools were used in the first year of an introductory physics course for civil engineers. Through active learning techniques and modelling by the teacher, students shed the traditional role as passive receptors and learn and practice how to apprehend knowledge and skills and use them meaningfully [8].

In this paper we analyse the effects that an integrator curricular component ("The Physics Elevator Project"), which was used in order to combine a real word problem

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with all the course contents, had in students learning. This project was developed in group by the students. Group work has long been accepted as an effective learning strategy because it provides opportunities for students to negotiate meaning and manipulate ideas with others and reflect upon their learning [9].

DESCRIPTION OF "THE PHYSICS ELEVATOR PROJECT"

In "The Physics Elevator Project" the students had to design a proposal for an elevator. Each week, in the practical class, they had a task related with the subject that was taught in the theoretical class.

This project had two important proposals. The first one was to apply physics to a real word example. Many students claim that physical laws have little relation to what they experience in the real world [10]. Keeping this in mind this project had the aim to make physics contents relevant and useful to the students. The second aim was to find an element (the elevator) that integrated all the subjects taught in a one single project.

The students were organized in groups. As was referred before and each group had to develop a project of an elevator. In the first lesson students had to start defining some characteristics of the elevator:

- Type of elevator (residential, hospital…);
- The number of floors in the building;
- The number of people to transport;
- The dimensions of the cabin;
- The maximum velocity and acceleration;
- The weight of the counterpoise.

Then, in each lesson, they had to perform several reasonings and some calculations. It is important to refer that for each task they needed all what they have done before. (figure 1 are examples of tasks).

At the end of the semester students had to write a report with the different tasks. They also were asked to make individual comment about the importance of this project to their learning process.

RESULTS AND DISCUSSION

The research we report here had been conducted during the academic year 2006-2007, involving six teachers (one of them is the first author of this work) and a group of 81 first year undergraduate students, drawn from the 300 students attending an introductory physic course *(Física I)* given to Civil Engineering at the Instituto Superior de Engenharia do Porto (Portugal). This course had three kinds of classes: theoretical (2h/week), practical (2h/week) and laboratory (2h/week).The age range of students is very wide (from 18 to 54) as this course is given to full and part time students.

According with the number of floors of your building calculate the maximum and minimum velocity that the elevator would gain if the rope breaks. Make the necessary approximations to the free fall model.

In a previous lesson two velocities were calculated (one maximum and another minimum) for the free fall of the elevator. With those velocities calculate the average impact force of the elevator against the floor. Also, calculate the average force that the passengers will feel. Make the necessary approximations for the modelling for the problem.

In previous lessons you had the chance of calculating the impact forces when an elevator hit the floor after a free fall due to the breaking of the ropes.
The result was enormous. Because of that elevators have security systems. One of them are the brakes. When the ropes cracks the emergency brake starts to work against the lateral tracks (as shown in the figure). Because of that four vertical forces act in the elevator.
Now you have to estimate the pressure force that your brake systems has to do for letting the elevator go down with a constant speed that permits the survival of the people inside (for doing so you need also to predict the response time of the system).

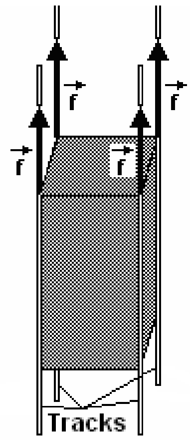

Table of Coefficient of friction:

Material	Static coeficient	Sliding coeficient
Brake material	~0.3	0.3 - 0.7
Rubber / Steel	0.6 - 0.9	0.3 - 0.6
Rubber / Iron	0.7 - 0.9	0.5 - 0.8

FIGURE 1
EXAMPLES OF THE PROBLEMS THAT STUDENTS HAD TO SOLVE IN THE ELEVATOR PROJECT

The results we present here were obtained from two different sources: questionnaires (one given to students and one to the teachers involved in the teaching, both at the end of the semester) and information taken from the project made by the students. The aim of the questionnaire was to find out students opinions about some of the strategies implemented in the course. The questionnaire had 28 questions and we report here only the results related with "The Physics Elevator Project". Each question had a likert scale (1-5, 1 less suitable to 5 most suitable). In the analysis we count as a positive opinion an answer equal or higher than 3. The questionnaire given to teachers aimed to find out how they had implemented the teaching strategies and their opinion about the results achieved by the students with them.

The questions made to students had four main objectives:

- The importance of the work group in their learning process;
- The importance of "The Physics Elevator Project" on the development of the physical concepts taught in the course;
- The importance of "The Physics Elevator Project" as an element to promote the participation in classroom;
- "The Physics Elevator Project" as an element that promotes the connections between the different concepts taught in the course in a "real world" environment.

For 93% of students the discussions in their working groups was an important element in their learning process; for 83% of them "The Physics Elevator Project" was an important element to clarify the several concepts taught in the course and for 74% of the students this project was able to promote their participation in several lessons. Finally 93% of the students refer that this project was broad enough to cover all the subjects taught in the course and made the connection to a "real word" environment (see figure 2).

The individual comments made by students in their final report were also analysed in terms of the following four dimensions:

- Work group;
- Learning Process;
- Connection to "real world";
- Motivation.

Work Group

Almost all students said that working in group was very important to their learning process. One of them wrote "*In my opinion working in group is very important because it implies a constant exchange of ideas. It also promotes the interaction between different persons and different ways of thinking. In this work we were always learning, always exchanging ideas and always discussing our doubts.*" Another student said "*this kind of work helps to deal with our differences and transform them in new ways of sharing and applying our knowledge*"

We can say is that for students the benefits gained by working in groups are centered in human relations and the consequent exchange of ideas and personal experiences.

Learning Process

Here also almost all students said that the project was essential to improve their learning. In the students opinion this kind of project helps them to understand and apply the abstract concepts of physics. One student said that "*I think that the elevator project was very useful for organizing and applying ours theoretical knowledge. To do this project we have to use all the contents given in the course and this helped me to learn physics.*" Another said "*The methodology used and the task sequence helped me to understand better the physics concepts*"

From what students said we can affirm that this project helped them organizing the concepts and the consequent application in a practical situation.

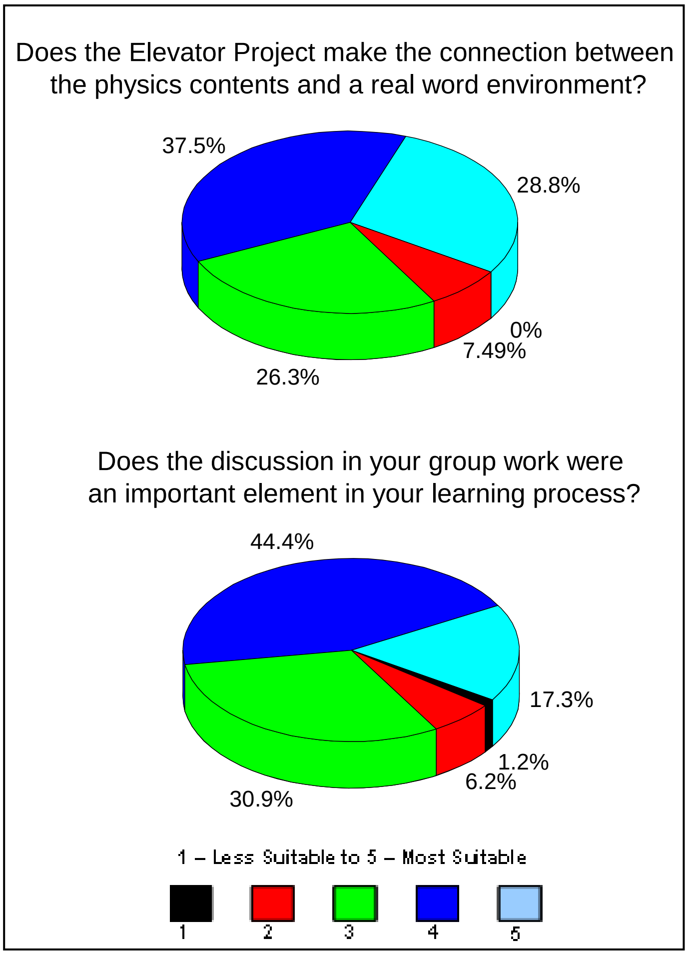

FIGURE 2
RESULTS OBTAINED FROM STUDENTS QUESTIONAIRES

Connection to "real world"

All the students have the opinion that this type of project is important to help them to understand our everyday life and see the importance of physics in the way we understand the world were we live in.

To illustrate this one student wrote "*This project is an application of physics in our everyday life. So show us the utility of physics turning it more interesting and appellative*." Another said "*This kind of project helps us to develop our study and our comprehension about physics concepts. As a future civil engineer work group is very useful and this project promotes it*."

The main idea taken from student's opinion is that this project helps them to realize the importance of physics to everyday life and in particular their future professional activity.

Motivation

In general students said that they were motivated by this project because they have to work in group along the semester and the tasks were connected with civil engineer. They said that "*This project was very motivating and interesting for the developing of a future civil engineer*" Another student said "*This project… help us to be active in our learning because we had work to be done along all the semester…*" Another student said "*This was a very motivating project and with a huge importance to personal developing of a future engineer…we had to answer to several questions that permit us to project an elevator using the physics contents that were taught…*"

From student's comments we can conclude that the project motivate them to be active in their learning process. Another important aspect was that they had to work along the semester and so it a way of studying for the final exam.

In the teachers' questionnaire four questions are analysed here:

- Do you think that "The Physics Elevator Project" was able to promote the interaction between teacher and students?
  In general their replies refer that the project was able to promote the interaction between teachers and students. This interaction did not occur only in the classroom but also in the attendance hours. Because the project deals with a real object students felt more confident to ask questions about it.

- Do you think that "The Physics Elevator Project" was a dynamic element in the classrooms?
  Almost all the teachers said that the students worked with interest in the several tasks. They were so engaged in the work that sometimes teachers had to intercede to calm down the discussions. In general the group work allowed eliminating some inhibition and transforming the classroom environment.

- In your opinion what was students reaction to "The Physics Elevator Project"?
  Teacher's referred that at the beginning students were not very enthusiastic because they did not understand the objective of the project and the only thing they said was "more work". With the development of the project they started to be more interested because they realize that they were dealing with a real situation.

- Do you think that "The Physics Elevator Project" helped to improve the students learning process?
  Almost all the teachers said that the project improved students learning because they understand the connection between the physics concepts and "real world". Also, because with the discussion it was possible to clarify some concepts. The work in group helped the students to interact with each other and with the teacher and this was a way of being engaged in the contents of the course.

CONCLUDING REMARKS

From what has been presented, both in terms of the theoretical framework and the results from the empirical study, one can say that the strategy used has been an important element for the students learning process. This importance come mainly form:

a) the "real world" context used and its relevance for the future professional activity of students;

b) the fact that it allowed the integration of the several contents taught in the course ;

c) it has been centred on tasks along the semester and in which students were able to work in group.

Therefore, and despite some aspects which need to be studied further (for example, the impact on students´ performance in more traditional situations, like exams), we advice the use of projects, like the "Physics Elevator", in the teaching of Introductory Physics Courses for Future Engineers.

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