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Analysis of the impact of Medical Technology Assessment Subjects on BME Curricula

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Abstract— **This paper presents and analyzes the factors that have arisen on the implementation of the medical technology assessment and management courses, and the academic methodologies used to deal with them. Five courses that cover topics as Technology Management, Health Economics, Quality Assessment, Innovation and Entrepreneurship were designed as electives for BME curriculum and have been taught for the last two years. The activities carried out within the courses are described and their impact on the comprehension of the course contents are presented. Also, several elements and factors pertaining to the teaching-learning process are discussed. Future perspectives for the students that follow this sub-specialty branch of the BME curriculum are presented**

I. Introduction

In Mexico the Bachelor's degree in Biomedical Engineering started to be implemented in the mid 70s at two Universities (Universidad Iberoamericana and Universidad Autónoma Metropolitana) and is now being offered in twenty-five institutions. For historical reasons the main orientations or "branches" were Medical Instrumentation and Clinical Engineering. With regard to the current Biomedical Engineering (BME) curricula being offered, there is a growing interest to incorporate issues related to the context of the health devices are involved in. The need to provide an integrative vision and a proactive approach that will promote the optimal utilization of technologies in health care systems has become a general concern among those interested in a BME career within a healthcare institution. Some important events have led to this situation.

The World Health Organization has developed a series of documents as a result of initiatives on topics related to medical technology. Some examples of this kind of work are: hospital safe from disasters [1], patient safety [2] or medical devices [3]. In Latin America, the Health Agenda for the Americas 2008-2017, promoted by the Pan American Health Organization (PAHO), has pointed out on how important the integration of a scientific approach is in the decision making processes, as well as on the reinforcement of the necessary skills to carry out this function through the use of suitable knowledge [4]. In Mexico, the National Health Plan 2007-2012 established that technological health innovation and research had to be reoriented in order to conform a strategy that dealt with emerging health problems and non-communicable diseases that primarily affect the Mexican population by supporting the technological R&D activities [5]. The official Mexican agency that deals with Health Technology assessment, the National Center of Heath Technology Excellence (CENETEC), tries to organize the efforts around these topics, but the size of this task is huge, complicated and sometimes unclear and CENETEC's resources are very limited.

From the academic point of view this presents an opportunity to provide the Health System with B. E. graduates that are qualified in Technology Assessment and Management under the context of health care. The BME academic program at Universidad Autonoma Metropolitana (UAM) has included a number of courses that have been designed specifically to fulfill this goal. The courses have incorporated topics related to quality, economics, entrepreneurship in addition to medical technology management, and were described in a previous work [6]. Although the specific topics to be studied in each course have been specified, the teaching and evaluation modalities, as well as the capabilities for getting the students' interest, have proved to be a challenge for the professors that teach these subjects. This paper presents and analyzes the factors that have arisen on the implementation of the medical technology assessment and management courses, and the academic methodologies used to deal with them.

II. Subjects on Technology Assessment and Management and their Academic Approach

In 2010 a set of new courses dealing with Health Technology Assessment, Total Quality, R&D and Health Economics was designed since it was felt that this branch of the BME discipline was promising in Mexico and there were very few professionals in the field with adequate qualifications to teach them. Some of the courses were tested as elective subjects to monitor the alumni interest in the previous scholastic terms. A brief description of each course and their teaching methods is presented next.

A. Quality Analysis in Biomedical Engineering

In this course a study of the most frequently employed total quality models as well as emerging methodologies is carried out with the aim to define the set of elements that define a quality model that can be applied to the biomedical engineer's activities. The student has to read a set of publications in order to discuss in class the most relevant aspects of the model and how these could be incorporated into the biomedical department's functions. An introductory

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lesson on basic quality concepts and biomedical engineering aspects related to quality is presented at the beginning of the course as a motivation for the study. As there is no literature that covers the topics exactly, several examples on the application of the models and concepts are taken from other fields: automobile and aircraft industries seem to be the best cases for the understanding on how to implement a quality model. Exercises of theoretical scenarios on BME carried out in the classroom complement the lessons. The evaluation consists on research homework as well as the development of a project at the end of the course where a proposal of a quality program for a function of the BME department must be reported and presented.

B. Medical Technology Management

This course focuses on the study of health management from the point of view of the concept of technology, and on the application of the theory to the adoption of technology in a health care institution by the use of case studies. With regard to this field, many interesting handbooks and official documents can be found that explain the general management procedures and show examples for a variety of medical technologies. The didactic strategy consists on the presentation of cases by the students and the following discussion. Information on previous research, not only on the principal topic but also on the context around the case, are emphasized in order to make the student understand how important is the integration of all the aspects involved in the problem and the effect of the results of management on the healthcare system. The homework and projects are dedicated to analyze how the methods can be applied to particular cases and to clarify the role of a BME in management tasks related to medical technology inside the hospital; sometimes the presence of a professional BME reinforces the ideas. The consultation of multimedia content and proceedings of health care assessment congresses has been helpful to complement the study.

C. Innovation and Entrepreneurship in Biomedical Engineering

This course has the purpose of reinforcing the idea that the areas of design and development within the scope of entrepreneurship are more promising than those oriented to maintenance and service types of jobs (which has been an oft-treaded path). The course is based in teaching the phases of an innovation process as it relates to the BME field. Some important sections of this course are:

- Identification and characterization of a measurement process
- Identification and definition of innovation processes
- Modeling of medical instrument requirements in relation of the measurement process
- Identification and evaluation of medical instruments through their dynamic characteristics
- Learning how to use engineering documentation and statistical analysis.

It is based on the experience of several faculty members with the development of novel medical devices and industrial-academic relations, including cases of technology transfer. It is expected to be able to reproduce a series of industrial-academia cooperation agreements and a successful outcome for this course would be the establishment of spinoff companies.

D. Introduction to Health Economics

Recently, the economic aspect has become extremely relevant to the decision-making processes related to the incorporation of medical technology into healthcare institutions. Although it is clear for all that economic factors are very often the principal limitation for the selection of the devices, there is a lack of certainty on how to proceed when this aspect arises at the hospital. This course is a first approach to the health economics field; it involves the analysis of economic principles such as resources, scarcity and free market, and their application to the health care systems. Emphasis is presented on cost analysis, cost-benefit and cost-effectiveness, and on the relationship between the health status and the economic situation of the country. Readings are the most important element; national and sector health plans as well as Organization for Economic Cooperation and Development (OECD) reports are part of the required reading documents for the course. The homework is focused on the development of the student's critical point of view as these issues will directly impact them on an everyday basis when they are required to act as professionals. Although it is an introductory course, exercises devoted to carry out economic analysis for health situations that involve medical technology and a final project that aims to propose solutions to a specific health situation are developed in order for the student to appreciate the opportunities for a professional career in this sub-specialty.

E. Professional Practice

This course seeks to reinforce the engineering experiences and skills of the students by getting them in touch with working teams in biomedical industry that are developing or modifying equipments and systems. The academic procedures to carry it out and the course evaluation are quite different compared to the other subjects. The student must get involved in a specific project proposed by the company and approved by the professor in charge. The objectives and the course of action are first established, and the student's progress is continuously monitored by means of a logbook of work done. At the end, a presentation of results is made in the presence of the academic and industry advisors.

III. IMPACT ON THE ACADEMIC TRAINING OF THE STUDENTS

All of these subjects are electives and have been taught at least once per year; course scheduling depends on the professor's availability (sometimes he/she is on sabbatical leave or teaching a required course), the student demand (courses with a few applications are closed) and the opportunity for visiting professors to propose specific courses. Figure 1 shows the distribution of the subjects' demand, clustered by theme, for the 2009-2010 academic terms; technology assessment & management subjects had not been approved yet.

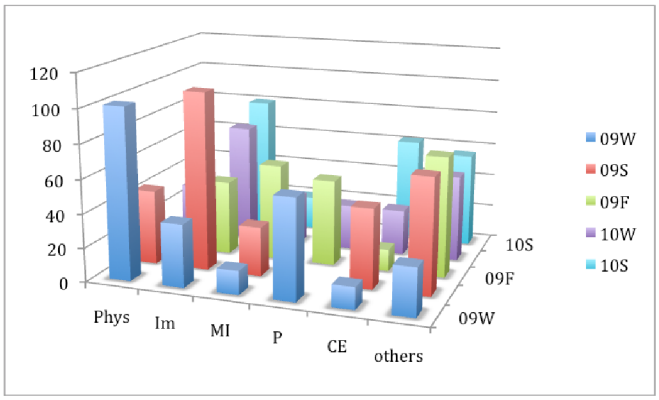

Figure 1. Demand for each one of the thematic elective subjects per academic term. Phys: Physiology, Im: Image Processing, MI: Medical Instrumentation, P: Programming, CE: Clinical Engineering. 09W: Winter 2009, 09S: Spring 2009, 09F: Fall 2009, 10W: Winter 2010, 10S: Spring 2010.

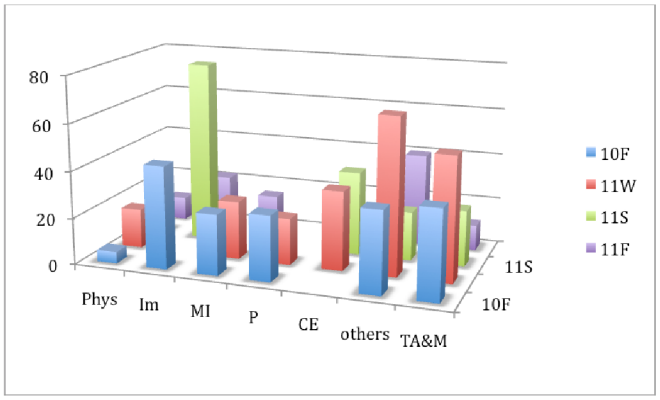

Figure 2. Demand for each one of the thematic elective subjects per academic term. Phys: Physiology, Im: Image Processing, MI: Medical Instrumentation, P: Programming, CE: Clinical Engineering, TA&M Technology Assessment & Management. 10F: Fall 2010, 11W: Winter 2011, 11S: Spring 2011, 11F: Fall 2011.

It can be seen that the subjects that are the most demanded by the students are Physiology followed by Image Processing and Programming. The Technology Assessment & Management subjects were officially offered in the third term of 2010 and they became a high demand group during the 2010-2011 academic terms, together with Image Processing and Others, as it can be seen in Figure 2; this last group of subjects included novel themes such as Biomaterials and Nanotechnology. It should be noted that each student may request up to 5 elective subjects for each term.

Several activities were carried out during the courses and they had different impact on the learning process. Table 1 shows the type and number of activities that the students had to develop in order to successfully complete the courses. Readings are the most used type of activity followed by reports and analysis homework.

Although there is at least one reference for consultation, and these are mostly books, the publications are updated as new technology advances, and quality issues and quality methods are published, so the same course does not have necessarily the same readings every time it is taught. All the subjects included individual and group projects and at least one lecture from healthcare professionals. Essays were used to incentivize a critical and reflexive point of view in the students and Health Economics seemed to be the best topic to initiate analysis and discussion sessions in class.

TABLE I. ACADEMIC ACTIVITIES PERFORMED IN THE MT&A COURSES

	Readings	Analysis	Reports	Project	Research	Essays	Lectures
QA	17	5	8	1	2	0	1
TM	20	4	5	2	2	0	1
HE	19	3	3	1	4	2	1
IE	5	6	2	2	0	0	1
PP	4	0	5	1	0	0	1

QA: Quality Analysis, TM: Technology Management, HE: Health Economics, IE: Innovation & Entrepeneurship, PP: Profesional Practice

It was found that students had difficulty writing essays, which were often confused with abstracts; the students were not able to write a reading report without including direct information from their sources. This means that they had difficulties in grasping concepts and synthesizing information from different sources.

Another inconvenience that was encountered was the difficulty in comprehending the scope of these projects where in some cases what seemed to be a promising idea didn't fulfill the expectations. On the other hand some research and capstone projects have turned out to be opportunities for professional development. It has turned out that after some of these projects were concluded, graduates were able to continue their studies at a graduate level, get a job in health care management or even create their own R&D and consulting firms.

IV. DISCUSSION

The introduction of these technology assessment and management subjects is not easy for students from the engineering disciplines, as they are more focused on solving specific problems and not dealing with more diffuse goals as improving health care or maximizing the use of monetary resources. BME students have probably not been introduced to these types of problems before that in a way are more complex since there are social and political issues to consider as well as the measuring of impact of these on health indices.

This area presents the teachers with previously unknown issues. For example, there might be a difficulty in explaining concepts because students have not been exposed to this kind of thought before. This can be either a challenge or an opportunity to enable the students to analyze different types of evidence and to be able to carry out analysis at a more profound level. Some teaching resources that may be useful in these courses are simulation and modeling tools that can be used first so simulate simple scenarios that can later be scaled up and be made more realistic. Our experience shows

that faculty and students of Economics Departments use only the basic functions of some tools such as TriagePro but students and faculty with an engineering background can exploit the capabilities of this type of software more fully.
In general it can be said that the type of work carried out favors a more dynamic approach to teaching, it is well suited to multimedia techniques, and allows the use of real information.

A series or groups of these electives can be taken together to reinforce different sets of themes within the curriculum. For example: Health Economics can be paired with Quality Systems, Innovation with Professional Practice, Clinical Engineering Programs with Hospital Practice or Management with Clinical Engineering. This approach of pairing the electives has several advantages: in the first place, some subjects are not well contextualized when taken independently. It is customary for the Health Economics courses to be taught by professors in the Economics Department who have experience in this field, but for BME students, the understanding of the issues involved in this subject is difficult, but when a course on Quality Systems is taken concurrently with Health Economics, there is melding of ideas and examples that can enable the student to profit more from the courses.

The experience two years after the new courses have been offered has been mostly positive and some examples of this are:

- The acceptance of this series of courses by the students and faculty dedicated to the field of clinical engineering, where now several tasks that were carried out empirically are now undertaken using specific methodologies taught in these courses.
- An increased interest in subjects and projects dealing with health economics where project participants have to deal with different sorts of criteria in order to propose an optimal solution that is not simply based on fulfilling the design criteria of an experiment but has to take factors as diverse as costs and society's response among others. Some examples of this interest have been the increase of the number of capstone projects being proposed in this sub-discipline, and even the recent-graduate's founding of consulting firms.

In conclusion, the results regarding the teaching of these series of electives has been very positive as it has allowed the students to evaluate the impact of their work beyond the engineering or workbench aspects of their jobs. They are able to assess how their products can have an impact on the economy and the health system, not solely focusing on the engineering merits or the financial gain of their work.

Finally, these subjects have provided opportunities for the development of new competences for professionals that choose the field known as Clinical Engineering.

It appears that graduates with these qualifications have advantages taking this approach when dealing with Health Technology Assessment in comparison to people who come into the field from the economics or medicine professions.

Circumstances have dictated that groups of these professionals have needed to convert from their typical management tasks to more complex decision-making positions without adequate training. Recent graduates with this new background will be able to competitively seek positions inside the Health Ministry at a higher level,

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