**From the Hands-on Methodology to Problem-based Learning: Experiences and Perspectives of an Introduction to Non-conventional Engineering**

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**Abstract**

This essay presents a briefing about the introduction of engineering course of the Center for Sciences and Technology of the Pontifical Catholic University of Rio de Janeiro, recent tracking, regarding the period from 1997 to 2010, demonstrating the positive background and the obstacles faced during the course’s progression, relating all different experiences.     
The offer of this subject to first period students is been constantly updated through methodological innovations, looking forward to improve the freshmen development, building talents from making students act directly on engineering areas, involving them in practical situations, cooperative work, scientific matters, social and sustainable technologies.

1. **Introduction**

Traditionally, as in many engineering courses, the Introduction to Engineering course has the inherent characteristic of being a subject taught by the use of lectures and films, among others. The first version of this course at the Center of Technical Science - CTC at PUC-Rio, when it was implanted in the common studies cycle (basic cycle) of the Engineering department was not so different. Initially, the course was intended to present the professional potentials of the different engineering specialties existent at PUC-Rio, as well as address academic issues related to CTC students in relation to student life at the university. It also aimed to present the education and research possibilities and opportunities at the institution. However, this approach was not attractive to students. Therefore, a new proposal for the course was elaborated, combining two priorities: the familiarization of freshmen with the very essence of Engineering, in itself a constant need shown in several reports of the students themselves, and the work on engineering projects, in order to meet another freshman demand, since the students felt distant from the engineering field during the basic cycle.

From the mid-90s onwards, and, in particular, due to discussions and studies under the REENGE Program[[1]](#footnote-1), the CTC implemented the hands-on methodology. Thus, beginning in the first semester of 1997, nearly 500 freshmen were divided into classes of up to 30 students. Different engineering CTC areas (at the time Civil, Mechanical, Electrical, Production, Chemistry and Computer Science and Metallurgy, currently including Automation and Control, Environmental and Petroleum) were responsible for each class. A teacher from each of these areas was chosen as coordinator, and was responsible for proposing projects that could be conducted by freshmen students using simple, accessible and affordable material resources, and using only scientific concepts that they brought with them from high school.

From this first experience with the hands-on approach, the course has undergone several reformulations. In this sense, new methodological approaches have enriched the experience, by promoting entrepreneurial attitudes and, more recently, by applying the Problem Based Learning – PBL – methodology, aiming at student performance in projects related to concurrent Engineering, among others.

1. **The Methodologies - From Hands-on to the PBL model**

One of the proposals for the Engineering Innovation program (Inova Engenharia - IEL, 2006), is the training of engineers with extensive application of the hands-on learning methodology, according to which the training of professionals should promote the development of projects that encourage the application of theoretical knowledge in solving real problems, thus producing innovations.

The hands-on approach is a methodology based on the resolution of practical issues, and allows an active and cooperative participation, differentiating itself from the traditional methodological paradigms. It can be understood as:

• An active learning, in which the student is at the center of the learning process;

• A cooperative learning, in which the students seek to build the collective knowledge by working in groups, under conditions that assure both positive interdependence and individual contributions.

Among other benefits, this methodology enables the development of a capability for critical analysis, the establishment of a relationship between scientific knowledge and production, a further reflection on reality and the use of different languages ​​and different sources of information.

One of the first projects using the hands-on approach at a gained knowledge level executed during the Introduction to Engineering course of 2002 was the Rodrigo de Freitas Lagoon Project. This project aimed to introduce the notion of engineering activities to students through theoretical and laboratory analyses, accompanied by engineering professionals, in this case, Environmental Engineering, as well as placing the student in touch with teamwork dynamics. The aim was to check the water quality of the Rodrigo de Freitas Lagoon, located in the Southern District of the City of Rio de Janeiro. The proposal was to conduct an evaluation of different parameters indicative of pollution in the waters of the lagoon, considering location and sampling times. To carry out the tasks, students attended lessons about the lagoon’s history, characterization, hydrographic contributions and the identification of possible pollution sources. With these tasks at hand, students went to the practical aspects and, guided by a teacher, conducted ​​several *in situ* measurements. Specific times and locations were set, both for lagoon and river and surrounding area samplings. Samples were also collected and analyzed in the laboratory. In possession of these data and supported by research conducted in previous years, plus the interview with FEEMA, the students were able to better understand the results. Each group conducted ​​a presentation about the tasks at the end of the school term.

From the use and experimentation of the hands-on approach, this methodology began development based on the student's exposure to contextualized problems, and learning occurred throughout the problem solving, evolving to PBL, Problem Based Learning, current name.

The PBL methodology model adopted in the new phase of the Introduction to Engineering course can be considered a hybrid, since this course is given during the first semester, and it was observed that students needed support, in order to implement some of the projects.

To facilitate a better understanding of the subject, there are classes on "Fundamental Concepts of Engineering", which are given as seminars at the beginning of term and for which specific educational material was prepared, involving the following topics:

• The Engineer and Engineering: What is Engineering, the attitude and behavior of the Engineer, the evolution of Engineering, Engineering and Basic Sciences, the interdisciplinary and systemic perspective, the KISS Principle (Keep It Simple, Stupid); teamwork;  
• Engineering Project: modeling, simulation, software and models, dimensioning, norms, specifications, costs, inventory, worksheets, and experimental tests;  
• Project Management: teamwork, schedules, costs, logistics, quality, marketing;  
• Project Presentations: preparation of reports and seminar presentations, the use of graphs and tables, systems of units, measurements, instruments and orders of magnitude; experiment analysis;

• Safety in Engineering: basic safety norms and the need for the use of individual protection equipment.

In the execution phase of the projects, students begin by assessing the challenge and discussing the project. Then, the teams organize themselves and prepare a work plan. Resources are made available (limited), whether human, material or financial resources and the project must take these into consideration. During execution, some lectures or experiments are given regarding the concepts involved and, at the same time, the students gather information and seek solutions. Sources of information are discussed and evaluated. The individual and group activities take place throughout the process. In the end, students develop a written report and orally present their work.

PBL models usually follow a cycle, in which case the Introduction to Engineering course can be summarized as follows:

1. The presentation of the problem by the teacher (client);
2. The task assignment among the groups, that will be guided by specific monitors;
3. The presentation of partial reports (raising hypotheses and attempting to arriveat solutions with the knowledge available);
4. The identification of learning needs and the concepts and difficulties involved in the problem;
5. Parallel research and learning (concurrent) in order to form the theoretical framework;
6. The sharing of solutions and experiments by the application of the new knowledge learned;
7. Reworking;
8. Prototype or product or service.

To illustrate the transition from the hands-on approach to PBL, the continuation of the Rodrigo de Freitas Lagoon can be cited in this current version. In the new proposal, students seek ways to facilitate the flow of seawater to the lagoon and vice versa, adding to the level of water oxygenation and reducing pollution caused by improper disposal of sewage *in-natura*, proposing corrections to the imperfections of the process used today. The idea was to assemble a practical blueprint of how the exchange of water occurs between the Lagoon and the sea through the channel of the Jardim de Alah and Visconde de Albuquerque Street and propose solutions to make this water exchange more efficient, using models.

1. **Current Stage**

Society demands engineers qualified to act as specialists, as well as being able to interact with other fields of knowledge. Thus, their preparation, for the purpose of exercising their professional citizenship, has to, increasingly, articulate in an interdisciplinary and multidisciplinary manner, especially regarding innovative activities and attitudes as change agents. Concomitantly, the emergence of new technologies and the increasing complexity of products, among other factors, have resulted in an increased product development period, and a proposed solution to this issue is the simultaneous engineering.

This scenario, coupled with the fact that the freshmen still have little knowledge available to be able to choose their specialty, spurred the current proposal of the Introduction to Engineering course at the CTC, PUC-Rio, which involves the implementation of projects that integrate several engineering areas and work by using concurrent engineering. Thus, this proposal aims to give students the opportunity to learn more about other engineering areas and not only the one indicated initially[[2]](#footnote-2)3 at the time of admission.

The students are, therefore, enrolled in classes in the specific engineering areas they indicated when applying to the university. These classes are divided into groups that make up the projects that integrate some engineering areas. To implement these projects, students attend both specific engineering classes and those that involve the different engineering areas of the project. Periodically, groups of all the engineering areas that compose the project gather, to assess their progress or to list the parameters (demands and specifications) necessary for its achievement. There is a coordinator for each project who is responsible for organizing the activities, along with the help of specialist teachers and support monitors in each of the areas involved.

An example of this approach, which has been held since 2008, is the **RoC** (**R**ace **o**f **C**hampions) **or Autonomous Ground Vehicles Project**, that involves the Control Engineering and Automation, Mechanical, Electrical, Computer, Civil and Production Engineering freshmen. The challenge essentially consists in developing an autonomous scale car that must be moved on a track, taking a pre-defined route, at a certain distance from the guardrails, without bumping into them, using sensors and / or a pre-established programming.

Each engineering area is responsible for a certain part of the project, namely:

* Mechanical Engineering - Vehicle Construction and Testing
* Control and Automation Engineering - Instrumentation and Simulation
* Computer Engineering - Vehicle Programming
* Civil Engineering – Runway fabrication
* Production Engineering - Project Management and Business

1. **Results**

From the undertaken questionnaires and reports, some important aspects about the current state of the course could be observed:

• **Difficulty level of the projects.** In some projects, the difficulty level is considered very high, beyond the capability of the students and, sometimes, even of the monitor. This difficulty is not only due to lack of knowledge, but also by the lack of initiative in searching for solutions. It became clear that the PBL methodology is too complex for a large number of students, and that they would certainly work better with more guidance from teachers using the hands-on approach. What is also observed is that not all teachers are really prepared for the implementation of the PBL methodology. The projects are considered real challenges both for the advising teachers and for the monitors that help, and of course, for the freshmen, who have never been exposed to this type of work before.

**• Devaluation of the course with regard to the number of credits.** The issue of why the Introduction to Engineering course does not have its workload increased was raised. The argument was that if the course increased its number of credits, students would strive accordingly, since this subject would then become more important in accounting for the Grade Point Average (GPA), which reflects the overall performance of students throughout the school year. Moreover, there is a consensus among students, monitors and teachers that there should be more time for project delivery. Also according to these teachers this point was emphasized, since the involvement and dedication necessary for project organization requires a much greater workload than normally given to "conventional" blackboard and chalk course, or, nowadays, "data-projectors" courses, and that they are, not infrequently, a simple transfer of the "pasteurized" knowledge found in text books. It is not enough to just prepare for the subject or the project once, because every term new steps must be performed with a new group of students, that should be formed so as to continue the project from the stage reached in the previous term.

1. **Challenges**

Some difficulties have been found among the students and faculty involved in these projects. Among them, the following can be highlighted:

• Projects that involve concepts not yet learned in high school. The issues involved should promote the transfer of conceptual and procedural content, as well as attitudes, to the situations involved in the project. However, the teachers claim that they show a common doubt between teaching detailed content that students still are not substantiated enough to grasp, versus revising a few concepts in the form of a "black box".

• Joining PBL work alongside learning some of the fundamental concepts in Engineering. Due to the dynamic nature of the adopted methodology it is difficult to close class planning in advance, and some concepts are often no longer covered. Also, because it is student-centered, in a way, it's up to them how the course goes, which may differ from the way previously planned by the teachers. Another difficulty is the creation of evaluation mechanisms that indicate how deeply the students grasp these concepts.

• Get students to work in teams. During High School usually students are not encouraged to really work as a team. What often happens is group work, where some of the more passive students hide behind other more active ones, preventing equal participation. Students also do not always know how to respect diverse opinions and build a consensus. Likewise, not all students show the same level of responsibility with regard to compliance with the timetable for the project planning.

• Have students identify what task they must perform. It was observed that this difficulty, as expected, was higher than estimated. According to the students themselves, the course lacks the assignment of more specific tasks by the teacher, a more objective approach, basically telling the students what to do. This was also expected, but not to the extent in which it was presented.

• Allowing the students increased opportunities to gain a broader view of the several engineering areas, without losing sight of their desire to deepen their knowledge within the area chosen on admission.

1. **Final Considerations**

The Introduction to Engineering course is becoming, year after year, of great importance for the CTC AT PUC-Rio and its freshmen, since it has contributed to reducing the dropout rate and in supporting the increasing student interest in engineering. Some results can be seen as progress:

• Attitude changes in the classroom, by both students and teachers (with students becoming more active and teachers acting as mediators);

• The appreciation of individual student ideas, but also the socialization of these ideas with the whole group, contributing to the collective creation of knowledge for the  
development of respect and for the creation of critical thinking, fundamental for an engineer;

• Further development of oral and written expression;

• Greater student satisfaction for having their expectations met regarding learning more about their future professional area as well as having a broader vision in relation to other engineering fields;

• Greater student encouragement to seek participation in other activities such as class monitoring, scientific research work, or participation in student competitions.

Therefore, the improvements made in the course since its inception, are just some of many options that can be implemented within its current format. Regarding future work, we intend to strengthen the sense of Ethics and Social Responsibility, and of Innovation with Sustainability. Certainly many other developments are still ahead, but always seeking to meet the expectations of incoming students as well as making them experience and understand the procedures involved in the processing of engineering projects.

Finally, we observe that the Introduction to Engineering course supports and has served as a pillar for the development of the Lapin Project (Laboratory of Learning in Innovation), coordinated by Prof. José Alberto dos Reis Parise, under the auspices of FINEP and the CTC at PUC-Rio, and whose goals and guidelines are aligned with the current phase of the course.

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1. The REENGE - Restructuring of the Engineering Education, a program supported by FINEP (Financiadora de Estudos e Projetos - Financier of Studies and Projects), CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico - National Council for Scientific and Technological Development), SESU (Secretaria de Educação Superior - Department of Higher Education) and CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Coordination for the Improvement of Higher Education), aimed at restructuring higher education, encouraging the performance of different teaching and learning experiences for the advancement of teaching and research in Engineering. [↑](#footnote-ref-1)
2. Currently the students, although enrolling into the basic cycle of the CTC (which includes the various specialties of the engineering course), indicate their preference for a particular specialty. [↑](#footnote-ref-2)