The Use Of Experiments In Physics For Engineering DisciplineS

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Abstract

Experimentation is often seen as a mere support to theoretical Physics, with rare initiatives of stimulating a participative and reflective posture of the students [1]. The use of didactic experiments in the classroom is usually associated with observation and repetition of procedures, for the purpose of proving physical principles [2]. In this perspective, experimentation ends up having almost no educational value, since those activities are rarely part of pupils' quotidian [3], culminating in lack of interest.

Regarding this matter, the present article proposes a different pedagogical approach, so as to the use of experiments in Physics for Engineering disciplines instigates the student to go beyond the experimental results observed, looking for possible practical applications to the concepts involved.

This proposal consisted of the elaboration of new Physics texts concerning experiments that are going to be accomplished during the basic subjects cycle, such as the Rotating Platform, the Gyroscope and the Foucault Pendulum. For each physical concept, three main aspects were broached: the historical rescue [4], which means the first unquietness of physicists in the past, going through recent practical applications and finally future aspirations.

Therefore, the use of experiments should not be restricted to the verification of laws and principles [5], considering that the absence of a more practical approach is one of the most serious deficiencies in Engineering courses. An interface between theory and the students' own reality is extremely important, so that the broached subjects have meaning for them and could be related to their own life experience.

Keywords: experimentation, Physics, Engineering, practical applications, life experience.

I- INTRODUCTION

Taking into consideration that Physics is an essential tool for the engineer's career, supposed to provide the world vision needed to sensible decision making, some changes of the traditional teaching strategies are fundamental. Nowadays, it is very common to find intelligent and dedicated students who have learnt how to deal with problems and situations broached during the class, but become completely without initiative when they have to face new problems. The knowledge discussed on the blackboard does not fit the world in which the student lives, it is not connected with real life [2], and the engineer's profession is certainly going to demand two major competences: the ability to apply theory in practice and communication skills.

Due to this distance between the theory given in class and the students' own reality, they end up becoming disinterested and passive instead of reflective and participative. Thus, the present paper began with the discussion on 'why would an engineering undergraduate be interested in learning Physics?', as a continuation of a previous study [5], which was concerned about the relevance of the use of experiments during classes, in order to improve the assimilation of physical principles and instigate the students about its applications. Experimentation truly is a proper mean of starting to break the barrier between theory and practice, but what we learnt from previous researches is that only the use of experiments itself is not enough for that purpose.

The use of experiments in an Engineering course should emphasize practical necessities issues, in a greater degree then in a Physics course. This is explained by the fact that many times physicists study science for the science, that is, with the purpose of theorizing the reality, not necessarily worrying about future applications of this generated knowledge. However, engineers aim at the transformation of the reality based on Physics theories, and that justifies that a different approach between Engineering and Physics courses is needed.

Regarding this matter, a significant change in the last decades inside the University of São Paulo was analyzed. A couple of years after the beginning of the dictatorial period of 1964, in Brazil, a University Reform was approved, which had the departmentalization as one of its measures. It means that subjects regarding Physics, for instance, started to be given by teachers from the Physics Institute, not by teachers with an engineering formation anymore [6]. This event has consequently modified the way this discipline was given, assuming a more theoretical approach and less emphasis in showing the engineering undergraduates how the study of Physics can be a useful tool in order to bring concrete benefits to society, pointing out which aspects are truly going to be important during their future career.

On the other hand, physicist teachers are much more able to broach epistemological issues and how knowledge was constructed throughout the history, giving a meaning to all the theories they show at classes. The comprehension of the history of science must be included in the learning process, providing the students with critical sense and demystifying the scientific knowledge.

Taking this deficiency of a more practical approach in Physics to engineers into consideration, the present paper proposes the construction of a new material as a complement to the experiments in theory classes, which are going to be accomplished throughout the basic subjects cycle. The idea is to chiefly emphasize three aspects for each physical principle: the historical rescue, which involves the concept of epistemology and history of science, as well as current applications/daily situations and finally future aspirations, with the description of very ambitious projects, showing that Physics is in constant evolution and dynamism.

II- THE RELEVANCE OF EPISTEMOLOGY TO THE TEACHING OF PHYSICS

According to Robilotta, "some tasks need to be faced so that the teaching of Physics could be improved, and one of them is the notion that Physics is a process in which the confrontation of ideas is always present". Regarding this matter, a possible role to history of science and its epistemology is to be an alternative visions of the universe source, likely to be contrasted with the official version, taught at schools. Recognizing the existence of alternative solutions to a specific problem promotes the development of a critical posture, because it makes the person make an option. And non-uniqueness of criterions makes each one take a position, forcing a less passive posture towards knowledge [2].

It is exactly this change of posture, from passive to active and participative, one of the main objectives of this proposal. The idea of a static and unquestionable science should be eliminated and the students ought to realize that it is in a slow and gradual transformation, assuming a more critical and daring position.

The difficulty of comprehending how knowledge is structured leads most of the students to consider Physics as a pile of formulas and equations with almost no sense, since they do not have any idea of where all of them came from. The pupil is not interested in discovering the origin of the equations shown by his professors because he lacks historical and philosophical knowledge, having as the only solution the act of memorizing [3].

With the proposal of broaching History when teaching Physics, the objective is to overcome not just the knowledge fragmentation but also the lack of meaning of the great majority of its contents, promoting more interest and improving the assimilation of the subjects as a whole.

III- THE USE OF EXPERIMENTS IN PHYSICS THEORETICAL CLASSES OF AN ENGINEERING COURSE – AN APPROACH FOCUSING ON REALITY

Experimentation was, undoubtedly, an important step forward to the teaching of sciences, succeeding in permitting the student to observe the studied phenomena and confirm the veracity of the involved theories, translating mathematical language to visual language. However, if the use of experiments is restricted to the verification of the concept, it will end up falling into forgetfulness due to the inexistence of any connection to reality.

Professional qualification increasingly demands "capacities of coordinating information, interacting with people and dynamically interpreting the reality" [4]. The new engineer, when proposing solutions, should take into consideration the problems in their totality, not just in technicalities, but also inserted in their conjecture of causes and effects of multiple dimensions. Thus, the use of experiments should be based on a pedagogical approach centered on the own student, with a strong relation between theory and practice [5].

According to Pietrocola [7], an intensification of the knowledge construction strategies is important to the students as they realize that scientific knowledge acquired during classes is useful for interpreting the world which surrounds them. For this purpose, he considers that reality should be an object of scientific education, emphasizing the knowledge constructed by science as a sketch of this reality.

In the same direction, Fourez [8] points out that an approach in keeping with quotidian is capable of generating autonomy, permitting the apprentice to be able to negotiate his decisions and to better communicate when facing concrete situations. Fourez presents humanistic reasons when referring to the individual's autonomy and his possibilities of acting and communicating, as well as economic reasons when it is a question of educating engineers as qualified workmanship. For that very reason, he judges that scientific education should be related to a contextualized teaching, not to a learning which is justified by itself, without any connections with the real world.

IV- CASES

Many studies concerning new methods as a way to improve Physics education have been developed, revealing a wide range of possibilities and tendencies with a practical approach. Some of them were even applied to high school students, showing that the obtained results can also bring profitable modifications to the superior education. The following cases were specially analyzed, taking into consideration their emphasis on the students' quotidian and the change of behavior expected in the sense of stimulating a critical sense and a more active posture.

Another case is a project conceived in the National Chi-Nan University [9], Taiwan, in hopes of helping students become more active and intellectually engaged learners while conducting Physics experiments, created a multiple-choice question-generated learning strategy as a supplement to traditional lab reports. By requesting students to construct multiple-choice questions related to interacting physical phenomena during the learning process, the researchers aimed at inducing them to be more attentive to their tasks and more reflective on their own thinking, cultivating a more active learning atmosphere in physics laboratories.

The multiple-choice questions were around experimental elements, based on King's higher-order thinking (H.O.T) definition of questions which "cannot be answered by the factual materials in the texts or by teacher's lectures. They require students to think, rather than remember or look up"[10]. According to the students' responses, the multiple-choice question generation made them "think and reflect more on physics-related questions and phenomena (82.05%)", "discuss more frequently and intensely with group members (64.10%)" and "more focused while conducting physics experiments (51.28%)".

The previous case shows us that creating an opportunity for the students to reflect about the experiment, not just in terms of experimental and technical procedures, but also correlated concepts, relation with other disciplines and possible applications, can improve significantly their behavior. The results confirm that this kind of activity enhances in-class question asking, makes the students feel more interested and improves their communication skills, helping them to become more active learners.

Many ideas regarding Physics basic concepts applied in several quotidian situations have been developed, broaching phenomena and devices related do scientific principles, as Valadares' work with high school students about the photoelectrical effect, the laser and the dark body [12]. Therefore, they would start to understand the functioning of the public illumination system and elevator's door, optical fibers, bar code reading and greenhouse effect.

Also exploring Modern Physics phenomena, Laburú's work [13] tackles elements which are easily found in the students' quotidian, such as liquid crystal displays present in digital watches and calculators. With some electricity and light polarization concepts, it was possible to study and introduce the advanced technology of LCD devices, which are more and more present in our daily life.

One of the objectives of science learning in Engineering courses is to provide the student with world vision and show him that based on this vision it is possible to transform the nature, by technological artifacts which will later serve mankind. Regarding this matter, the referred work reinforces the importance of dealing with technology and future applications, even more when considering the new engineer's profile, who will be constantly demanded an innova-

tive and creative mentality.
Broaching the Physics involved in daily elements, the same author stresses the possibility of creating a stimulating atmosphere to the pupils, motivating them to comprehend some Contemporaneous Physics concepts, including in this case another of his proposals, which consists of an experiment that permits the visualization of the same electromagnetic stationary waves present inside a microwave oven [14]. Its main idea was, starting from the initial motivation given by the experiment, when studying the topic 'waves' in the discipline, make the student comprehend the functioning of this household appliance which is part of his daily life.
With this kind of experiment, Laburú enabled the approximation of Physics contents and students' quotidian, being useful not just for comprehension and nature vision but also for the understanding of principles involved in technological devices they frequently interact with. Thus, the student will be able to look around him and make the connection of these two apparently separated worlds: Physics theories and real life.

V- THE FORMULATION OF NEW PHYSICS TEXTS - A PROPOSAL

The first two years of the Engineering Course at the Polytechnic School, University of São Paulo, consist of a great amount of basic subjects necessary to the formation of any engineer, in which Physics disciplines exert a notable importance. The structure of an undergraduate student curriculum comprises four modules of Physics disciplines, divided throughout the Basic Cycle.
The first two modules approach basically issues involving Mechanics, aiming at the revision and deepening of Classical Mechanics concepts as energy, linear momentum and angular momentum conservation, as well as rigid body dynamics and relativity. Regarding the last two modules, during the second year of the graduation, the broached issues are essentially electricity, magnetism and Modern Physics, with the proposal of introducing its basic principles.
As a continuation of a previous research, which established the theoretical outlines of the project and the favorable aspects of experimentation, the present study took a new direction. The difficulty to be faced up was how to make broached issues in class have meaning to the students, in other words, how to construct this interface between theory and proximal reality.
The previous study defined the most relevant contents of Physics for Engineering disciplines, according to the results of an interview carried out with fifteen professors of Physics Institute at the University of São Paulo [5]. The next stage consisted of a research in order to obtain information on available experiments involving those contents, to subsequent acquisition. 'Table 1' shows the final result.
With the experiments already acquired by the coordination of the basic subjects cycle, known as Basic Cycle, and with the teachers' consent for using them during classes, a way of stimulating the students needed to be created. The idea of formulating complementary texts to each one of those experiments came to fill this blank, so that the experiments accomplishment was not restricted by the verification of the studied principle, one of the main causes of disinterest and deficient learning.
To make the subjects have a meaning to the students, the new texts broached daily situations, routine devices as well as recent and future applications in the engineering field, related to each one of the experiments.

Table 1: Experiments broaching the most relevant issues pointed out by Physics professors, with their respective discipline.

Discipline	Experiment
Physics II	Rotating Platform
	Rotation Device
	Resonance
Mechanics A	Gyroscope
Physics III	Central Forces and Center of Mass
	Magnetic Force / Eletric Engine
	Parallel plate variable capacitor
	Thompson's Ring
	Pendulum - Foucault current
Physics IV	Oersted Experiment
	Vat of Waves
Chemistry	Kit for Electrolysis Study
Materials	Spheres in Tempered Steel

The texts elaboration was based on the ensuing logic:

Basic Sciences → Applied Sciences → Technology

Each text covered three main aspects: historical rescue, inasmuch as the epistemology of science plays an important role in the construction of a critical posture, quotidian situations, which facilitates the identification of the student towards scientific knowledge, and finally future applications with very daring proposals, developed by important research centers.

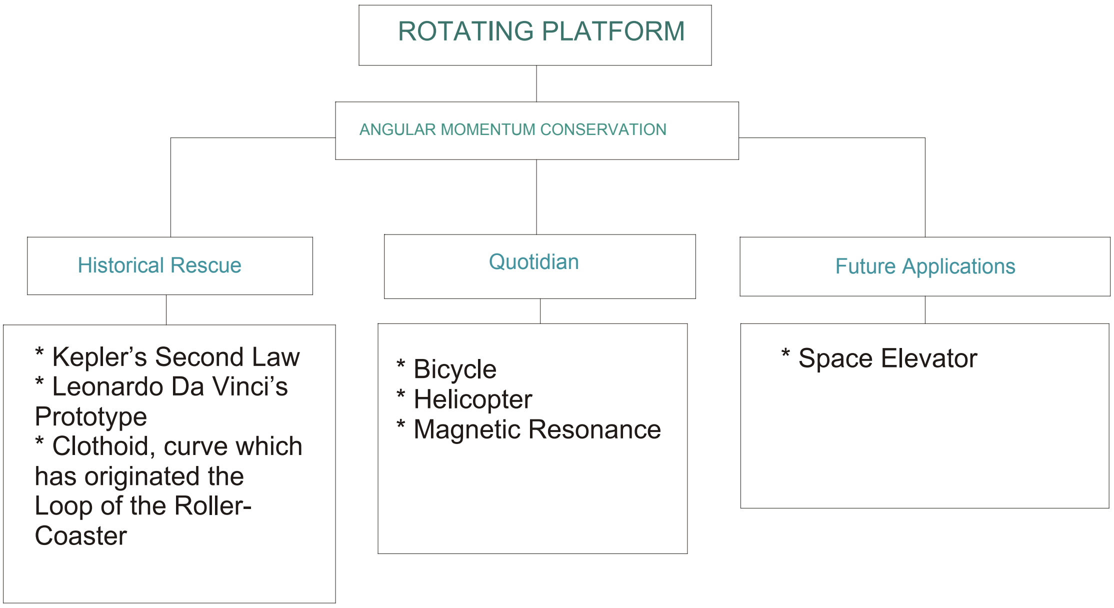
The first text to be conceived regarded the Angular Momentum Conservation, principle which rules the Rotating Platform experiment. Firstly, it was reckoned that an explanation on what the students were going to observe was necessary, so that they could better comprehend the phenomenon and could be able to associate it with the rest of the examples described in the new material.

Figure 1: Interactive joint for dynamics of rotation study – Rotating Platform

The introduction was divided in two parts, each one about a different approach of the Angular Momentum Conservation: the first one as a vectors cancellation (platform turning clockwise and the person in the opposite sense) and the second one as compensation between angular velocity and moment of inertia (retracting and extending the arms, each one holding a dumbbell).

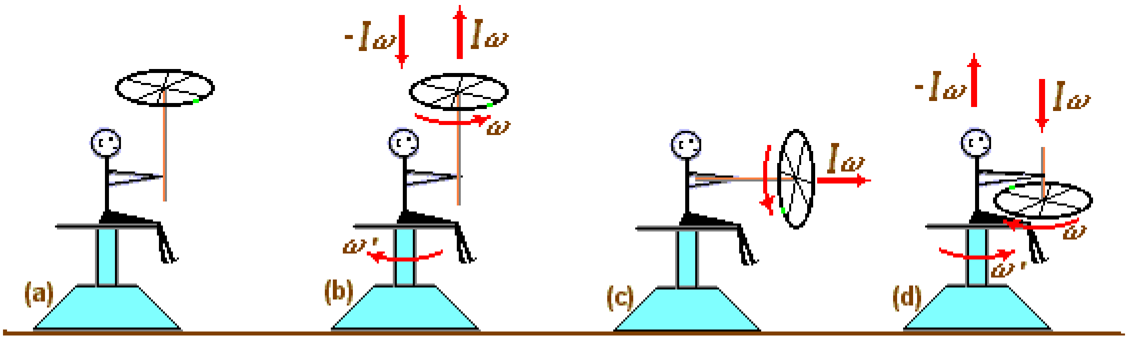
After the experiment explanation, we started to describe situations in which the studied principle can be visualized, not setting aside the use of a mathematical language when required, proper to engineering students and aiming at the systematization and facilitation of the phenomenon's analysis. This part can be schematized by the following flowchart:

Figure 2: Schematization of the broached contents in the text about Angular Momentum Conservation.



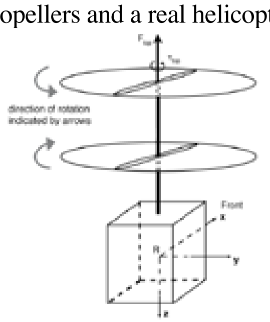
The text formulation prioritized a more attractive approach for the students, with diagrams, photos and drawings. In the introductory part, a drawing was used in order to represent the vectors cancellation case:

Figure 3: Illustration of Rotating Platform experiment.



Regarding the historical rescue, one of the examples was the Second Kepler's Law, showing the compensation between radius and velocity ( ) so that the angular momentum is conserved, and the same can be observed in a loop of a roller coaster, which was created in 1774 and is still a present element in student's daily life. The helicopter was another example of the text, describing the existence of two propellers turning in opposite senses in order to maintain the body of the helicopter stable (with just one propeller, the natural tendency would be the turning of the rest of the helicopter in the other sense). This case clearly shows the engineering undergraduates how contents studied throughout Physics disciplines can be used in a profitable and beneficial way, so as to supply the necessities of society.

Figures 4 and 5: Illustration of two opposite senses propellers and a real helicopter.



VI – CONCLUSION

The lack of connection between the current approach of Physics and the reality lived by the engineering students implies less commitment in the learning process, to which they do not see a meaning. Knowing how many electrons fit electronic layers of an atom, for instance, does not arouse so much interest among them. Questions like this are not familiar to them, not even present a relation with their universe of interest, despite of having to be taught.

Therefore, the present study aims at facilitating the students' learning process, favoring the development of their analysis, reflection and generalization capabilities. In this sense, the proposal of formulating complementary texts with a more practical approach tries to make Physics disciplines more attractive, aiming at motivating an active participation of students, arousing their curiosity and enabling an effective involvement with the subject.

The new aspect about this proposal is the idea of joining epistemology and practical applications in a single purpose, in order to provide the undergraduate students with meaning to the broached issues in Physics, not just in the sense of concrete finalities but also allowing them to comprehend the dynamism of science and showing how physical concepts were originated and in which measure their approach has changed so far.

The study of Physics as a whole contributes to a basic comprehension of the nature and can develop several abilities in the students, stimulating their creativity and providing them with pleasure, broad mind and new challenges, essential skills to the new engineer's profile.

References

01. Yunfang, L., *Reflection on Modern teaching Theory and Practice in Physics*. The China Paper (2006)
02. Robilotta, M. R., *O Cinza, o Branco e o Preto – da Relevância da História da Ciência no Ensino de Física*. Caderno Catarinense de Física, 1988.
03. Hülsendeger, M. J. V. C., Os Prós e *Contras da Utilização da História da Ciência no Ensino da Física*. XVI Simpósio Nacional de Física, 2005.
04. CNE. Resolução CNE/CES 11/2002. Diário Oficial da União, Brasília, 9 de abril de 2002. Seção 1, p. 32.
05. Pellegrini, S. P.; Olguin, G. S., *Uso de Experimentos nas Aulas Teóricas de Física, em um Curso de Engenharia: Um Estudo Preliminar*. In: Encontro Nacional de Pesquisa em Educação em Ciências, Florianópolis (2007)
06. Svab, H.; Olguin, G.; Gaspar, H.; Aiello, C.; Antunha, A., *Reflections on the "Basic Cycle" of engineering studies at the Polytechnic School, University of São Paulo: Contemporaneity and Problems*. ICEE (2007)
07. Pietrocola, M. O., *Construção e realidade: o realismo científico de Mário Bunge e o ensino de ciências através de modelos*. Investigações Científicas, Instituto de Física, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil (1999)
08. Fourez, G., *Alphabétisation scientifique et tecnique. Essai sur les finalités de l'enseignement des sciences*. Belgique: De Boeck Université (1994)
09. Liu, Y. H.; Yu, F. Y., *Active Learning Through Student Generated Questions in Physics Experimentation Classrooms*. ICEE (2004)
10. King, A., I*nquiring minds really do want to know: Using questioning to teach critical thinking*. Teaching of Psychology, Vol. 22, 1995, pp. 13-17.
11. Araújo, M. S. T.; Abib, M. L. V. S., *Atividades Experimentais no Ensino de Física: Diferentes Enfoques, Diferentes Finalidades*. Revista Brasileira de Ensino de Física, São Paulo (2003)
12. Valadares, E. C.; Moreira, A. M., *Ensinando Física Moderna no segundo grau: Efeito fotoelétrico, laser e emissão de corpo negro*. Caderno Catarinense de Ensino de Física (1998)
13. Laburú, C. E.; Simões, A. M.; Urbano, A. A., *Mexendo com Polaróides e Mostradores de Cristais Líquidos (O ensino da Física Contemporânea, tendo como pano de fundo a Física do cotidiano)*. Caderno Catarinense de Ensino de Física (1998)
14. [14] Laburú, C. E.; Ota, M. I. N.; Basso, R. L. O.; Almeida, C. J., *Visualizando Ondas Eletromagnéticas Estacionárias (Um Experimento na Cozinha de Casa)*. Caderno Catarinense de Ensino de Física (2000)