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Alignment and Misalignment: A Comprehensive Analysis of undergraduate Biomedical Engineering Programs and Workforce Needs in Mexico

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ABSTRACT

This study presents the first comprehensive analysis of all 60 undergraduate Biomedical Engineering (BME) programs in Mexico. We conducted a national curricular census of all 60 programs, a thematic analysis of graduate profiles, and a complementary employer survey.

Curricular review, including stated aims, focus areas, and course content, was complemented by a survey of employers in the biomedical technology sector. The findings reveal a persistent misalignment between educational objectives and workforce needs. Although most programs formally prioritize medical device Design and development, only a minority offer formal, project-based Design coursework. Conversely, employer feedback indicates a greater demand for competencies in clinical engineering, such as medical equipment maintenance, healthcare technology management, and programming, with less emphasis on new device Design. The diversity of Mexico's higher education institutions—including research universities, technological institutes, and teaching-focused universities—creates opportunities to develop differentiated BME pathways aligned with specific labor-market requirements. We argue for a strategic shift from a maintenance-centric to an innovation-oriented paradigm, facilitated by curricular models like the integrated spiral curriculum.

These results highlight the urgent need to align program objectives, curricular implementation, and industry expectations to enhance the relevance and impact of BME education in Mexico.

KEYWORDS

Biomedical Engineering curricula, Biomedical Engineering programs, graduation profiles, Mexican Universities.

INTRODUCTION

From antiquity until the late nineteenth century, palpation and auscultation were the primary techniques for detecting physiological signals and abnormalities in the human body.

Significant advances in physics and technology during the late nineteenth century enabled the detection of physiological signals and the creation of medical images. The pace of technological progress accelerated after World War II, as electronic equipment developed initially for military applications became available for medical use.

These technological developments contributed to the establishment of biomedical engineering programs in the United States, which began as graduate programs in the 1960s and expanded to undergraduate degrees in the 1970s [1].

In Mexico, the origins of biomedical engineering can be traced to the collaboration between Arturo Rosenblueth, physiologist Walter B. Cannon, and Norbert Wiener at Harvard, the Massachusetts Institute of Technology (MIT), and the National Institute of Cardiology (INC), which contributed to the development of cybernetics. Some researchers from this group facilitated the establishment of a master's program in bioelectronics in 1972, which later helped launch undergraduate programs at the National Polytechnic Institute (UPIITA) in 1982. Concurrently, programs at the National Autonomous University of Mexico (UNAM) supported research groups in biophysics and biomedical systems, which continue to shape current curricula [1].

The first department dedicated to the maintenance and service of medical equipment in Mexico was

founded in 1965 at the Mexican Social Security Institute (IMSS), which was staffed primarily by electronics engineers. This department was essential for the establishment of the Clinical Engineering profession in Mexico. It significantly influenced the early objectives of BME programs, distinguishing them from their counterparts in the United States.[2]

FIRST UNDERGRADUATE BME PROGRAMS IN LATIN AMERICA

As medical technology began to expand in the 1970s, the first undergraduate programs in BME were established. Mexico led the region by launching two programs in 1974 at Universidad Iberoamericana and Universidad Autónoma Metropolitana. Other countries, such as Brazil (1976) and Argentina (1978), followed [3], [4].

KEY DIFFERENCES BETWEEN BME PROGRAMS IN LATIN AMERICA AND THE US.

In the United States, the focus was on developing medical devices and technologies. In contrast, Latin American programs primarily aimed to address the operational, maintenance, and managerial needs of hospitals and emerging clinical engineering services.

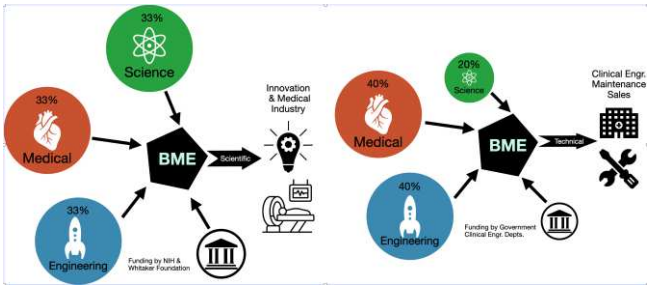


Fig. 1: Differences between the aims of Biomedical Engineering programs in Mexico and the US in the years 1974-1980. The arrows represent significant influences from key players involved in the development of the programs. In Mexico, the input from the scientific community as well as funding are reduced importantly.

The year 2024 marked the 50th anniversary of the establishment of undergraduate BME programs in Mexico. Today, there are 60 BME programs with diverse focus areas.

Although this historical context explains the initial objectives of BME education in Mexico, the rapid advancement of medical technology and evolving global industry trends pose critical questions regarding the alignment of current Mexican BME programs with workforce demands. Additional considerations include whether these needs should be the sole drivers of curricular reform or if greater emphasis should be placed on research and development, innovation, and entrepreneurship. The present study addresses these questions by analyzing all identified undergraduate BME programs in Mexico.

By systematically examining publicly available curricula, graduate profiles, and complementary employer perspectives through an employer survey, this work seeks to characterize dominant curricular patterns, identify sources of variation, and situate Mexican BME education within broader international discussions on engineering education.

Unlike our earlier studies, which relied primarily on curricular descriptions, the present work provides a complete national census, normalized quantitative comparisons across institutional types, and employer-derived competency priorities [5,6].

Rather than evaluating program quality or accreditation outcomes, this study adopts a descriptive and comparative perspective that emphasizes transparency and replicability. In doing so, it contributes a unique empirical dataset and an analytical framework that may inform curriculum development, institutional self-assessment, and future comparative studies in biomedical engineering education.

AIMS

Guided by the objectives outlined above, the study addresses the following research questions:

- What are the dominant curricular structures of undergraduate BME programs in Mexico?
- How consistent are stated graduate profiles with the observed distribution of courses and thematic emphases (focus areas) within these programs?
- How do curricular emphases align with employer needs?

- What patterns of curricular variation can be identified across different institutional types (e.g., research-intensive universities, technological institutions, and teaching-focused universities)?

Together, these questions seek to provide a comprehensive characterization of undergraduate BME education in Mexico and to situate national curricular trends within ongoing international discussions on engineering education and workforce alignment.

METHODS

A. STUDY DESIGN

This study employed a mixed-methods, descriptive-comparative design that combined systematic analysis of curriculum documents with an exploratory employer survey. The objective was to characterize the structure, content distribution, and stated graduate profiles of undergraduate Biomedical Engineering (BME) programs in Mexico, and to examine their alignment with reported workforce needs. One aim of the study was to determine whether the programs exhibited similar structures and course equivalencies.

We also analyzed the number and types of core courses in the institutions under study, as well as the stated graduation profiles for each institution (i.e., the kinds of activities graduates were expected to perform).

B. PROGRAM IDENTIFICATION AND INCLUSION CRITERIA

A comprehensive census of undergraduate BME programs offered in Mexico was conducted between June, 2024 and December, 2025. Programs were identified through:

- Official university websites
- National higher education directories
- Prior academic literature on BME education in Mexico
- Cross-referencing institutional catalogs and admission portals

Programs were included if they met the following criteria:

- Offered a complete undergraduate degree explicitly titled Biomedical Engineering or Ingeniería Biomédica (or a direct linguistic equivalent)
- Had a publicly available curriculum or study plan
- Were active during the period of analysis

Programs with related but non-equivalent titles (e.g., Bioengineering, Bionics) were excluded.

Using these criteria, 60 undergraduate BME programs were identified and included in the analysis.

C. CURRICULUM DATA COLLECTION

For each program, the following information was collected from official institutional sources:

- Complete study plan (course titles and sequencing)
- Credit structure (where available)
- Program duration (semesters or trimesters)
- Stated graduate profile or learning outcomes
- Institutional type and governance (public/private)

When multiple curricular versions were available, the most recent officially published version was used.

D. COURSE CLASSIFICATION AND CODING FRAMEWORK

To enable comparative analysis across institutions with differing structures, all courses were classified into thematic categories based on course titles, official descriptions (when available), and standard disciplinary conventions in biomedical engineering education.

The classification framework included the following categories:

- Mathematics
- Physics and Chemistry
- Electronics and Electrical Engineering
- Computing and Programming
- Signals, Systems, and Image Processing
- Physiology and Life Sciences
- Core Biomedical Engineering Subjects
- Electives & other courses
- Design, Integration, and Capstone Projects

Each course was assigned to one primary category to avoid double-counting. Interdisciplinary courses were classified according to their dominant learning objective, inferred from course descriptions.

The course classification was conducted independently by three researchers, with

disagreements resolved through discussion and consensus.

E. NORMALIZATION AND QUANTITATIVE ANALYSIS

Because programs differed in length (semester vs. trimester systems) and the total number of courses, curriculum data were normalized to the percentage of total courses assigned to each category. Tree trimesters of study (33 weeks of effective teaching) are very similar to a two-semester academic year (32 weeks of teaching).

This normalization enabled direct comparison across programs regardless of the diverse institutional calendar structures.

Descriptive statistics were used to compute the mean and range of category representation, the distributional differences across institutional types and variability in emphasis on core BME domains

Programs were additionally grouped into institutional typologies (research-intensive, technological/polytechnic, and teaching-focused) based on publicly stated missions, research output, research infrastructure, and degree offerings.

F. GRADUATE PROFILE ANALYSIS

Stated graduate profiles were analyzed using qualitative content analysis. Texts were coded for recurring competency themes, including:

Technical depth
Clinical orientation
Research and innovation
Industry readiness
Management and regulatory competencies

This analysis compared declared educational objectives with observed curricular emphasis, identifying areas of convergence and divergence.

G. EMPLOYER SURVEY

To complement curriculum analysis, an exploratory survey of employers in the biomedical and healthcare technology sectors was conducted. The survey was sent by email to 80 employers, with a reply rate of 25%.

PARTICIPANTS

Respondents included professionals from:

- Medical device companies
- Healthcare technology service providers
- Clinical engineering departments
- Biomedical R&D organizations

Participation was voluntary and anonymous.

INSTRUMENT

The survey collected information on:

- Desired technical competencies in entry-level BME graduates
- Perceived strengths and weaknesses of current graduates
- Relative importance of electronics, computing, clinical knowledge, and soft skills

The survey was descriptive in nature and not intended to produce statistically generalizable results, but rather to provide contextual qualitative insights.

H. LIMITATIONS

Several limitations should be noted:

- Curriculum analysis relied on publicly available documentation, which may not fully reflect enacted curricula.
- Course classification involves interpretive judgment, despite efforts to standardize coding.
- The employer survey sample was limited and not statistically representative of the national labor market.

These limitations do not invalidate the analysis but should be considered when interpreting the results.

I. ETHICAL CONSIDERATIONS

All data were obtained from publicly accessible sources or collected anonymously. No personal or sensitive data was collected, and thus Institutional Review Board approval was not required under applicable guidelines.

RESULTS

A. DATA FROM THE TABLES

From the tables containing course information from Mexico (Table 1, provided as an annex), and from the institution's websites we can obtain the following information about the graduation profiles, which are sets of skills and competencies that Universities aim to provide students by the time they graduate. Across

the 60 programs, design and development dominate graduation profiles, while hospital engineering remains a secondary but persistent objective (Figure 2).

The graduation profiles and the core courses do not necessarily align: In particular, most institutions state that the profiles emphasize the need to develop skills in design and development, yet in most cases, they do not offer design courses, understood as a project-driven, experiential learning experience where students systematically apply engineering principles, biomedical knowledge, and professional skills to conceive, develop, and validate a solution to an open-ended problem with real-world constraints.

Focus areas are determined from the principal emphasis of the program, as determined by the kinds of courses that are represented in the BME curriculum (Figure 3).



Fig. 2. Graduation profiles for all 60 institutions. Most institutions mention that the major aims are to produce graduates capable of designing & developing medical devices, but maintenance and hospital engineering are important as well.

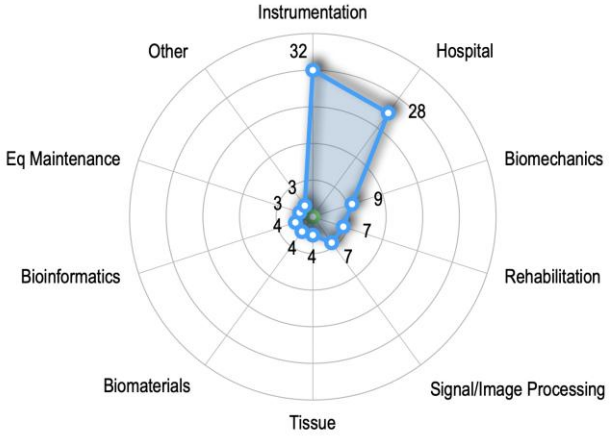


Fig. 3. Focus areas for all 60 institutions. Curricular focus areas concentrate primarily on biomedical instrumentation and clinical engineering, with limited representation of design-oriented or computational tracks

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The only coincidence between profiles and actual courses concerns the need to provide courses in hospital or clinical engineering.
Further information regarding the results from the table will be provided in the Discussion section.

B. DATA FROM THE SURVEY

The employer survey offers an overview of the biomedical engineering job market and workforce expectations in Mexico. The surveyed companies represent a balanced distribution of small, medium, and large organizations, primarily operating in the medical device industry, service provision, and healthcare institutions, with limited involvement in research and development. Employers are currently seeking candidates for managerial (35%), technical (30%), specialist (20%), and Design & development (15%) roles. Most surveyed responders hold director-level positions or work as clinical engineers or researchers

From this data, instrumentation is identified as the leading technical area (17%), while hospital-related fields such as clinical practice, regulation, and management account for 39% of responses (Figure 4).

Employers also report that new graduates frequently lack practical experience, interdisciplinary collaboration skills, and alignment between academic training and industry requirements.

From a technical standpoint, companies prioritize skills in equipment Design and maintenance (25%), hospital technology management (22%), and programming and data analysis (19%). In this case, when maintenance, management, and regulatory affairs are combined, it appears that prospective employees are selected to work in the hospital environment.

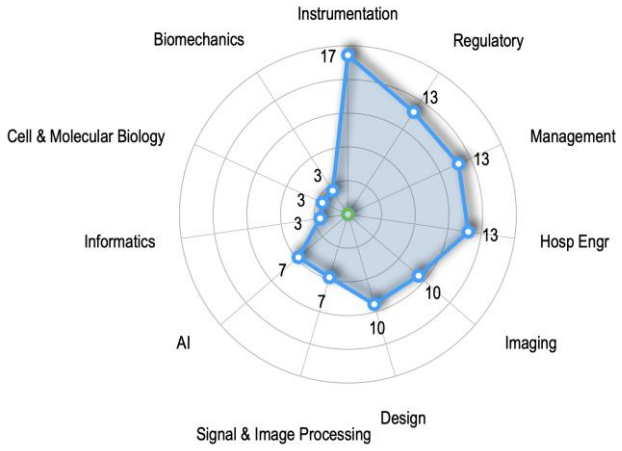


Fig. 4: Importance of different professional areas to employers. In contrast to the graduation profiles, Design and development are not that important to employers.

Figure 5 shows the technical skills required for employment, according to the survey.

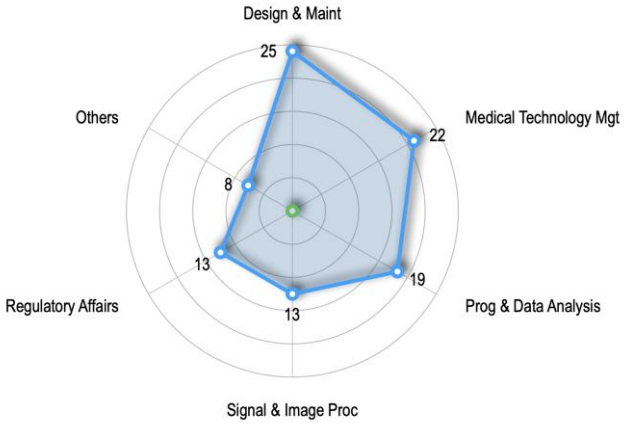


Fig. 5: Technical Competencies according to employers. The overall responses suggest the need for Hospital engineers with emphasis on maintenance.

Teamwork, problem-solving, and communication are the most important soft skills, which are shown in Figure 6.

Employers anticipate future growth opportunities in areas such as artificial intelligence (24%), wearable monitoring devices (20%), Telemedicine (18%), nanotechnology (12%) and digital medicine. These emerging fields are not yet fully addressed in most academic curricula.
The most valued professional attributes include ethics, responsibility, and patient safety.



Fig. 6: Soft skills preferred by employers. Educational institutions should emphasize these skills through problem-based and team-based learning.

Some of the problems encountered when hiring new employees include the disconnect between the academic skills recent graduates possess and the actual needs employers require. Lack of teamwork skills is another area that teaching institutions could

address when designing the teaching modalities for each course. Lack of practical experience has also been noted, and although this is not surprising, it can be addressed by including interships in the curricula.

The survey, although exploratory, suggests potential misalignment between industry and academia, expanded practical training opportunities, and curricular updates to address emerging technological trends in healthcare engineering.

It should be noted that most industry respondents in Mexico represent organizations focused on the sales and maintenance of biomedical equipment. Few responses were received from manufacturers, and none from large industrial groups dedicated to the export-oriented manufacturing of biomedical devices. This sector employs 170,000 people and positions Mexico as the leading exporter of such systems to the United States However, the results may be well correlated with the industry as a whole.

DISCUSSION

This analysis of undergraduate Biomedical Engineering (BME) programs in Mexico reveals a discipline in transition, anchored in strong STEM foundations but exhibiting considerable variation in the prioritization of specialized content. The following sections interpret the patterns identified in Table 1 and relate them to global trends and contemporary workforce requirements.

A. PROGRAM DURATION AND STRUCTURE

Mexican BME programs typically follow the international four-year model, averaging 8.5 semesters. Programs extending to nine or ten semesters often include mandatory internships or thesis requirements, reflecting a shift toward experiential learning. More significant than program duration is the typical course load of approximately 57 subjects, which determines the curricular space allocated among foundational sciences, engineering, and BME-specific content. This distribution varies substantially across institutions.

B. CURRICULAR INTEGRATION:

The data suggest an opportunity to enhance early professional identity formation. Although the literature strongly recommends a first-year introductory BME course to contextualize basic sciences, its implementation remains inconsistent. In contrast, capstone Design experiences are more prevalent, particularly in research-intensive universities, reflecting a 'pyramid' model in which specialization occurs later. A more effective structure would include introductory BME courses early and integrative capstone experiences at the end, yet this approach is not universal. Incorporating core BME subjects in the initial semesters could increase students' motivation to persist in their studies.

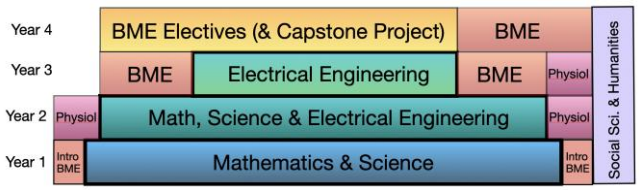


Fig. 10: Pyramidal structure of most BME curricula. The most important subjects must be taught in the senior year.

There is an alternative to this model that addresses the issue of deferring core courses to later years. The “spiral curriculum” model, where each "loop" or "spiral" of the curriculum revisits a key concept (e.g., mass transport, circuitry, signal processing, the Design process) with greater complexity and in a more authentic context, has been adopted by many leading programs (Bruner, 1960, 1966; Linsenmeier & Saterbak, 2020).

This structure aids in motivating and identifying students in the program (Froyd et al., 2012). Given that Design is a key component of graduation profiles, it should be explicitly included in the curriculum.

C. FOUNDATIONAL SCIENCES:

Mathematics, physics, and chemistry form a substantial and essential core, averaging 10.3 courses. However, the distribution—5.5 mathematics and 4.8 physics/chemistry courses—varies significantly across programs, often due to historical precedent rather than pedagogical necessity. Several programs exceed the national average in mathematics and basic science requirements, reflecting legacy curricular structures rather than contemporary disciplinary needs. This constrains curricular space for emerging BME content. Streamlining foundational science requirements would allow for the inclusion of more contemporary BME content.

D. THE LEGACY OF ELECTRICAL ENGINEERING AND THE CENTRALITY OF COMPUTING

A distinctive feature of Mexican BME programs is the pronounced influence of electrical and electronic engineering (EE), with an average of 5.7 courses—occasionally surpassing the requirements of dedicated EE degrees. This emphasis reflects the field's historical association with the maintenance of medical equipment. While foundational knowledge of instrumentation remains important, many programs continue to teach traditional, component-focused electronics sequences that are increasingly less aligned with current industry expectations, as reported in the employer survey.

Contemporary approaches prioritize a systems perspective, integrating sensors, conditioning circuits, and microcontrollers from the outset. These patterns indicate a transition from component-level electronics toward integrated, computation-centered BME practice.

Conversely, the average of 2.4 programming courses aligns more closely with modern needs. Competency in Python, MATLAB, and embedded systems development is now central to data analysis, simulation, and algorithmic control, making this allocation appropriate and arguably the minimum required.

E. BIOMEDICAL SCIENCES

The average requirement of four courses in anatomy, physiology, and related biosciences conceals a significant philosophical divide. Programs within medical schools tend to emphasize biomedical sciences, while engineering-based programs often prioritize electronics. Establishing a coherent BME identity requires balanced integration; The current national average represents a reasonable minimum but highlights the need for improved alignment.

F. MODERN SIGNAL AND IMAGE PROCESSING

A notable finding is the limited emphasis on signal and image processing, with programs averaging only 1.5 courses in this area. This number contrasts with global BME practice, where biomedical data analysis—including ECG, EEG, EMG, medical imaging, and wearable sensors—is increasingly central. Programs that prioritize analog instrumentation without robust digital processing training, risk producing graduates trained for historical rather than contemporary data-driven practice. Leading curricula include at least two core courses (signals and systems; digital signal and/or image processing) and advanced electives, a model that merits broader adoption.

G. CORE BME CONTENT AND INSTITUTIONAL IDENTITY

A core-to-elective ratio of approximately 40/60 provides curricular flexibility; however, core content remains focused on traditional biomedical instrumentation, hospital engineering, and basic physiology, reflecting the historical service-oriented role of BME in Mexico. Electives diversify offerings but do not compensate for the structural absence of formal design instruction.

CASE STUDIES & INTERNATIONAL CONTEXT

The institutional type can explain the variations among the programs. We propose a classification based on the infrastructure, the faculty and the existence of research groups, which are similar to the ideas proposed by Krishnan [12], [13]. The unstructured development of BME programs in Mexico has resulted in different aims coalescing into three different types. Whereas [12] proposes a two-tier classification of universities that offer BME degrees, plus a third model for Biomedical Equipment Technicians, we incorporate institutions that were originally dedicated to educate these kinds of technicians but now are more in line with an Engineering curriculum. In [13] the same author proposes a more design-centered curriculum, that we agree with, after analyzing the disparity between program aims and the real curricula.

A: RESEARCH INTENSIVE UNIVERSITIES

These institutions (marked in blue in Table 1) are characterized by structured capstones, stronger research production, and graduate programs. Their curricula are more likely to include advanced signal processing, computational modeling, and research-driven electives. These institutions have diverse research groups which publish in recognized journals, have significant research facilities and laboratories. Faculty is composed of professors who hold mostly Ph.D. degrees.

In these instances, the excess of electronics courses can be traced to the founders of the original programs, which as it has been noted, were electronics engineers. In contrast, the large number of mathematics courses is explained by the fact that they are taught by personnel from the mathematics departments to students pursuing diverse degrees, including sciences and engineering, rather than tailoring the mathematics to specific programs.

B:TEACHING-FOCUSED POLYTECHNIC AND TECHNOLOGICAL INSTITUTES:

These institutions (marked in orange in Table1) are oriented toward vocational goals and regional industry needs; their programs emphasize applied projects, equipment maintenance, and a more substantial EE influence.

There is heavy emphasis on electronics (8 courses, compared to the average of 5.7) and on medical equipment maintenance (3 courses), which reinforces the idea that the program aims to provide the manpower for medical equipment maintenance needs.

C: TEACHING UNIVERSITIES:

Public and Private These are a heterogeneous group (marked in green), with some developing emerging research capacity and others maintaining predominantly teaching-oriented missions. There are many similarities among these institutions. The first is that there is no capstone requirement. Many offer internships instead.

From the point of view of the different types of programs their diversity of objectives align with the different types of personnel required by industry, where graduates from type B institutions can fill the technical needs; manager and product specialists by graduates from type C universities and Research & development positions can be met by students from research universities, who can probably fill positions at the managerial level as well.

D. ANALYSIS OF OTHER BME PROGRAMS AROUND THE WORLD

To put the information from Mexican Universities in context, we carried out an analysis of Several institutions worldwide: We studied a total of seven U.S. Universities: Four were among the most highly ranked research institutions (Wisconsin, Georgia Tech, Duke, Johns Hopkins), and three Teaching Universities (Wichita State, Iowa State, and Miami).

U.S. Universities

All of the programs have the same foundations:

- Mathematics (an average of 5 courses),
- Physics & Chemistry (5 courses) and
- Biology (3.3 courses, although there is some variation here, with GATech and JHU requiring 5 Courses and IA St. requiring one).

The information is shown in Table 2.

In this instance the foundational courses are similar in both U.S. and Mexican universities. However, significant differences arise in the second and third year of studies: The first is that U.S. institutions do not require more than one course in electronics. This is due to the fact that the knowledge that is needed is incorporated into the syllabus of the specific course that requires it.

An important difference about Mexican institutions is that most curricula in the US. Universities include several Focus Areas for each program.

The heavy emphasis on Electrical Engineering at Mexican institutions is not present here. In some programs, one or two EE courses are required, while in others, they are not. Such courses are required only while pursuing a career in instrumentation or medical devices. In others still, these topics are included in the instrumentation course. There are no digital electronics, except for the computing focus areas. This same approach is followed for courses in programming and signals & systems.

Subjects dedicated to Hospital Engineering do not exist in U.S. and European Universities. On the other hand, Design courses (one or two) are common, except at JHU, where the entire BME undergraduate program is centered on Design. It requires four of those courses.

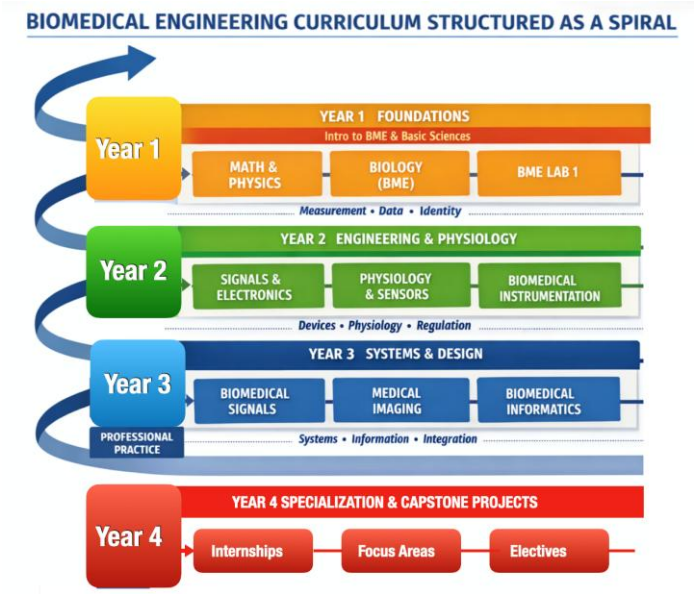
European Universities

In Europe, there is significant variation among programs. It is common to find three-year undergraduate BME programs, which are typically followed by a one year masters. Comparisons are difficult to make.

There are some well-regarded 4-year programs in Europe. These programs are structured similarly to those in Mexico.

It is worth noting that among Mexican institutions, only two offer several focus areas (Instituto Tecnológico de Monterrey and Universidad Autónoma Metropolitana) and only Universidad Iberoamericana offers a series of Design courses throughout the four-year curriculum.

Some explanations for the current situation in the curricular structure may be:



- Faculty Incentives: Teaching existing EE courses is easier than developing new BME-specific, project-based ones. Older faculty may be resistant to change. Research universities may prioritize graduate research over undergraduate curriculum innovation.
- Accreditation & Inertia: Accrediting institutions, such as CACEI may provide incentives to conform to their standards, which are more traditional and may inadvertently reinforce traditional structures. Changing a mandated, multi-year plan is bureaucratically difficult.
- Resource Disparities: Teaching-focused institutions may lack laboratories for advanced Design/projects, reverting to theory and maintenance training that were part of their traditional aims.

CONCLUSION AND RECOMMENDATIONS

A dual heritage shapes Mexican BME education: its origins in electronics and medical technology maintenance, and the demands of a rapidly evolving global sector driven by biotechnology, digital health, and data-intensive innovation. Although the STEM foundation is robust, strategic modernization is urgently required. Reducing legacy electrical engineering coursework in favor of computing, digital signal processing, and data science; ensuring consistent integration of biomedical sciences; and strengthening early exposure to BME concepts would better prepare graduates for emerging opportunities. Curricula must also incorporate artificial intelligence, as employers have identified it as a key future trend.

Future curricular revisions should incorporate educational models that promote integration of skills throughout the curriculum. Moving from a sequential structure towards the integrated spiral curriculum as discussed by (Linsenmeier & Saterbak, 2020) would require introducing cornerstone and Design courses in the first year to provide immediate context for the freshmen; revisiting core and clinical applications in a progressively complex applications; and using sequential project-based learning (Lattuca et al, 2006; Froyd et al 2012). This approach would also solve the employer needs for practical experience and interdisciplinary skills.

A spiral curriculum, as shown in Figure 11, builds these iteratively, so by the final year, students have had multiple cycles of applying knowledge.

Fig. 11: A spiral curriculum incorporates BME concepts from the first year and progressively increases complexity in each of the subsequent years, from the foundations to a systems perspective and finally to a year of specialization.

This proposal would incorporate two design courses: an introduction to BME design at the end of the sophomore year and another course at the end of the junior year.

This structure also means that this approach would solve the problem regarding the electronics engineering problem: in the spiral curricular structure, these concepts can be introduced gradually inside the core BME subjects when they become necessary, for example, within an instrumentation course (as is now the practice in several instrumentation courses in U.S. institutions).

Teaching-focused institutions should strengthen industry partnerships and emphasize applied digital skills, while research-intensive universities should

expand offerings in advanced computation, biosensing, and modeling. Across all institutions, the priority is to transition from a maintenance-centered paradigm to an innovation-oriented approach, with curricular structures that reflect the evolving technological and clinical landscape.

Some specific recommendations for the three different types of institutions may include:
To Research Universities, lead the modernization: formally replace 2-3 traditional electronics courses with integrated design-for-health modules, mandate two signal processing courses, and create AI/Bio-data science electives.
To Polytechnic and Technological Institutes: Formalize and expand industry partnerships for internships; integrate microcontroller programming and data analysis into maintenance courses; develop strong clinical engineering pathways."
To Teaching Universities: Implement a mandatory first-year 'Introduction to BME Design' course and a robust capstone; strengthen soft skills and healthcare management curricula explicitly.

For policymakers and accreditors: create incentives for curricular innovation. For university leaders: empower curriculum committees to make bold, integrated changes. For the BME community: initiate a sustained national dialogue aligning education with the future of healthcare technology.

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Appendix:
Table 1 of results for the 60 institutions that were analyzed and Table 2: Brief summary of course distribution for selected universities

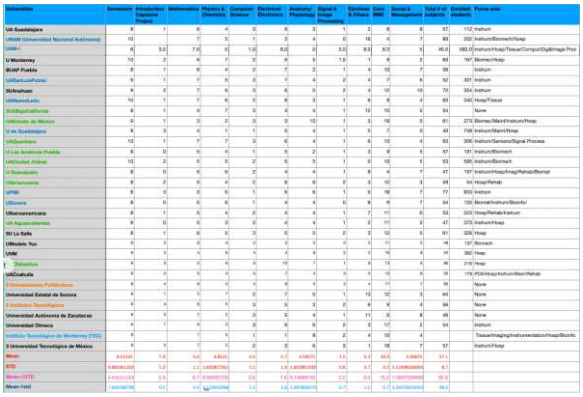


Table 1.

Universities	Semesters	Introduction Capstone Project	Mathematics	Physics & Chemistry	Computer Science	Electrical/ Electronics	Anatomy/ Physiology	Design	Signal & Image Processing	Electives & Others	Core BME	Social & Management	Credits	Focus areas
Wisconsin	8	3	4	4	1	0	5	4	0	9	3	4	128	4
GeorgiaTech	8	2	6	5	1	2	5	1	0	7	7	10	128	4
Duke	8	0	6	6	1	1	3	2	1	3	7	7	128	5
JHU	8	1	6	4	2	0	3	2	2	5	8	5	129	7
Wichita St	8	3	4	7	0	1	3	1	0	5	5	7	128	3
Iowa State	8	2	6	3	0	2	1	0	1	7	4	7	131	3
Miami U	8	5	5	3	1	0	3	2	0	7	6	5	128	3
Mean	8	1.833333333	5.333333333	4.833333333	0.833333333	1	3.333333333	1.666666	0.666666666	6	5.666666	6.666666666		
STD		1.169045194	0.942809041	1.343709624	0.687184270	0.816496581	1.374368543	1.247219	0.745355992	1.91485421	1.795051	1.885618083		
Universidad Carlos III Madrid	8	2	5	4	2	2	4	0	1	3	12	5		

Table 2.