Problem-Based Education on the interface between the School of Engineering and the K-12

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Abstract *— Problem-Based Education is an important learning tool that associates a real problem born outside the walls of the academia or the pre-university school to the educational environment. The first feature to be discussed is the advantage of the intrinsically interdisciplinary aspect of this kind of problem in order to direct the learning process from reality to the establishment of knowledge, within an environment that is common to the Schools of Engineering and the K-12, and where the commonly accepted educational mechanism considers that applications must follow knowledge creation and dissemination within a traditional sequential set of disciplines. The interface of the K-12 and freshmen disciplines is treated by acknowledging that several questions are common to the first two years and the outreach programs dealing with the K-12, most of them represented by the growing need to add more attractiveness to the area of Engineering. The profile of the student of the last couple of years in high school presents similarities with that of the freshmen students. This profile is presented by the student's need to frame their studies in the real world, where scientific and technical problems blend with social and human questions. This "real world" contribution brings questions treated in the newspapers and other media to the classroom, adding to the student's daily life in school the flavor of the daily life outside the school. The interface of the School of Engineering of the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), Brazil, is discussed as an example; the outreach program (PIUES) develops the same set of problems either for High School students as for freshmen in the same laboratorial environment. This activity is also discussed considering the necessity to increase laboratorial activities in the high school programs, mostly in Latin America where didactic laboratories are rarely found in the pre-university school.*

Index Terms *— Pre-university studies, School of Engineering, Problem-Based Education , Problem-Oriented Learning (POL).*

INTRODUCTION

There are several aspects of Science education common to the last few years (High School level) and the first two years of engineering schools, (freshman and sophomore level) some of which deal with the growing need to add more attractiveness to the area of Engineering. The profile of the student of the last couple of years of High School presents similarities with that of the freshmen college student.

The 10-year-old outreach program (PIUES) of the Pontifical Catholic University of Rio de Janeiro (PUC-Rio) focuses mainly on creating opportunities for High School students, especially in regards to science. By working with real problems born outside the walls of academia and schools, a PUC-Rio University/High School integration program fosters in the students a pro-active attitude not only to their own communities, but also to society in general. The idea of using problem-based education was first implemented in Introduction to Engineering course for Engineering freshmen students, and was so successful that it was extended to the PIUES program. Professors at PUC-Rio involved with the PIUES program and the Introduction to Engineering course developed, in the same laboratories, a common set of "real world" problems for both groups.

Additionally, several studies have pointed out the need for a new Engineering professional trained to act effectively on local development, however, with inter-regional mobility. In this paper, we discuss four aspects considered paramount to Engineering teaching:

- Pedagogical orientation towards the solution of problems;
- Interdisciplinary education in order to counteract current trends towards radical specialization;
- Entrepreneurship through environmental education, as a means to mitigate the challenges identified and to change the reality of the community involved;
- Sensitization to environment preservation and the natural resources degradation problem.

The four elements mentioned above – problem-based education, interdisciplinary education, entrepreneurship and environmental education – are permanent agenda items for discussions about engineering education. Theoretical research, as well as hands-on experience at the PIUES program, led us to realize the importance of these four elements when developing a common set of topics to be taught to High School students and to students in our Introduction to Engineering course. As discussed below, they are the backbone of the model adopted for our University/High School integration program.

PROBLEM BASED PEDAGOGICAL ORIENTATION AND INTERDISCIPLINARY EDUCATION

The education methodology adopted by the University of Aalborg[1] has confirmed that it is important to include in the curriculum structure fundamental concepts related to real problems, in addition to traditional courses.

The Problem-based education, or, sometimes, mentioned as Problem Oriented Learning (POL), has been considered an useful pedagogical tool, inclusive in some medical programs of solving mental deficits in contrast with cognitive problems[2].

The use of the POL pedagogical tool with the support of Information Technology it is showing new forms of collaborative works to develop the teaching and learning process[3]. The use of POL it is also being spread by some universities as the experience of a Hands-on Universe[4].

The PIUES program, in which we provide hand-on experience in Physics, Math and Chemistry for High School students, and the final projects in our Introduction to Engineering classes have given us insight regarding the motivation and learning capability of the students. We realized that these young students need to frame their studies in the real world, specifically, when scientific and technical problems blend with social and human questions. They need to visualize fundamental concepts by relating them to real problems in their own communities. This "real world" contribution brings to the classroom current events treated in the newspapers and other media, adding to the student's daily life in school the flavor of the daily life outside school.

In addition to improving student learning achievement by motivating them and offering concrete examples, these "real world" problems have the benefit of being intrinsically interdisciplinary. The students are taught that the use of scientific concepts in order to identify, qualify and propose solutions to real problems is more effective when they work with an interdisciplinary attitude, often resulting in solutions different than those in use by the community. They learn to solve problems with a broad approach, using all the tools available (Physics, Math, Chemistry, Engineering etc), as opposed to a narrow, specialized approach. This method directs the learning process from reality to the establishment of knowledge, within an environment that is common to High Schools and Engineering Schools, in which the commonly accepted educational mechanism considers that applications must follow knowledge creation and dissemination within a traditional sequential set of disciplines.

The merge between the High School environment and the Engineering School was built upon the same set of interdisciplinary "real world" problems. This interaction between the University and High School has accomplished solutions based on theoretical concepts, however, with a practical assessment of the situations, which has sometimes resulted in effective products.

When dealing with the PIUES program, specifically as an interactive learning environment[5], does not focus only on computer-aid interaction, but it underlines a vital element for success: *the participation of the High School students with their own teachers* . In addition to observing their students' progress, the teachers can bring their teaching methods up to date and bring back to their classrooms new pedagogical tools.

With this objective, the teachers have a specific parallel up-dating program that includes at the end a transportable-kit to perform scientific experiences when they return to their schools, and pedagogical information about how to improve their teaching methods and how to use the problem oriented method as a motivation tool. This method of improve the quality of the teacher allows other students from the same community, who did not participate in the PIUES program, to benefit from the outreach program.

ENTREPRENEURSHIP

Entrepreneurship is an innovative behavior, underlined inside the PUC-Rio walls that can be used to tackle the challenges of satisfying the demand for actual products, which rises when problem-based education is adopted. A positive outcome of our selection of the problem-based education methodology was the development of low-cost prototypes designed and built by the students; the students designed these prototypes based on the experience and knowledge acquired in the laboratories visited by participating in the PIUES program.

Besides being recognized as a teaching and research institution that supports the development of solutions for public and private companies with specific problems, one of PUC-Rio's most important competitive advantage is that it has established its own methodology for the development of business ventures, by molding entrepreneurs and supporting new businesses.

Entrepreneurship was introduced into PIUES as an additional resource to stimulate and motivate the students to develop local solutions to specific problems, with the support of the university's researchers and professors. The hoped aftermath for this setup is that solutions developed at PUC-Rio's Entrepreneurship environment can be later on transferred onto other environments, starting businesses that will contribute to the sustainability of local actions, in addition to generating jobs and income for the community.

The social entrepreneurship is now performing a administrative model of integrating the researching laboratories, the Genesis Institute - that has the responsibility in managing the initiatives that can generate business, and several local non-government institutions that interact directly with the communities.

ENVIRONMENTAL EDUCATION

In the beginning of the nineties, PUC-Rio has embraced a more hands-on methodology – problem-based education – for its Introduction to Engineering course for engineering freshmen students. The new arrangement for the course delivered successful results and motivated further and constant polishing of the methodology. This, in turn, encouraged the University to apply the same procedures to the PIUES program, with an ambition to energize its University/High School integration program. The field chosen to bring together High School and freshmen engineering students through the new methodology was environmental studies, with the additional positive outcome of stimulating environmental education in High School.

Environmental education was selected due to its relevance and because it targets not only ecosystem concerns, but also socio-cultural aspects that affect the ecosystem in one way or another. Accordingly, the selection of this topic was meant to unfold a social, economical and political awareness in the students involved, instilling in them necessary qualities in the young population of a developing nation like Brazil.

As a practical example, is thee *Lagoa Project* ; a project involving a lagoon located 2 miles from PUC-Rio, called *Lagoa Rodrigo de Freitas* . Coupled with theory classes, the students are shown by laboratory experiments how each polluting source contributes to degradation of the different components in the ecosystem. The *Lagoa Project* is an environmental education project intended to educate and alert society to environmental protection and preservation, by disseminating knowledge to High School students and their teachers, as well as to our Introduction to Engineering students. Hopefully, these will help spread the message that it is important to assure environment preservation and that natural resources are greatly affected by man's actions.

One important target of the environmental education supplied by the PIUES is the development of young environmental agents, who, motivated by the scientific experiences, spontaneously decide to educate their own communities, by teaching the habitants how to handle environmental aspects of the area where they live.

PIUES AS AN INTERFACE BETWEEN PUC-RIO AND HIGH SCHOOL

PIUES is an acronym in Portuguese for *University, High School and Social Integration Program* . This program started 10 years ago to fulfill a necessity to promote the interface between the University and the "outside world", particularly the High School environment. In addition to building a bridge between the University and High School activities, one of the main objectives of PIUES is to improve the K-12 Science Education, especially Science Education in High School[6]. The program has reached thousands of High School students in Rio de Janeiro, Brazil, providing them with laboratory classes in dedicated pedagogic laboratories at PUC-Rio. This is an important service offered by the PIUES program, particularly critical and needed in Latin America, where High School didactic laboratories are rarely found in the pre-university schools.

The program germinated in PUC-Rio's Physics Department, and during ten years, important joint activities were developed by the Physics, Chemistry and Math Departments. Nowadays, the PIUES program is independent and maintains its interdisciplinary trademark; it continues to work with High School students and their teachers, improving the quality of education and helping teachers bring their teaching methods up to date.

The PIUES program main tasks are:

- To interact with High Schools by offering laboratory classes in Physics, Chemistry and Environmental Studies, often with a Metrological approach, as well as with the use of computers in Math, demonstrating that it is essential to learn these concepts in order to comprehend the world surrounding them. The program offers, free of charge, two sessions of approximately three hours on each one of the different topics. Each group can have up to 25 High School students, and the students must be accompanied by their Science teacher.
- To participate in Educational fairs in schools.
- To acquaint High School and freshmen engineering students with basic Engineering concepts, by prompting them to design and build low-cost prototypes.
- To offer and manage the *Lagoa Project* .

LAGOA PROJECT - RESEARCH ACTIVITIES

The pedagogical characteristics of problem-based education created an important motivational space in the PIUES program with the incorporation of aspects related to the Environment; the arena used was the Introduction to Engineering course and the Lagoa Project discussed in the Environmental Education session of this paper.

The *Lagoa Project* aims to unite the problem-based educational approach to a business-oriented approach to Engineering, with teamwork underlying the project execution. Moreover, it aims to increase the awareness of teachers and their students to environmental concerns, and to help them understand the importance of being proficient in basic science concepts and their technological applications. The project motivates the students to learn Biology, Physics and Chemistry.

Several research activities have been carried out in the *Project Lagoa* , bringing together High School and freshmen Engineering students. The students are divided into groups that have certain tasks assigned to each one of the groups: comprehend a complex problem involving technical and non-technical features; evaluate the real problem, studying the data available and eventually acquiring their own data; and present the solution found in a convincing manner.

Some examples of the problems assigned to some groups were::

- Study and evaluate the main pollution sources of the lagoon, as well as the hydrographic contribution of each river that empties into the lagoon, and the water interchange between the lagoon and the ocean.
- Study the air pollution, mainly of heavy elements, caused by the Constant car traffic around the lagoon.
- Construct a prototype for extracting mud from the bottom of the lagoon, and perform a chemical and a microbiological analysis, using the laboratories at PUC-Rio.
- Perform a chemical and a bacterial analysis of water samples from the lagoon.
- Construct a prototype to simulate the water interchange between the lagoon and the ocean through the two existing channels.
- Evaluate the water condition before and after induced algae formation.
- Study the lagoon's Mangrove ecosystem, which surrounds the lagoon, and evaluate the Mangrove vegetation as a possible pollution sensor.
- Measure the concentration of chlorophyll fluorescent profiles of each one of the existing Mangrove, utilizing a LIF-LIDAR (Light Induce Fluorescence - Light Detection and Ranging) technique.

Its worth mentioning that this project engages students from many schools; schools that traditionally have several of their graduation students carrying on their college education at PUC-Rio. After their participation in the project is over, at the end of the semester, they scatter the knowledge acquired in the project over their schools, thus contributing to spread Environment education in their communities.

CONCLUSION

Results achieved by the PUC-Rio's PIUES program showed that the use of problem-based education on the interface between High School and the Engineering School proved to be an important tool to help uplift the students. The use of this methodology motivated the students, improved their comprehension of the theoretical concepts, and spin-offed new experiments related to problems identified in the communities to which the students belonged. Due to the interdisciplinary nature of the problems chosen, the students learned that real problems, as opposed to classroom problems, require a broad, non-segmented approach.

After realizing that students in the last couple of years in High School and freshmen college students have similar characteristics, PUC-Rio used problem-based education in the PIUES program to build a common set of topics that would bring together both groups of students in the search for practical solutions for the problems identified in their communities.

The problem-based approach in the PIUES program solutions developed at PUC-Rio's Entrepreneurship environment is now in a process of extension onto other environments, starting businesses that will contribute to the sustainability of local

actions, in addition to generating jobs and income for the community.

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