Biomedical Engineering Curriculum at UAM-I: A Critical Review

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Abstract—**The Biomedical Engineering (BME) curriculum at Universidad Autónoma Metropolitana (UAM) has undergone at least four major transformations since the founding of the BME undergraduate program in 1974. This work is a critical assessment of the curriculum from the point of view of its results as derived from an analysis of, among other resources, institutional databases on students, graduates and their academic performance. The results of the evaluation can help us define admission policies as well as reasonable limits on the maximum duration of undergraduate studies. Other results linked to the faculty composition and the social environment can be used to define a methodology for the evaluation of teaching and the implementation of mentoring and tutoring programs. Changes resulting from this evaluation may be the only way to assure and maintain leadership and recognition from the BME community.**

I. Introduction

This work deals with a critical assessment of the evolution of the Biomedical Engineering (BME) curricula from the founding of the BME program in 1974 up to the present. The aims of the program as well as its structure have been in continual evolution, and we believe it's appropriate to evaluate the results of the program as we face our fourth decade as educators in this discipline.

Although there have been constant minor modifications to the program throughout the years (11 changes in all), there are four distinct programs that can be identified:

A. 1974-1979
B. 1980-1995
C. 1996-2005
D. 2006 to the present

Program A was somewhat improvised. It was research oriented and was characterized by proposing two branches in the curriculum: Engineering Applied to Physiology (EAP) and Mathematics applied to Physiology (MAP). In essence it tried to stress the fact that BME needed to be taught and applied as a multidisciplinary discipline. Core subjects were taught concurrently by physiologists and electrical engineers with medical instrumentation backgrounds. In the end it had good but limited success, as the MAP subjects were difficult to carry out adequately in a pre-PC era, and collaboration with physiologists and M.Ds proved to be very resource-intensive.

Program B proposed three main branches of BME, and the student was to choose among them according to her preferences: Biomechanics (a group of four PhDs in biomechanics was hired in 1980), Medical Instrumentation (derived from the EAP subjects and electrical engineers) and Clinical Engineering (derived from the pressure to give maintenance and technical support to the growing Medical Engineering infrastructure in Mexican hospitals). It was not primarily a research-oriented program. It tried to address the lack of technical resources in institutional health care facilities.

Program C was derived from the interests of half a dozen faculty members who had recently returned from postgraduate studies and who wanted to incorporate signal and image processing in addition to pattern recognition into the curriculum. The approach was to increase the course load or number of credits to add these disciplines to the regular instrumentation branch in program B. Due to a financial crisis in 1982, all of the biomechanics faculty left UAM in order to work abroad, so this branch was dropped when program C was approved.

Program D was established as a bridge between a heavily Electrical Engineering (EE) oriented program and the new emerging disciplines in biomaterials, nanotechnology and entrepreneurship and innovation. It replaced most of the required instrumentation subjects (7 in all in the original Program C) with a cloud of electives that were more in accordance with the Basic Sciences and Engineering Division's research units that were working in fields related to BME.

When these programs started, there were very few BMEs in Mexico. In particular, at UAM, at the time of Program A, there was only one professor with a PhD and two with M. Sc. degrees in BME. The rest of the faculty was made up of EEs who had experience running or maintaining medical technology in addition to doing some design. In particular at UAM there were some successes in medical instrumentation, pharmacodynamic and cardiorespiratory modeling. The situation was very similar at Universidad Iberoamericana, where a BME undergraduate program was initiated at practically the same time.

It was until the early nineties when recent Ph.Ds and M. Sc. graduates were incorporated into the faculty that significant research oriented activities were started. At present the BME faculty is made up of over 75% of PhDs, 20% MSc and 5% engineers.

It is important to note that there have been external and internal forces that have changed the characteristics and conditions of the teaching-learning process at UAM:

Internally, teachers have become more academically qualified while nationwide, high-school educational quality has diminished substantially, starting in the eighties (the start

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of one of at least three economic crises). At present, according to PISA, Mexican high school students have an educational handicap of over two years with regard to the average OCED educational levels, in the mathematics, science and reading comprehension areas. So presently, at UAM we are basically asking 9th grade engineering students to pass subjects taught by Ph.Ds. from the theoretical mathematics Department.

The aim of this study is to evaluate the performance of the different BME programs over the years considering the social and political environment at the time as well as the strengths and weaknesses of the BME Department for the duration of the different programs. We believe that these studies will help explain different outcomes of the programs and will aid us in avoiding the same mistakes while at the same time helping us in the design of new curricular initiatives.

The results of this study allow us to come to several conclusions, which will be important to devise a path for the amelioration of the education processes and policies and the improvement of the curriculum in the near future. This paper presents the results of recent reorganizations of the BME curriculum together with an analysis of future directions that may be needed to be taken in order to reorient the program towards these new emerging sub-disciplines[1-3].

I. Methods

Our study was based on the institutional (AGA) database containing records from all of the 5287 registered students, starting with the first generation in 1974 up to the present. This database contains information such as the status of the student, number of credits taken, time taken to graduate, grade point average, and grade of the entrance examination. Student records were grouped into the different programs, A-D, and the following information was obtained:

- Number of credits in each program
- Average graduation rates.
- Relationships between: entrance exam grades, GPA and time to graduation.
- Graduation rates overall and at the end of four, five and six years.

At UAM the time limit for graduation from a Bachelor's degree is twelve years (ten years plus a possible two year extension which is almost always granted). We believe that this is a very questionable policy when taken in the context of institutional costs as well as for the benefit to society. We believe that graduation rates are affected by these policies since students may be tempted to "follow the path of least resistance" and to sign up for subjects only at the time when a teacher who is considered to be less strict is scheduled for several “hard” courses. In this study the selection of a segmentation of the graduation rates into durations of 4, 5 and 6 years is designed to follow a student population through more "normal" or "expected" graduation times.

II. Results

From the AGA database the global numbers for the BME students enrolled since 1974 are the following:

- Total number of students: 5288
- Total number of graduates: 925
- Students discharged by request: 671
- Students administratively discharged: 3516.

Students discharged by request are dropouts that officially requested to leave the University; Administrative discharges means that the students could no longer remain in school because either

- They failed the same required subject 5 times
- They failed courses 12 times during their first year
- The students failed to finish the curriculum in the allowed amount of time (10 years plus a two year extension).

So globally this means that out of over five thousand students, only 17.5% finally graduated and it could have taken as long as three times the programmed amount of time!

In particular, from the same databases table 1 shows results from the different programs: A to D.

Program	A	B	C	D*	Totals
Year	74-79	80-95	96-05	05-14	
Graduates	99	480	315	30	924
Registrations	323	2742	1210	1010	5288
Grad.Rate %	30.65	17.50	26.03	3	17.5
Total Credits	503	533	541	541	

Table 1. Number of graduates for the different versions of the BME program as well as the number of credits required for each program. *Program D data is incomplete as very few students have graduated.

Likewise, table 2 shows the results of the graduation rates (in percentages) of the different programs for four, five, six and over six years.

Program	A	B	C	D*
4 Years	22.6	1.4	6	20
5 Years	34	12	15	50
6 Years	22.6	21	20	10
Over 6 years	21.5	65	59	20
Total Credits	503	533	541	541

Table 2. Graduation rates for different programs at the end of 4, 5 and 6 years of study. *Program D data is incomplete as very few students have graduated.

III. Discussion

There are several factors that are revealed upon the analysis of the data, and others that require additional information:

From the analysis of table 1, there is no doubt that the most successful program is the original Program A, which has a graduation rate of 30.65%.

Program B appears to be the least successful of all, with a global graduation rate of 17.5%, while program C appears to have a reasonable graduation rate.

However, these numbers do not reveal an important problem: graduation rates are taken in their totality, and the permissiveness of the system allows very long graduation times. Table 2 shows this phenomenon: For program A, almost 80% of the graduating students did so within 6 years, while this figure drops dramatically for programs B and C, where over 60% of all graduating students take longer than six years to finish their studies.

It is important to note that at the national level, there were two significant changes in public education policies, which affected programs B and C most: First, as a result of an economic crisis (80s), primary education daily class hours were reduced from six to four and a half, in order to allow primary and secondary school teachers to hold two full-time jobs in compensation for the economic losses stemming from the crisis. The second major change was the legislation to make a 12-year secondary education mandatory, which in effect increased pressure on university institutions to accept more students. The results of these policies have been questionable. It is incongruous to reduce class hours and to increase access to university education.

Another factor explaining the differences of graduation rates is the political pressure to admit a growing number of students. As a result of this, admission exam requirements have been lowered over time, and there is a clear relationship between these grades and duration of studies. From figure 1 we can see that an entrance exam grade of 750 virtually guarantees the successful completion of the B.Sc. in BME program within four years, while a score of 600 practically assures that the students that eventually graduate, will do so in at least twice the expected time (8 years).

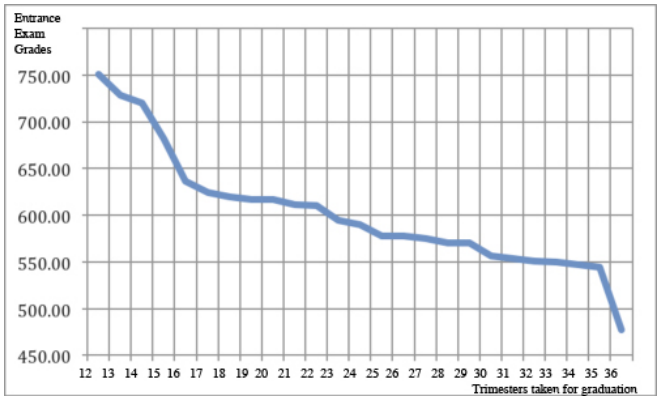

Figure 1. Plot of entrance exam grades vs number of trimesters needed to graduate.

Figure 2 shows the grade point averages on a 100 point scale) for different ranges of scores in the entrance exam (from 400 to 1000). It is evident from these figures that allowing for differences in these exams and for different types of students entering throughout these years, there is information derived from this exam to set admission policies based on the expectation of the student's performance.

For public universities, external evaluation policies determine funding for these institutions, to some extent, and in this case there is an incongruity between the need to admit more students and to reduce graduation times. This has led to pressure to lower educational standards, and while for the moment UAM-I has resisted this change, the problems arising from this have resulted in an increase in students that do not advance from their first year of studies. This is compounded by the fact that, high school student competencies in mathematics, reading and science subjects are two years behind the OCED average[6]. Although the university has tried to address these deficiencies by introducing, among others, a remedial trimester for admitted students with low

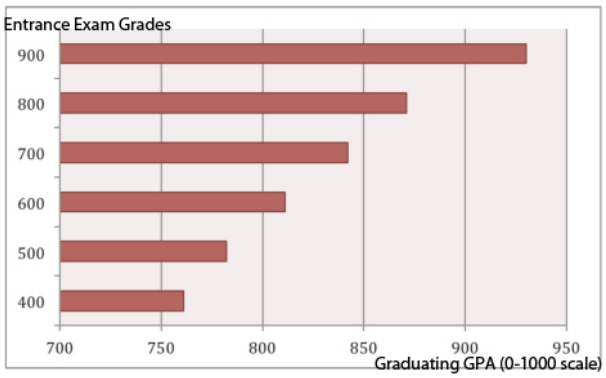

Figure 2. Grade point averages (0-1000 scale) for students within different ranges of scores (400-900) in the entrance exams.

entrance exam grades, these programs have been very costly in terms of human and physical resources while the results have been modest.

There are other factors regarding the structure and organization of the University that must be taken into consideration in order to fully understand the present results:

University Structure

At its founding in 1974 UAM was conceived as a modern university, which incorporates teaching and research within a Departmental structure. Teaching and research are supposed to be intimately related so students should ideally participate in the faculty's research. However, since the university's founding, faculty members have come from traditional Mexican universities, who do not have this structure. In Mexico, research has primarily been carried out in Institutes, while undergraduate degrees have been granted by "teaching" universities. The "research university" concept has been hard to understand, so there is a gap between the student's abilities and the researcher's expectations.

One of the major challenges regarding the future of BME education at UAM will be to successfully manage a transformation in the competencies of students who enter the university with a 9th grade equivalent into prospective graduate students, four years later. This will require an investment of a very large amount of resources of every kind, but will require the understanding of the faculty that traditional approaches to basic subjects such as calculus, physics and chemistry will not be successful [4,5].

Faculty composition and pressures

As it has been already stated, BME faculty at UAM is made up of a large amount of professors with Ph.Ds. and M. Eng. degrees, which in the Mexican context is outstanding. With this competency level come recognition and external pressures. Since performance determines sometimes more than 50% of salaries, and the National Research System rewards investigators with extra income, there is a pressure to deliver research-oriented results, while teaching rewards are based only on hours in front of class.

In addition to this, the faculty's background and their high expectations regarding the students have led to the overextension of the curriculum, as it was noted in table 1. Most

courses in BME are adaptations from semester long courses that are crammed into 12 week (11 week classes plus one week for examinations) trimesters, so in effect the curriculum is overloaded by both of these causes.

Tutoring and mentoring students

Although the relationship between the entrance examination and the performance of the students is clear, it does not explain the whole phenomenon of high dropout rates. A study by Rodríguez [7] shows that as it has been explained, freshmen are ill-prepared to achieve the expected standards in academic performance. They enter an unknown environment and instead of finding mentoring and tutoring that might help them adapt to these new circumstances, they frequently encounter teachers with unrealistically high demands who are not well disposed to provide some sort of personalized support. The joint action of these factors practically assures failures for a large number of freshmen.

External factors

Up to now, we have focused on understanding the complexities surrounding curricular design, the need to keep up with advances in the scientific and technological fields, and the declining performance of students together with the increasing demands by the BME faculty. Compounding this scenario is the fact that competition from other universities has become important. In 1974, at the time of program A, there were only two universities granting undergraduate BME degrees; at the time of program B only another university, the National Polytechnic Institute, initiated their BME program. There are now 26 universities in Mexico that offer this degree. These institutions are now widespread throughout the country and are both public and private. And although: a) most of these institutions have modeled their curricula after UAM'S program B, and: b) there is wide recognition that the program at UAM is still the best from the point of view of research and laboratory facilities and quality of faculty members, it is necessary to take all the necessary steps to assure and maintain quality in education and to directly address the problems that have been mentioned in this work. Unfortunately, no work has been published by other Mexican universities regarding the problems presented in this work. However, we believe that open discussion of such topics on university education is more conductive to an overall improvement since most of the underlying problems are shared by all institutions. Another factor to be considered is local job market conditions. Most job offers currently open for BMEs with an undergraduate degree are for sales, maintenance and service, with a few others in hospital engineering. In this sense the program at UAM reflects the tension between the idea to adapt to the current job market on one hand, while it strives to be different from the other institutions and promote innovative design and research.

Social context

Many of the policies that deviate from a rational pursuit of excellence in education are explained by the desire to remedy some of the handicaps derived from inequality in income and educational opportunities in Mexico. For example, by requiring by law that secondary education must be universal and obligatory without improving the basic quality of education or reinforcing infrastructure. However, it is clear that these tensions can't be resolved solely by the university.

IV. CONCLUSIONS

The conclusions from this work can be summarized as follows:

- It is necessary to implement rational admissions policies. It is in no one's interest to admit students who have an extremely low probability of graduating or who will be low-performing students.
- It is necessary to impose reasonable limits on student graduation deadlines. Allowing low performing students to remain at university for up to 12 years is not (in our opinion) contributing to their social advancement. In any case it would be interesting to study the possibility of granting intermediate or associate degrees.
- Professors' teaching performance should be graded in the same manner as research is. At present there is a teaching bonus dependent on courses taught. It should be dependent on performance and production of teaching material and evaluated as research is, by promotional review boards.
- Special mentoring and tutoring programs for undergraduates should be set up. In addition to this, special policies should be implemented to provide academic coaching to promising but (academically) handicapped students.
- Special emphasis should be given to study the issues of credit requirements and the adaptation of semester long courses into trimesters. In particular, attention should be brought to the disadvantages of a Departmental structure upon a mostly Engineering Division, especially regarding freshman basic mathematics courses.

These changes are probably difficult to implement in the near term, but we believe that they are the only way to assure and maintain leadership and recognition in the field of BME education.

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