Proposals for the Didactic Innovation in the Engineering of the XXI Century

***Abstract*– The teaching of current engineering requires urgent changes, there are several situations that have degraded the quality of it, among the most damaging factors is the creation of new careers without sufficient infrastructure, lack of laboratories, curriculum overloaded with scientific topics and little specialty contents. However one of the worst factors is the lack of experienced teachers, since universities compelled by the need to compete within current standards, hire young professionals with postgraduate studies (Credentialism), but without professional experience or experience as teacher, so that in many engineering careers, there is a team of teachers, who only do theoretical decency and in many cases with low quality. This type of teachers only repeat what they received as students without having gone through the demanding requirement of extra-university career life, as was done in the past, when teachers were hired in universities, from professional field with enough experience regardless of the possession or not of postgraduate level.**

This paper analyzes these conditions and proposes some solutions to correct the didactic deficiencies that are affecting many institutions throughout the planet.

***Keywords*—Teaching, credentialism, engineering, education, simulation.**

I. Introduction

There is ample evidence that engineering education in various countries is in crisis [1] [2] [3], many graduates report that most of the content they received in their careers do not apply in professional life, they also indicate that many professors are people disconnected from the specialty and unable to answer questions of practical and concrete issues, that their explanations and applications in exercises, are purely theoretical, as well as other criticism about bad teaching. The above condition has various explanations, one of which is the fact that universities are currently competing for indicators, one of them is the level of education of their academics, so it is preferred to hire young teachers with postgraduate degrees, even if they have little or no professional experience, (concept known internationally as "credentialism") [4], instead of experienced professionals to make teaching more efficient. Credentialism can be important in certain disciplines of human knowledge, but it is inadequate in engineering, since it is established that the best teachers [5] are people with professional experience of many years, although they do not have postgraduate titles.

Even systematic reviews have been made to the specialized literature, seeking to answer the question whether the teaching of engineering in the world is or not in crisis [6].

Other causes of the deterioration of education have to do with the lack of laboratories, the curricular structure loaded with abstract scientific subjects and low content of applications to the real world of productive or industrial problems, and in general the low link between university classrooms and work reality.

This paper contains various proposals to overcome the shortcomings of current teaching in engineering.

II. Common Problems of Teaching in Engineering

A *Lack of sense of reality of teaching*

There is very little link of the didactic contents delivered by the university with the applicability in the professional world, this phenomenon has as its main cause, the disassociation of the teachers with extra-university professional tasks, so that teachers who have not practiced what they studied, are unable to criticize the validity of the texts they use and their contents.

For some authors [2], the lack of updating of many teachers, led to carry engineering studies as if it were to train doctors or scientists, with a tendency to theoretical digressions and theorem demonstrations, situation very different from the reality of engineers, knowing that the mission of an engineer is not to solve intricate theoretical problems, but to achieve concrete results, where the economy, innovation, efficiency and sustainability are present in a relevant way.

B Failure to deliver true competences to students

At present it is necessary to be clear in the fact that the teacher is an enhancer of the abilities of the students, it is established that the knowledge (are delivered), the abilities (are discovered) and the skills (are enhanced).

The modern professional not only needs to be a specialist in his own discipline, he also requires other skills and peripheral professional competencies, necessary for interaction with their peers and with other types of professionals, since currently the processes and projects are not only they execute in a restricted scope, on the contrary, more and more it requires the concurrence of diverse hard specialties and many times the professional in his daily work, must use other specialized knowledge of the so-called soft skills, such as the ability to obtain and manage financial resources, the ability to coordinate the work of various professionals towards a same purpose, the ability to motivate and engage to subordinates, the ability to clearly expose projects and results [7].

III. Importance of Laboratories in Didactics

Laboratories have been used as an important learning resource, a necessary bridge between theory and actual practice. Practical and laboratory activities constitute a distinctive feature of the teaching in science and technology [8]. In both engineering and science, teaching should tend to consolidate knowledge, to demonstrate concepts, theorems and laws in a clear and definitive way for students. It is not enough to explain the theoretical and perform corresponding mathematical exercises, it is essential that the student, at least in a first stage, is able to check practically each of the most important scientific laws and thus be able to definitively consolidate the fundamental concepts, this It is possible using the didactic laboratories especially built for that purpose, however in the current engineering it is required to take a step further, it is necessary that the students are able to make own creations of topics related to their future professional performance, for that reason the teaching modern must tend to train engineers capable of creating [9] technologies in all its manifestations, software, equipment and devices, systems, sets of modules, which correspond to the disciplinary area that each university career represents.

The didactic laboratories used in almost all the universities, are created by specialized companies that manufacture them in such a way that they allow to develop demonstrative experiments of laws or verifiers of scientific and technical concepts, which is fundamental in the engineering, This type of laboratories are useful so that the student can consolidate in their brain what he studied theoretically and that many times he does not fully understand only with theory. However, these laboratories are not sufficient for the formation of a creative and innovative professional, it is required that in addition teachers encourage students to create their own instruments, equipment or systems, as close to reality as possible, given that once graduates should be able to work precisely in the creation of new products within their specialty. An electronic engineer must be able to design and build circuits and equipment, a computer engineer must be able to design new algorithms and software, a biomedical engineer must be able to create conventional medical equipment and also innovative devices and so each specialty expects its graduates have the right skills to be creative and productive. This is achieved to a great extent, providing universities with different types of laboratories that encourage such creativity.

At the same time, the didactic material that can be used allows the student to have interactive multimedia resources, which constitute a complementary tool for the development of their courses, suitable to acquire certain knowledge and skills more easily [10]. The methodology of work with the students must be designed so that the student will be reflective about the reason for the activities he carries out, so that he has a greater and better knowledge of the process and the result; and taking advantage of new technologies, a more interactive and attractive teaching is established for him and with high degree of participation. Another advantage of this model is that the student has access to this material at any time.

There is an abundant bibliographic production on laboratory practices; some considered as traditional, as well as those that are innovative [11]. In the latter, its main objective is to develop skills that enable students to formulate questions, systematize information and analyze, including activities that generate significant learning, developing factors such as teamwork, motivation, self-efficacy, and good use of ICT (information and communication technologies).

IV. Promotion of Creativity, Design and Construction as Part of The Study

The modern world is saturated with technology, all human activities, from the industrial production, communications, health and even entertainment, are provided with devices, electrical, electronic, mechanical, fluidic, computer or composed of a combination of these disciplines, so that today engineers can not reduce their activity only to the concept of users, it is required that professional training be focused on the creation of technology, going beyond the management of it.

This is possible, if in the training of engineers the didactic and the use of its resources are organized to encourage creativity and the approach to the solution of problems; the today engineer, must be an agent of transformation through innovation and the search for new ways of doing things, that encourage saving of resources, simplicity of designs, usability, ergonomics and the environmentally friendly policy.

"In some professional disciplines such as Medicine or Engineering the student is required to graduate having reached the top of the Miller's pyramid, it is not enough for him to know how something works, or how to demonstrate it, he must be able to create or modify it" [12], as shown in Fig. 1.

These new paradigms are an essential part of modern education, and should be assumed by those who teach technological disciplines; Engineer of the 21st century must be an empowering professional of creativity, with ability to work in a team and provided with tools obtained during his training at the university.

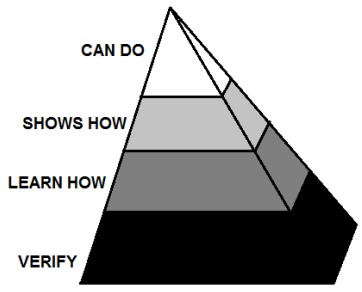

Fig. 1 Miller pyramid of learning.

A. *No to credentialism, more application than abstract theory*

All activity of the graduate engineer in the real world must correspond to the theoretical studies, however this concept is not always valid, since many times the curriculum of a career is saturated with topics somewhat divorced to the specialty itself, this causes graduates find in their professional work, aspects never seen in the university theory, causing incompetence, disappointment and in many cases frustration, to avoid this it is necessary that the academic training be accompanied by several practices in companies or institutions highly related to engineering that it is studied, allowing that the topics realized in practice be feedback to teaching and introduced as didactic contents. In this way the dynamic curricular structure will be modified in order to satisfy the real requirements of the working environment in the professional world.

The inexperienced teachers, those who stayed at the university that formed them, develop a form of institutional "endogamy" that demerits their knowledge, since by not enriching with extra-university practice what they studied [13], they do not accumulate new experiences and end up teaching less knowledge than they learned and transmit lower quality and quantity than what another docent one gave them. This cycle is disastrous for professional training and unfortunately its consequences are verified after a certain time, when remediation is not always viable and much less immediate.

B. *Intensive use of didactic simulation*

The human being is able to retain: 20% of what he hears, 40% of what he sees and hears, 75% of what he sees, listens and builds, this highlights the importance of practical theoretical learning through the use of laboratories, however not always is possible to acquire laboratories for all subjects, so the use of didactic simulators is revolutionizing teaching by becoming excellent substitutes for real laboratories. Nowadays it is possible to make computerized laboratories that allow you to carry out experiences very close to what can be done with real equipment.

At present, many teaching activities in scientific subjects use different types of simulators either to substitute high-cost real equipment, systems or instruments, as to save consumables and replicate as many times as possible an experience, additionally, in health disciplines, has reduced and almost eliminated the use of animals for teaching purposes, since the simulators provide an adequate teaching without environmental damage or sacrifice of living beings.

V. Our Results

In the field of Biomedical Engineering, our university uses various simulation systems to optimize teaching, some are commercial products that have been purchased to deliver to students, others are our own developments, arising from the need to implement more advanced teaching aids in critical issues.

The developed simulators allow to emulate as closely as possible, the operation of the real equipment, so that students have a very useful didactic tool at a very low cost compared to the professional medical devices. So we have created a radiological generator simulator, designed and built with materials available in our country. It is intended to teach to obtain x-rays images with correct parameters [14]. Also a haptic and virtual ultrasound simulator that positions images on a screen, obtained on a human heart emulator torso.

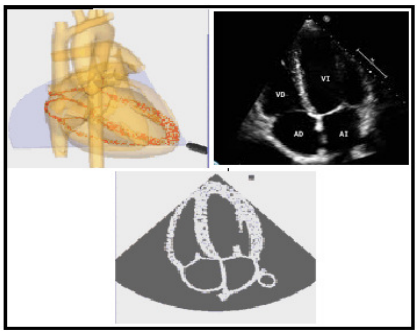

Fig. 2 Our echocardiography simulator.

The echocardiography simulator presents dynamic real images and their corresponding simulation, from all possible exploration planes, as shown in the Fig. 2. The Fig. 3 shows a didactic system used to teach about electro-medical installations, with different options, including connection errors that can be placed, this system is used to teach how to detect and solve several faults. Other equipment simulates the behavior of a lung, showed in Fig 4, used to test and calibrated different types of professional servo-ventilators.

A unique system that simulates a medical gases installation, allows teach, all possible ways of connection of medical gases and its most common faults.

At the same time, other commercial simulators are used to teach electrocardiography [15], vectorcardiography, anesthesia [16], servo-ventilation, electrophysiology, cardioversion [17], laparoscopy and other specialized disciplines in the field of Biomedical Engineering.

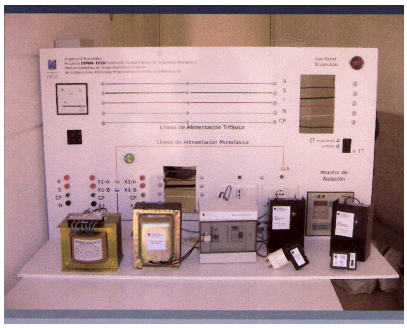

Fig. 3 Electro-medical installation trainer.

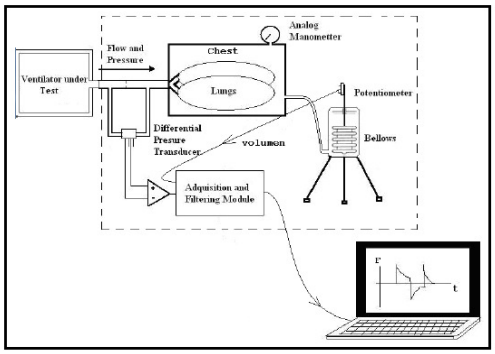

Fig. 4 Artificial lung to teach Servo-ventilation.

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