Integrating Practice and Theory in Basic Physics Undergraduate Courses: A New Physics Teaching Lab Proposal

Alexandre Guimarães Rodrigues* and Jhon Rewlyson Torres dos Reis†

*Instituto de Tecnologia, Universidade Federal do Pará, Belém, Brazil
E-mail: alexgr_28@yahoo.com.br

†Instituto de Tecnologia, Universidade Federal do Pará, Belém, Brazil
E-mail: jhon_etho@hotmail.com
Abstract: The undergraduate basic physics courses performed in the traditional way, based in theoretical expository methods, is attracting an ever smaller contingent of students, which complain about the abstraction and lack of application of scientific knowledge. In addition, the positive impact that experimentation exerts on physics classes, when performed with a proper and well-planned didactic purpose, is largely known. Here we present a proposal that intends to insert experimental activities as support to the basic courses of physics, which is in resonance with the so-called active learning methodologies based on challenges, projects, open questions and experimental investigative practices that give students deeper levels of commitment and learning. The proposal also finds support in modern pedagogical projects of undergraduate courses in which the theoretical and practical knowledge are integrated in a concatenated and synergistic way. The first step is to employ usual physics classes to construct the knowledge based on problem solving, creating in the students the curiosity and the research spirit. After, some problems are selected, adapted to experimental projects and addressed to the research groups.
formed by students. As a prototype case we employed our hypothesis in an electromagnetism basic course, along one semester, where a voluntary student worked on an adapted problem about physics of capacitors and dielectrics. Based on the classical problem of a parallel plate capacitor with the inner volume equally filled with two different dielectrics, the student, under the supervision of professors, was able to expanded the canonical solution of the problem creating a solution that takes into account different filling dielectric profiles. Then, a new technique to measure the dielectric constant of liquids was proposed and implemented, employing a liquid and the air as the two dielectrics in variable proportions. The chosen liquid was the hexane that has its dielectric properties well established in literature. The values measured in the present work for the dielectric constant of the hexane are very close the value reported in literature (less than 5% error). Furthermore, it is worth to mention that employing the new experimental approach a critical problem in dielectric constant measurements assigned to parasitic capacitance is solved. Concerning about the impacts on the student formation it is clear that, along the course, he developed sharp scientific skills learning how to approach experimental problems from theoretical constructions. Besides the investigative approach this lab proposal incorporates demonstrative activities intending to show through simple practices qualitative and/or quantitative aspects of the physical phenomena presented in the classroom. The current stage of
this proposal, which is in implementation at present days, involves theoretical refinement, adaptation of physical area and participation in calls for funding lab equipment. Finally, the results obtained up to now, support the idea that the present method constitutes both a new physics lab teaching approach as well as can be employed as an innovative proposal for the construction of a new curriculum structure of basic disciplines in the Engineering Courses. The authors are indebted with CNPq, CAPES, FAPESP and Universidade Federal do Pará.

**Keywords:** Active Learning Methodologies, Investigative and Demonstration Practices, Lab Proposal, Physics Teaching for Enginnering, Theory and Practice Integration.

### 6.1 Background

The undergraduate basic physics courses performed in the traditional way, almost totally based in theoretical expository methods, is attracting an even smaller contingent of students, which complain about the abstraction and lack of application of scientific knowledge. Nevertheless, it is well known from literature the positive impact that experimentation exerts on physics classes when performed with a proper and well-planned didactic purpose\(^1\). This proposal
intends to insert experimental activities as part of basic physics courses, which is in resonance with the so-called active learning methodologies based on challenges, projects, open questions and experimental investigative practices that provide deeper levels of engagement and learning for the students.

6.2 Purpose/Hypothesis

This work synthetizes the idea transformed in a project that was awarded in a public funding call from UFPA’s Rectory. Basically, the proposal is conceived on two independent but complementary pillars: 1) Develop pedagogical resources with experimental practices for teaching Physics for Engineering and basic sciences courses. 2) Furnish opportunity, for undergraduate level students, to acquire good formation in experimental scientific research.

In some sense, the interesting and unusual aspects of the proposal are: Integration of the theory and practices by means of two different experimentation modes: demonstrative (bench of well-known pedagogical experiments) and investigative experiences (innovative and developing projects); Adaptation of physical area to merge theory and practice in the same time or in a indistinctly and easy way; Wide range of innovation with an extensive gamma of product and processes; and Mid-term goals in order to collect plenty of contributions to reformulate basic courses on Physics for Engineering.
It is worth keep in mind that the student do not need to have a real scientific problem to do science or to think scientifically. On the other hand, in the role of professor, he must to promote teaching by situations/activities that challenge and/or propitiate to think scientifically. Furthermore, it is extremely necessary that the professor must be straight about developing skills and apprentice´s competences. It means that the professor has to define the didactic (formative) objectives as precise as it possible. We consider that this set of sentences is the tacit background of this proposal.

6.3 Design/Method

The method presented here can be organized as follow. Step 1: at least one class a week is employed to discuss and analyse problems from textbooks. During the analysis of the problems, both the understanding as well as the generalization of them are sought. Step 2: A problem with potential to be transformed in experimental project is selected. Step 3: Under the supervision of the professor, project execution begins with the build of the experiment by the student. Here we have the most critical part of the method, since problems able to make the project unfeasible can take place. Step 4: The experimental data are collected, analysed and compared with the discussed theory. Based on the success of the project and on the commitment of the student to the
work a score is assigned to him, substituting a conventional evaluation. Finally, successful projects can be transformed on new lab practices.

6.4 Results

Our investigative experimental method has at least two different approaches. One of them, with real interface among Engineering and physics, has potential to produce new experiments that can be implemented as new practices in a structured didactic laboratory. The other one possibly can be thought as investigative, at least from the student perspective, and is structured from problems that are not so challenging or difficult, from a theoretical point of view. The experiments for both of the methods can be extracted from physics textbooks or even be elaborated by the professor. Here, it is important to emphasize that basic physics textbooks have hundreds of proposed questions that can be implemented as stimulating and economical viable experimental problems.

In order to verify the viability of the first type method mentioned above a prototype case study was implemented with a voluntary student from a basic electromagnetic course. In this one semester study, under the supervision of a professor, the voluntary student worked on an adapted problem about physics of capacitors and dielectrics. Starting from the classical problem of a parallel plate capacitor half-filled with two different dielectrics he was able
to create an expanded model considering different profiles of filling for the capacitor. Additionally, he was also able to build and perform the correspondent experiment employing a liquid (hexane) and the air as the two dielectrics, obtaining a dielectric constant value for the liquid very close to the value reported in literature (less than 5% error)\(^2\). The results obtained with our case study show that, the student involved with the issue of determining the dielectric constant by means of capacitor of parallel plates was able to understand and generalize the theoretical original problem. Besides that, he faced the experimental challenge and experienced scientific method in fact, by doing a real experiment that produced accurate experimental results when compared with theoretical model developed. The main point in this activity is that the student was able to develop worth competences for research in experimental area. The observed developed competences in the case study investigated are: generalization of a stablished situation; elaboration of a theoretical model; idealization and construction of the related experiment; data analysis; comparisons between theoretical model developed and experimental results and finally proof of the developed model through extraction of an expected value for a physical parameter.

The current stage of this proposal, which is in implementation at present days, also involves refinement by means of studying different kinds of methodological approaches to establish theoretical foundations of the proposal\(^1,3-5\).
The team is also researching formats to synthesize kinds of reports and registers (media) for projects and for didactic assessments with the purpose to get all the material available for guiding others professors and students in experimental research.

6.5 Conclusions

We believe that a proposal which use the principle of merging theory and practice by means of two modes of experimental activities (demonstrative and investigative ones) in a physical area with mutual access (classroom and lab with the potential to interchanging theory and practice in a easily and natural way) is a stage for innovation in an extended significance, including innovations of content, methodology on teaching/learning activities and in evaluation forms. Here we successfully employed this idea on a case study where we evaluate the impact of the methodology on the learning process of a voluntary student.

The results observed showed that the student developed a series of skills and competences related to how to use the experimentation to obtain knowledge. It is propitious for thinking in terms of mid-term goals with the intention of producing plenty of contributions to reformulate basic courses on Physics for Engineering in a stimulating manner and offering support to hands on
activities related with investigative questions in the interface between Physics and Engineering.

Bibliography


