INTERDISCIPLINARY ACTIVITIES AS A WAY OF ACQUIRING KNOWLEDGE IN A COURSE OF ENGINEERING

Marcio Vieira Soares, Naval Engineer, Polytechnic School, University of São Paulo, and Douglas Lauria, Mechanical Engineer, Ph.D. Mauá Engineering School
Department of Fundamentals in Engineering, Mauá Engineering School, São Caetano SP, Brazil

Introduction

Knowledge has been always divided into different modalities to make it easier to extend its span within a frame that is comprehensible to those who just learn it or to those who create it. According to this criterion, scientific disciplines have been in modern times, quite arbitrarily, divided into three different areas: *human* (the humanities), *biological* and *exact and technological sciences*. The three are weak names that should replaced sometime in the future. For example, the term Biology was created in 1800 by the German anatomist Burdach, who defined it as "*the study of living beings*". Since the so called "human sciences" deal with human beings, that are biological beings, they are obviously also biological. Unfortunately, semantics is little known to most people, including scientists, and so this drawback is responsible for a large number of gross errors no less serious than the exclusion of the so called human sciences from Biology.

In Brazil teaching is divided into *fundamental* (or primary, as it was called in the past), *medium* (or secondary) and *superior* (university) levels. Fundamental teaching lasts 8 years; the first 4 are intended to provide alphabetization and instilling a basic and very simple knowledge of arithmetics and a few other primary notions. During the following 4 years teaching is intended to pass to the young students information on History, Geography, Portuguese and another language, mostly English (up to 1941 at this level French, English and Latin were taught in addition to Portuguese), Mathematics (mainly Algebra) and what is termed Sciences. The medium level comprises several disciplines, including Physics, Chemistry and Biology. The student is then naturally required to concentrate on one of such areas considering his/her future decision regarding the university course that will be chosen, which in turn is not seldom a matter of fashion. The University courses are standardly made up according to disciplines arranged in series and in parallel, whose content the students are supposedly able to integrate by themselves. However, since they were never trained, at any preceding school level, to do so, most students find it extremely difficult to accomplish such a task. A general trend among the students, mainly during the initial years, is to overlook the relevance of the basic disciplines for their professional future. By the way, in many United Kingdom universities the students are not subjected to examinations during the entire course; they have to pay a final and comprehensive examination at the end of the course, which may be the best way to force the students to integrate knowledge by themselves.

In Brazil teaching as a whole is subjected to a Federal Law of Basis and Guidelines for Education (LDB), which among other things decrees that the student be prepared for a continued education. Peculiarly, however, they are neither prepared to understand what continued education is nor are trained to adhere to programs of a permanent training in a given field of activity. Most students believe that what they should know is already provided by the university courses. Such an odd behavior arises obviously from the fact that students are not trained to learn to read and to study permanently, despite the fact that knowledge never ceases to grow, be it in science, in technology or whatever. Obviously, there is a great need for procedures to teach the students to be aware that they have to cultivate knowledge not only as part of their school days but as part of their professional activity.

The present work is intended to propose that some disciplines spread along a University course should be used to fulfill this *desideratum*, using either the disciplines of one and the same school year or disciplines taught in different years.

Profile of the student when admitted to a University

During the fundamental term of teaching, the students are alphabetized and are introduced to the study of Portuguese, Arithmetics, History of Brazil and Geography of their own region and learn basics concerning hygiene and health. All this knowledge is passed to the students as a discipline called General Knowledge. Each year the students are tutored by a single teacher, whose background was acquired in a special kind of course: the "Normal Course", which is intended to prepare teachers to do teaching for the beginners. The Normal Course was primarily based on the courses offered by the famous Normal Schools,

created by the French Revolutionaries in the 18th century.

The primary teachers learn little as a matter of fact since they are exposed to basic teacherish, legislation on teaching and socializing methods. Only a few teachers at this level got a University degree, usually sought after as a key to ascending in the career up to directorship of a primary school. Up to 1941 primary and secondary teaching in Brazil was recognized as one of the best in the World, which should be attributed to a high percentage of teachers with a University degree in the Educational system and to a solid link to the French, German and Italian educational systems, which prevailed here for over one century.

At the first year of the second phase, i.e., at the beginning of the medium level, the students get in touch with teachers with a University degree, which means that they are taught Mathematics by teachers with a special training in Mathematics, they are taught History by professors with a degree in History and so on and so forth. The academic contact between teachers and students is, unfortunately scarce. The students have to incorporate a large quantity of information and the teachers usually pass to the students the impression that their discipline is the most important all along the course. Although it is not overwhelming so, it is usual that Biology be the best taught among the scientific disciplines. Not much relevance seems to be ascribed to Physics and Chemistry, except that they are important to understand biological phenomena. Mathematics and a few notions on Technology are not the rule at the medium level of teaching and only very few schools offer the students the opportunity of learning how to observe phenomena by themselves and how to draw conclusions from their observations, which is essential for building up a critical scientific mind.

At the medium level the students do usually choose to attend one of two branches: *a)* a traditional, non-professionally oriented course or *b)* a technically aimed-at course. The latter provides specific background for *a)* those who wish to follow a career in the field of technological or of exact sciences, *b)* for those who will follow one of the biological careers, *c)* those interested in being teachers at the fundamental level (the Normal Course) and *d)* for those who intend to become accountants. Most students do a choice around 15 years of age, which is obviously too soon.

If a student selects the traditional course he/she will not be entitled to be a technician or a fundamental school teacher, which is possible only for those who chose a professionally oriented course. He/she will have to attend a University to get a degree, which is also possible for those who chose the second option provided they pass the entrance examinations, which are obligatory to enter any Brazilian University, either private or maintained by State or Federal Governments.

The traditional course offers specific teaching in Physics, Chemistry and Biology. Physics, usually previously not well defined as to what are physical phenomena, jumps to description of phenomena in terms of mathematical equations and measuring units. Laboratory classes are provided only by a few schools.

Up to 1997 the access to the Universities has been focused exclusively on the students performance in the entrance examinations, there is no inferior limit for the marks, the candidates are just ranked according to their performance in the entrance examinations and thus those with the highest marks are selected. When a student who opted for the professionally aimed-at course decides to enter a University his/her performance in the entrance examinations is usually poor. In Brazil there is, however, a non recognized sort of course (the "*Cursinhos*", literally "short lasting courses") prepares the students for the entrance examinations and is, as a rule, more efficient than the formal medium level courses in getting them into the Universities. This is the only hope to enter a University for those who have not attended good pre-University schools.

A serious limitation arises as to the kind of students that choose the "Normal Course", which will allow them to teach at the fundamental level: usually this course if selected by those who do not like sciences, which means right away that those who teach at the fundamental level have not had a fair preparation for sciences whatsoever. In addition, they begin their teaching activities at the age of 18 or even earlier. It seems obvious to us that their lack of knowledge, trauma and insecurity are transmitted to their students.

To teach to medium level students the teachers are required to get a University degree (they are "licensed" to teach, some get a *baccalauréat* degree), complemented by a training in Pedagogy and Didactics, which eliminates those who are not linked to education. As we mentioned above, in the past lawyers, engineers and physicians were allowed to teach to the medium (then called the secondary) level, usually with a good result. Presently, special University courses are in charge of preparing Physics, Mathematics, Biology, Chemistry, History, Geography and Portuguese and English teachers. Engineers are allowed to teach only at Universities or at the medium level for the professionally oriented courses.

Teaching Engineering

After having finished the medium level course students are ready to be turned specialists in something. During the entire period of pre-University

learning they have been induced to think in an almost impervious way regarding each kind of knowledge, which means a weak capacity to generalize, to draw conclusions from complex scientific facts and to generate solutions. Some students that attended the professionally oriented medium level school gathered a reasonable knowledge specific to the area they have chosen but, due to insufficient background, they find it difficult to reason and conceptualize and even to handle mathematical analysis. When nocturnal courses of Engineering were created the access to a University degree made it possible for these technicians to become engineers. However, they resist to basic science and are more likely to understand and manage teaching of technology. It should be recalled here that in Germany and a few other countries this level of teaching is considered not a University activity but a kind of technical one, taught at a *FachHochschule*.

The courses of Engineering particularly, but all kinds of University courses, are organized as a set of disciplines, whose content is taught as independent from each other. Consequently, to the students Calculus, Physics, Mechanics, Thermodynamics etc. and natural phenomena are not related. When the students get to the end of the course they are often required to deal with a generic problem, a project, for which they have to integrate many methods they have learned in order to attain a satisfactory solution. For the first time the students get a real problem, whose solution had not been shaped in advance. Some criteria are then presented to the students to guide them in finding the correct solution. The technological disciplines are, accordingly, considered to supply the students with specific guidelines. The rational foundations of the project are usually put aside to make things easier, which turns the engineer just a high ranked technician.

So that such a common trend be avoided we hereby put forward the proposition that some disciplines each year be used to arise and enhance the students' creativity and integrate knowledge acquired in several disciplines.

How to implement the proposed philosophy of teaching?

Some subjects in engineering teaching are naturally multidisciplinary. For instance, in the first year some disciplines deal with facts and concepts necessary for the development of basic methods in Engineering. A few disciplines, such as Calculus, Linear Algebra, Analytic Geometry and Vectorial Calculus and Numeric Calculus, are taught mainly during the first and second years. Physics and Chemistry, and Design and Computing as well, are also mainly taught during this portion of the course of Engineering.

The main purpose of teaching Computing at the beginning of the course is to provide, through programming, a training in specific logical reasoning. Some Engineering Schools offer also a training in word processors and calculus tables, graphs etc.

Electronic computers were created to make it faster and easier to calculate; in Engineering they have been readily adopted to speed up calculating procedures, to free the engineers from boring calculations for more creative activity (it is said that Leibniz, one of the founders of Calculus, complained: "What a waste it is to spend so much effort and time doing additions, deductions, multiplications and divisions!"). We think that the discipline that teaches electronic computing can, and should, be employed to integrate the contents of other disciplines, simply because it lodges, as part of its purpose, a complete project: development of software. As a tool, creation of software involves specific studies for the final conception of a given program. The software industry puts in motion billions of dollars and is still complicated by the forensic dispute concerning the market takeover by some software producers. New tools and new technologies and paradigms involved in development of programs for computers have been created, aiming at more rapid performance, progressively more trustworthy results and larger capacity of handling information. Engineering students are not outsiders to all this progress and most of them do not bring the "Frankenstein complex" anymore, a drawback regarding computers that still haunts previous generations.

The necessity of modeling problems to find adequate solutions is shared by both computing and engineering. In fact, thinking about the whole, building up hypotheses, creating the system, dividing it into its components, understand each stage, specifying the construction, analyzing the interfaces and frontiers of the system and detailing each part are essential steps of any project, including producing software. Algebraic modeling, so elegant and so relevant during its golden days in Engineering, is being replaced in technical applications by numerical methods, that are becoming more and more efficient and fast.

There exists a necessity of great relevance for the utilization of the kind of integration we are hereby proposing: the professors responsible for each discipline and the Engineering Schools should adhere to the integration of knowledge. Evaluation of the students performance should include in every discipline the integrative aspect of teaching. Specific exercises should be adapted to the integrated approach, equipment and libraries should be modified accordingly, and the number of teachers working full-

time should be increased, allocating more time for the development of the integrated work.

Integrated teaching at the Mauá School of Engineering

The Discipline of Computing at the Mauá School of Engineering has already implemented a joint program to integrate teaching of the disciplines taught during the first year. Since 1996, we employed for this purpose some problems related to all day problems in engineering. One example is a problem of ballistic movements with and without autopropulsion, with and without variation of gravity acceleration as a function of position, altitude and latitude, what required from the students reasoning in which hypotheses that would simplify the problem be solved and analysis of the influence exerted by each situation or each new factor to be taken into consideration, all such experiences familiar to the engineers. Several concepts were developed and analyzed, from the physical factors involved up to the selection of numerical methods, as well as ordinary differential equations, differentiation and integration, changes in coordinates, significant digits etc.

A qualitative evaluation was possible by using as a basic parameter the research performed by the students in the library and the questions asked the teachers and student monitors to answer. An extensive discussion was thus possible among teachers and students, regarding the validity of the hypotheses that were advanced. Interesting enough, a turmoil was thus created among students, who fiercely competed for the priority of arriving first at the best solution.

In 1998 we intend to maintain this procedure, now using as a subject of integrated research the implosion of a tall building, Palace II, provoked in Rio de Janeiro. Obviously, discussions will focus from structural analysis to questions related to ethics and social consequences involved. Implosion is often considered a negative action of Engineering but this is a preposterous remark, inasmuch as it involves complex issues, from statics to virtuals in structural analysis, from security to material and the proper sequence of actions. A good knowledge of Statics (Physics), representation of the ground plates movements during the implosion (Vectors and Analytical Geometry+Dynamics) and released by the chemical reactions involved in the implosion (Chemistry), as well as integration and differentiation and approximations using Taylor series (Calculus and Numerical Calculus) and some knowledge on strength of material and theory of structures will be invoked by the Discipline of Computing. Since the latter disciplines will be taught in more advanced years, the lack of knowledge on these subjects will require simplification and approximations by using the hypothesis of iterative and "quasi-static" events, both tools of the utmost relevance in modeling in several branches of Engineering.

The success of this didactic experiment we are performing at the Mauá School of Engineering led us to believe that it was important for the proper preparation of the students. The change made possible by the vertical integration of other disciplines with Computational Methods (formerly Numerical Calculus) was very effective. Although the students are from the beginning properly directed to the modality of engineering in which they decided to practice their acquired expertise, and consequently their exercises are usually modality-specific, the integrated teaching does always require non specific creativity and individual effort in searching information and solutions.

We know it is difficult to evaluate how much interested the students become as a function of the hereby proposed training in creating, reasoning and searching appropriate theoretical solutions. However, we are quite sure that the method we are proposing is making the students much more aware of what they should do to be better engineers.