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Perspectives of the Biomedical Engineering Program at UASLP after ten years - analysis and criticism

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***Abstract*— The Biomedical Engineering (BME) bachelor program of the Faculty of Sciences in Universidad Autónoma de San Luis Potosí (UASLP) was created in June of 2010, with the aim of training professionals with an integral perspective in the engineering field by considering a multidisciplinary approach to develop and apply technology in the areas of medicine and biology. After 10 years, our BME program has achieved national recognition. Despite of being an emerging program, this achievement has been obtained by the consolidation of our academic staff, the outstanding participation of our students in national and international academic events, and the historical graduation results. In our comprehensive evaluation, we report an overall terminal efficiency (completion rate) of 67% and a graduation rate of 47.2%, where these values are above the average for an engineering program in our institution. Additionally, the BME program provides students with solid skills and background to carry out research activities, which has resulted in a considerable number of alumni pursuing graduate studies or have already completed one. Our results show that 90% of our former students are working after graduation, but only 44% work in the field of biomedical engineering, since the regional labor market starts to saturate given the fact that, at present, students from six generations have completed our BME bachelor program. In this way, few graduates visualize the wide spectrum of job options where a biomedical engineer can impact, by their distinctive comprehensive and multidisciplinary training. Therefore, it is necessary to propose new curricular design strategies to provide our students with an academic training that allows them to enter a globalized world, where there is an even greater spectrum of engineering possibilities related to the fields of medicine and biology, in line with current trends.**

I. Introduction

A strong health system is a fundamental element for the sustained growth of any government. The COVID-19 pandemic has raised the attention to the necessity of rapid development of standard and new medical technologies to respond a health crisis. To achieve this goal, the biomedical engineering (BME) field will be fundamental to lead multidisciplinary working teams with physicians, electronics, mechanical and electrical engineers, and product designers. This new field emerged in the late 60' and early 70's [1], and covers a very broad range of subdisciplines such as medical imaging and instrumentation, clinical engineering, tissue engineering, bionics and rehabilitation, biomedical optics, biomechanics, among others [1].

In Mexico, the development of the BME field started mainly in Mexico City around the 70's, with the creation of BME programs at Universidad Iberoamericana (1973) and Universidad Autonoma Metropolitana - Iztapalapa (1974), and just after 2000 diverse public and private universities initiated their efforts to open bachelor programs outside the national capital [2]. The initial programs in BME were dominated by strong components in electronics, electric and computing engineering, who were more well-established areas. In this sense, the early graduates in BME were rapidly hired by hospitals, medical equipment companies and laboratories. Nonetheless, the field can still grow even more, since the mexican regulations do not require to public and private hospitals to establish a BME department to support and maintain their medical technology and equipment. Furthermore, despite the strong influence by the United States, the health care innovation industry in Mexico is still in the early stages of development.

The Universidad Autonoma de San Luis Potosi (UASLP) is a public state university in Mexico, who was established in 1923, as the first autonomous institution in the country, and nowadays it offers 101 bachelor programs in its regional campuses. In Mexico, the UASLP is constantly ranked inside the 10-best national universities [3], [4]. In specific, the Faculty of Sciences in UASLP (FS-UASLP) was funded in 1955 and has a long standing tradition in basic sciences, education and research, such as physics and mathematics. Since 1993, the FS-UASLP offers also engineering bachelor programs, where one key distinctive component of them is a blend of scientific, analytical and practical training towards research and applications.

II. Methodology

Our BME program was officially approved in 2010, and it is offered by the FS-UASLP [5]. In 2017, the program received the Level I national accreditation level by CIEES (*Comités Interinstitucionales para la Evaluación de la Educación Superior*) [6]. Given the feedback received during the evaluation, the BME program was modified in 2019 [7], and we are currently working on a broader modification to follow current trends and needs in the BME field according to our socioeconomic context.

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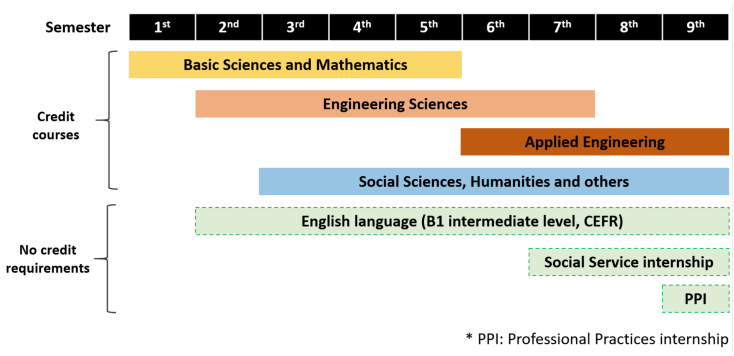

Fig. 1. Curriculum of the UASLP BME-2010 program.

A. Original BME program since 2010

Our academic curriculum of the BS degree in BME consists of 45 courses distributed in nine semesters, with an expected academic load of 5 courses per semester and 8 credits per course (except for the Biomedical Engineering Seminar course which has no credits) for a total of 352 credits [5]. As illustrated in Fig. 1, the courses are associated with four main areas: 1) basic sciences and mathematics, during the first five semesters, 2) engineering sciences, from 2nd to 7th semester, 3) applied engineering in the last four semesters, and 4) social sciences, humanities, and other disciplines, covered in the last seven semesters. In addition to the credit requirements, before the BS degree can be granted, our students must satisfy an English proficiency requirement, corresponding to the B1 intermediate level of the CEFR (Common European Framework of Reference for Languages) by means of institutional courses and/or exams, or equivalent results by external examinations such as TOEFL (Test of English as a Foreign Language). Students must also perform a social service internship and a Professional Practices internship within UASLP or in external institutions, after the accreditation of 30 and 40 courses, respectively. Although no credits are given, these activities are of vital relevance by establishing a link between their academic training and professional performance. Finally, in the 9th semester, each student defines a completion option to obtain his/her degree among the following five options: 1) general knowledge exam, elaborated by the BME faculty, 2) thesis project, 3) exception by a final average grade $\geq$ 9.0 across the whole BME curriculum, being 10 the maximum score, 4) exception by an average grade $\geq$ 8.0 during his/her first semester in a master program recognized by CONACyT (Consejo Nacional de Ciencia y Tecnología), 5) performance greater or equal to "satisfying" in the national electronics engineering general undergraduate exam (EGEL-IELECTRO) elaborated by CENEVAL (Centro Nacional de Evaluación para la Educación Superior) [8].

B. Minor changes to BME program in 2019

Since its creation, our BME program has just experienced one curriculum adjustment with the aim of increasing its flexibility without affecting the original structure of the academic program [7]. This adjustment was approved by UASLP authorities in 2019 and consisted of the following general changes: 1) a reduction in the number of prerequisites to reduce bottlenecks in the curriculum, 2) an increment in two elective courses that students could enroll within another BS program in UASLP, or within master's courses offered by the FS, and 3) a grouping of the economic-administrative courses in the curriculum, and an increment in their available courses options. It is worth mentioning that these adjustments did not involve adding courses to the existing curriculum, nor restricting the transit of active students in the educational program, but rather it opened new options for them.

C. Curriculum actualization process

The accreditation received in 2017 is currently under a new evaluation by the CIEES committee, with the new decision expected by the last term of 2021. In the previous evaluation, our BME program received the following criticism: 1) the curriculum had not been updated since its creation in 2010, 2) the bachelor's degree rate was only 28%, 3) the BME program did not have its own development plan, nor vision or mission statements, and 4) there was not a systematic procedure for the alumni to provide feedback to support decisions in the program. Accordingly, the BME faculty has been working since 2018 to accomplish the following tasks that will ensure a positive feedback during the upcoming accreditation:

- To generate a development plan of the BME program, including its mission and vision, in a collegiate way;
- To update and improve the curriculum plan by considering lecturers' experiences, as well as feedback from graduates and employers;
- To keep increasing the acquisition, maintenance, and improvement of infrastructure and laboratory equipment;
- To establish monitoring strategies and actions to determine the degree of fulfilment of students' training objectives;
- To increase the cooperation with hospitals and companies in the health sector to enrich the practice of our students and provide them better job opportunities;
- To implement certification courses relevant to the BME program;

- To put into practice an academic counseling and accompaniment program for our students;
- To carry out a program to detect and reduce dropout, and scholar desertion;
- To implement a mechanism to improve terminal efficiency and degree completion;
- To strengthen the mechanisms to follow-up students and alumni.

In addition, also in 2017, the new educational model of the UASLP was approved. Therefore, the new curriculum proposal of our BME program will achieve a comprehensive training that allows students to develop various professional competencies. The new curriculum has as main features: professional autonomy; development of collaborative work and communication skills; development and nurture of creative scientific, professional and social projects; growth of social responsibility and ethical reflection.

III. Results and Discussion

The general enrollment and graduation statistics of the BME program at FS-UASLP are presented in Table I. Here, we observe that the number of applicants has had a considerable increase since the opening of the program in 2010 (40 applicants) to numbers greater than 190 requests per year from 2015 to date. This increment is due to the promotion work done in the state of San Luis Potosí. These numbers set our educational program as the undergraduate degree with the highest demand at FS-UASLP, above educational programs such as Electronic Engineering, Telecommunications Engineering, Physics, Biology, among others.

Regarding the number of new enrollment, an increase is also seen from the first admission in 2010 of 25 students to 60 applicants admitted in the last seven years. This increase in the number of admissions is directly related to the number of professors, who year after year have joined the BME program. At the time that our BME program was created, only four full-time professors belonged to the faculty, and currently, there are 10 affiliated full-time professors. But, since 2016, there has not been an increase in the number of full-time professors, so the number of annual admissions to the BME program has remained unchanged in recent years. Hence the current academic staff could not attend more than 65 students per generation. However, the fact that the number of admissions remains at 60, together with a considerably higher number of applicants, could have a positive effect since there is more selectivity in the admitted students, and as a consequence, there could be an improvement in terminal efficiency and graduation rate.

We consider important to discuss also the dropout statistics (26.3% historically in our BS program). In FS-UASLP, students obtain this status by personal decision (withdrawal or career change) or by poor academic performance. In this sense, a low dropout rate suggests that the majority of BME students feel identified with the educational program, and that the overall students' academic performance is acceptable.

In terms of terminal efficiency, the analysis can be carried out by considering two key indicators. First, by evaluating the completion rate, which is the ratio of the admitted students to the number of students that complete the 352 credits in the academic curriculum per generation. In this case, the BME program at FS-UASLP has an average rate of 66.9% by considering students of six generations (from 2010 to 2015). This is a positive indicator and reflects that the majority of students complete 100% of the credits, a fact that is considered as a direct consequence of having a good selection process upon admission. In fact, the average time to conclude all the courses is five years, an excellent result considering that the duration of the BS program is 4.5 years. On the other hand, for the graduation rate (ratio between admissions and graduated students), we can observe a historical value of 47.2% that is a high value for an engineering program in Mexico. For this criterion, the most common options to obtain the degree are the thesis project and the application of an external exam (EGEL). Therefore, we can observe a good balance between students, who have a greater affinity for research activities and students willing to enter the professional world in the clinical environment. Nonetheless, there is a gap of roughly 20% between the students that complete the 352 credits in the academic curriculum, and the ones who obtained their degree. Note that this is a common dilemma for undergraduate students, since some of them are pushed to rapidly look for a monetary income to help their families. Another limitation is the actual graduation costs that are roughly twice the amount of a full academic year of their education.

These results show that, for six generations of BME students, there are 108 qualified graduate professionals ready to work in any of the various BME areas. However, it is important to mention that due to this high terminal degree efficiency, today the most common jobs for biomedical engineers in the region (clinical engineer or service engineer) have begun to saturate. For this reason, a reflection on the employability of our students is made below.

According to an alumni survey information, their actual employments are quite diverse, which reflect the BME curriculum model, as is showed in Table II. These employment areas are graduate studies (master or doctoral), hospitals or clinical institutions (activities of medical technology management), medical companies focused on services, maintenance and sales of biomedical equipment. Approximately 20% of our graduates are working in a sector different from BME, including industry and educational institutions.

Master and doctoral studies are among the main areas for professional development that our alumni choose at the end of their undergraduate studies. This result shows that the BME curriculum is strongly influenced by research, since throughout the program the undergraduates have the opportunity to be involved in research activities, such as science summer internships, collaboration in research projects to conclude their degree, participation in national and international congresses, and collaboration in scientific journal papers. In addition, many professors incorporate their re-

TABLE I

UASLP BME BACHELOR PROGRAM OVERALL STATISTICS FROM 2010 TO 2020.

Generation	Applicants	New Enrollment	Degree candidates	Completion rate (%)	Graduates	Graduation rate (%)	Dropouts	Dropout rate (%)
2010-2011	40	25	13	52.0%	11	44.0%	10	40.0%
2011-2012	103	30	19	63.3%	17	56.7%	10	33.3%
2012-2013	88	40	36	90.0%	26	65.0%	8	20.0%
2013-2014	108	50	38	76.0%	28	56.0%	8	16.0%
2014-2015	143	60	29	48.3%	18	30.0%	21	35.0%
2015-2016	198	60	43	71.7%	19	31.7%	8	13.3%
2016-2017	226	60	n/a	n/a	n/a	n/a	9	15.0%
2017-2018	206	60	n/a	n/a	n/a	n/a	8	13.3%
2018-2019	190	60	n/a	n/a	n/a	n/a	12	20.0%
2019-2020	199	60	n/a	n/a	n/a	n/a	3	5.0%
2020-2021	232	63	n/a	n/a	n/a	n/a	2	3.2%
Total	1733	568	178	66.9%	119	47.2%	99	26.3%

search findings in different courses and invite undergraduates to join in these activities, as part of the social service or professional practice internships. However, in this point, we detect as an opportunity area to include orientation activities for undergraduates to chose professional practice internships. This experience could impact their future professional life, and we observe two main interest areas: research and clinical engineering. In this context, we also identify as fundamental to plan collaboration strategies with BME industry and hospitals to provide real-world experience to undergraduates. This collaboration can be aimed mainly in the area of product development cycle with BME design projects, where these projects can be selected by faculty and industry representatives for completeness and applicability to typical usage, as is proposed in [9]. This approach could provide undergraduates with better job opportunities, and also cover some entrepreneurship abilities, which is the professional area that has not been exploited by our alumni. In particular, the collaboration with hospitals will help to highlight that the BME area inside a hospital is more than technical activities related to equipment maintenance. In this regard, we need to transmit to our alumni that they can apply to a wide spectrum of job options, where the BME discipline can impact and that the possibilities for more job opportunities could be outside the state.

IV. CONCLUSION

The BME program at FS-UASLP was created in June 2010, and by considering the results obtained so far after 10 years, it can be concluded that the opening of this BS program was a successful decision due to the high demand of admission and its terminal efficiency. One of the main characteristics of our BME program is the orientation to develop research activities, which is a direct consequence of being an educational program offered in a school of sciences. In addition, our results suggest that our graduates have a proper employability. However, despite the success of the program within UASLP, the academic faculty considers that it is necessary to update the curriculum structure to allow the alumni to have more job opportunities that are consistent with the current trends in the BME discipline.

TABLE II

EMPLOYMENT ANALYSIS OF BME ALUMNI

Employment area	**% of alumni**
Master or doctoral studies	26.27
Hospital, health clinics and clinical labs (public or private)	22.03
Medical companies (service and maintenance)	16.10
Companies not related with BME	16.10
Sales of medical equipment	3.39
Education institutions (Basic and intermediate level)	3.39
Entrepreneurship	1.69
Government institution related with BME	0.85
Unemployed	10.17

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