Reinforcing the teaching of basic sciences in undergraduate engineering programs and its correlation with teaching sciences of engineering

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Abstract: *Recently, in Mexican universities, there has been a drive to stress on the importance of offering a strong component of basic sciences in undergraduate engineering programs; not only as a matter of knowledge, but also as a way to improve the student's logical-deductive reasoning. Thus, emphasis has been made on contents of subjects such as chemistry, electromagnetism and advanced calculus.*

In particular, in the Division of Basic Sciences and Engineering of the Universidad Autónoma Metropolitana Azcapotzalco, a new plan was recently approved for the Basic Level (Tronco General), which integrates the first year (three trimesters) of the undergraduate engineering programs. A central aspect of this change was the reinforcement of basic sciences teaching.

However, is it correct to think that some of these topics should concern only the first stages of the studies as a cultural complement? Or should they be considered as an important precedent in the teaching of different subjects of the sciences of engineering, even in cases in which this practice was rarely usual?

In professional courses of civil engineering, for instance, when topics such as properties of construction materials or properties of soils and rocks are explained, usually the

teacher refers only to macroscopic aspects. Certainly it would be better to expand the basis of knowledge if these characteristics are explained starting out from considerations of the microscopic structure and chemical properties, a subject that was already introduced in the courses of basic chemistry. The same situation can be noticed in electrical and electronic engineering, where the electromagnetic properties of materials are often explained without considering their atomic structure. On the other hand, practically all engineering profiles need to find support on electronic instruments for measurements; it is important not only to teach how to use them but also to go into fundamental aspects of how the measurement is carried out in terms of basic properties of the systems involved.

A third example is found in the application of mathematical models, due mainly to the development of computers and computer science. It is relevant for the engineer to learn not only how to run programs but also to understand the equations that give rise to them. This paper is an attempt to emphasize the importance of giving continuity to the contents of several subjects, from fundamentals to applications, thus avoiding their organization as independent cells, even in careers that apparently do not need certain topics for their curricula. Some ideas are proposed.

Introduction

In recent years, quite an effort to increase industrialization has been promoted in Mexico, as well as the integration of the country to international associations related with commercial competitiveness (GATT, OECD, NAFTA). Federal programs, such as the National Development Plan, the Educational Modernization Program (PROMEP) or the National Program for Science and Technology 1990-1994, have already made clear that scientific research should be an important action for economic development. In addition, it is important to point out that the most important factors for activating foreign trade in developing countries, are no longer low production costs,

plenty of manual labor or natural resources; at present it is determinant for this purpose the ability for technological updating; that's why teaching, research and technological development are fundamental.

Some of the essential actions to obtain quality and pertinence in the development of qualified human resources, include innovation of substantive functions within institutions of superior education. It's necessary to update their professional programs or even to create new ones, in accordance with the present reality; as well as the application of new teaching methods; the improvement of the pedagogic skills in teachers, the interaction between teaching and research and, finally,

the link with the productive sector, as a strategy to strengthen education itself.
Regarding these ideas, the Division of Basic Sciences and Engineering of the Universidad Autónoma Metropolitana Azcapotzalco, 23 years after its creation, performed, during the last three years, different actions with the aim of evaluating its nine professional engineering programs. Internal, as well as external evaluation helped to identify strengths and weaknesses. The next stage, which is being performed at present, is to update the programs, and finally, a new action will be conducted for the certification of the professional programs as well as that of the certification of the graduates.
The engineering careers at this school, were designed from the beginning with great attention to basic sciences (mathematics, physics and chemistry). A basic block, namely the *Tronco General* was included as the first year of studies in the nine programs. This was a distinctive characteristic of this institution, while traditional schemes were followed by other engineering schools in Mexico.
The main objective of this paper is to emphasize the importance and pertinence of basic science in undergraduate engineering programs, not with the objective of providing a cultural complement but with the idea of giving the students a strong basis in this area in order to provide them with adequate continuity with the sciences of engineering and applied engineering. This may allow them to adapt better to technological changes and advances.

Equilibrium in contents of an undergraduate engineering programs

The basic sciences conform a group of subjects which are essential in undergraduate engineering programs. They are the natural precedent of sciences of engineering, whose orientation, specific for each branch of engineering, is in turn the fundamental educative core of the career. The third stage is conformed by the applied engineering subjects; this block is as important as the previous ones, but in a modern program it is not convenient to include engineering applications excessively. The important thing is that the student can learn how to apply the fundamentals of the sciences of engineering to the solution of selected practical problems.
Taking civil engineering as a case study, the student should learn the sciences of engineering to an adequate depth; in this case:

- fluid mechanics and hydraulics;
- soil mechanics;
- strength of materials;
- structure analysis;
- science and technology of materials and
- systems engineering

If at the final stage of the career, the student learns how to design and how to plan the construction of a specific work, for instance a road or a building, and later, during his professional exercise, he must deal with another, such as the construction of a bridge or a harbor facility, he shouldn't have any problem but experience; in fact, while he was a student he has learnt the fundamentals and the way to solve a specific problem, though not exactly the one at hand. A different situation is found when the student lacks some of the listed subjects; he will hardly deal adequately with a problem because he's weak in the fundamentals of engineering.
As an additional but very important complement, undergraduate engineering programs should include social-humanistic subjects, so that the future engineer is increasingly aware of the problems of the society he is endeavoring to build and the environment in which he will develop as a professional. It is important to consider that it is not enough to transfer knowledge to the student but he should also develop skills and attitudes; for this purpose, humanistic education is quite important. It is true that the student has done some learning in these contents in high school, but certainly with a different degree of maturity, and a basic one if anything.
Finally, the addition of complementary subjects to the programs, such as computer and information sciences is quite useful and an important support for essential contents.

The link between basic sciences, sciences of engineering and applied engineering

Continuity requirements between basic sciences and sciences of engineering are evident and there are many examples to be cited. Regarding the already mentioned example of civil engineering, courses of statics were always based in elements of basic physics and hydraulics is based in fluid mechanics, which rests in mathematic demonstrations that employ differential calculus and analytic geometry. In classic textbooks of fluid mechanics, for instance, practical formulas are deduced either by differential analysis (Euler equations) or by integral analysis (conservation principles applied to control volumes).
However, in teaching sciences of engineering, it is usual that the mathematic tools learnt by the student, are only applied in theoretical expositions and less in the resolution of problems. There exist textbooks on differential equations with engineering applications, with dozens of problems of engineering solved with the use of differential equations; instead, in specific engineering textbooks, problems are usually solved only with very simplified formulas.
Moreover, in traditional programs of civil engineering, mathematics and physics have always been present, but not always chemistry. Due to the advances and modern trends in the formulation of engineering professional

programs, it is more usual to find chemistry as part of those programs at present. However, that science is included only in some cases as a complementary subject without a link to the sciences of engineering and much less to applied engineering. It was already said that in the school that the authors represent, chemistry was included in that career and in others, as part of the basic block of subjects known as *Tronco General* . However, is has not been uncommon that civil engineering students wait almost to complete their studies to credit this subject. Is this correct? Should this problem be solved by means of an administrative regulation? Perhaps it is more adequate to design the programs in order to attain more profit of chemistry for the integral education of the student, with a real link with the sciences of engineering. Chemistry and basic sciences in general are not a cultural complement but a truly important basis in order to get a versatile and open-minded professional, able to adapt to scientific and technological innovations as well as social changes.
The following are some examples in which themes of sciences of engineering, generally included in civil engineering undergraduate programs, could be imparted with more support of basic concepts of chemistry:

Properties of construction materials

When this subject is faced, generally properties are explained from a macroscopic point of view, without considering their relation to molecular structure. Properties such as surface hardness, strength, elasticity and resilience must be understood considering the microscopic point of view.

Concrete hardening

Themes such as hydration reactions of cement substances, heat liberated by a chemical reaction, the kinetics of reaction and formation of micro and mesoporosity are aspects with close relation to such phenomenon.

Construction steel corrosion and its prevention

Severe economic losses are due to corrosion of metallic construction materials; degradation of industrial systems as related to various forms of corrosion can be traced in various catastrophes that have occurred in the past. Then, prevention methods can be incorporated in design tasks, on consideration of the basic principles that derive from the chemistry and physics of the systems involved, where a very large variety of steels play a principal role in the construction of industrial plants.

Steel deformation and breakage

The different phases of the deformation of steel in elastic and plastic state have a correlation with the steel's crystalline structure. It's interesting to explain the initiation of breakage due to the defect structure in crystalline metallic materials.

Properties of iron and different types of steel

It is important that the student understands the chemical structure of steel and the incidence in its properties depending of the incorporation of carbon, and several other alloying additions.

Properties of clays

Clays are very important in civil engineering; as a foundation material, as a sediment but also as a drilling mud. As well as in the other examples, properties of clays, such as expansion and plasticity can be explained considering its particular molecular structure, which is different depending on the clay type.

Rheologic phenomena

Civil engineers are aware of the problem named *creep*, this is the deformation of materials after long periods of time, but they generally ignore the link between this phenomenon and the crystalline or amorphous structure of the materials.

Presence of water in soils

To dry a soil sample in an oven is a common experiment in soil mechanics laboratories. But it is important for the student to know that water is incorporated in the soil in different ways, including the crystallization water, the isolation of which is practically impossible, without giving rise to other significant changes in properties.

Incrustations in pipes

The chemistry of waters, whether recirculating or natural, is a fundamental aspect to be cared for, as a decrease of the cross area for appropriate flow control is of paramount importance to the efficiency of water distribution and recirculation systems.

Conclusions

As expressed in the examples, reinforcing basic sciences in undergraduate professional programs should refer not only to include new subjects, but also to strengthen the link with sciences of engineering. From a pedagogic point of view, the student should learn well rather than learn much. One way of achieving this purpose and getting a more permanent learning is to apply the acquired knowledge to the learning of other subjects. This practice will help the future professional, because he will get a solid basis, general and specific for his

career, in order to make him able to work and develop in a world characterized by constant changes.

The examples given mostly refer to contents of chemistry in civil engineering programs, but there can be found analogous cases in other careers.

Finally, another fact that must be considered is the importance of basic sciences in the development of reasoning abilities; an exercise that should be taken at every step of the professional education.