

Higher Education of Biomedical Engineering in Greece: Undergraduate Students' Outcomes from 1989 to 2019 [†]

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Abstract: This manuscript presents the educational evaluation performance of the BME department in Greece. The results are provided in terms of the (i) diploma degree and (ii) duration of studies, enumerating 1845 graduated students in total, over the past 30 years. The following conclusions can be drawn: (a) The mean grade value of all time was approximately 6.5; (b) the majority of students (59%) graduated after 7.4 study years with an average grade of 6.1; and (c) the most cost-effective degrees seem to be those that correspond to 5–6 study years for graduation.

Keywords: biomedical engineering; student outcomes; educational framework

1. Introduction

1.1. The Field of Biomedical Engineering

Over the past fifty years, biomedical engineering (BME) has been thought of as a cross-disciplinary specialization of traditional disciplines, mainly mechanical and electrical engineering, that has a focus on human medicine [1,2]. The implementation of interdisciplinary education considers concepts and methodologies from different branches of science which are combined [3,4] and thereafter adapted in sections of a first-year engineering course [5,6] in order to identify common practices and recommend improvements [7,8]. During this evolutionary period, BME has recently been emerging as its own discipline since several specializations (e.g., bioengineering, medical and clinical engineering, etc.) have risen [9].

This evolution of BME as an independent scientific discipline, with the purpose of combining engineering and biomedical knowledge, is due to the rapid improvements in health care systems, corresponding to new exciting results and fascinating breakthroughs in medicine and biology research and development [10]. As a result, the field of BME is called to cover by itself a new realm of a broad array of subfields, such as bioelectricity and biosensors, bioinformatics, biomaterials, biomedical optics, medical imaging, genetic, neural, pharmaceutical and tissue engineering, robotics, and artificial intelligence in medicine and biology [11,12]. The field of BME is recognized as a key challenge within essential innovation strategies of the European Union (EU) and other countries worldwide [13]. In particular, the BIOMEDEA project has tried to establish guidelines for high-quality BME educational programs in the EU including training, continuing education, and certification for future professionals in the field [14,15]. As the requirements are aggressively increasing and the interest in modern BME applications gradually grows, several engineering schools in universities have now implemented independent BME undergraduate and postgraduate programs [16]. In 2010, bioengineering/biomedical engineering education has shown global growth, with 704 programs offered in 6.73% of the world's universities [17]. Furthermore, the job market for BME is expected to grow annually by 5.0% (faster than average) until 2029 according to the U.S. Bureau of Labor Statistics [18], and the profession of BME



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has been recognized by the World Health Organization (WHO) as necessary to ensure the quality operation and safety of health care technologies around the world [19].

However, due to the interdisciplinary nature of and tasks in various scientific fields, BME educational programs may vary focusing on different scientific domains (either engineering- or life-science-based), often presenting different choices of courses and corresponding subjects [20,21]. Such differences are often shown at the national (between different countries) or global level (between different continents). Due to the aforementioned reasons, the development of the BME educational program structure should consider several parameters [22,23], which include the academic background of the academic staff (academic and research expertise), research status of the university, perspective country policy in education, funding possibilities, national biomedical industry requirements, [24] and the BME's professional demands. Finally, in the process of continuous improvement in a BME department, the content of the courses and the study plan (curriculum) should be updated based on the assessment of student outcomes over the years [25,26] and technological achievements [27]. Sophisticated assessment and evaluation of student outcomes can significantly be used as feedback to teaching effectiveness and conquest to highlight academic performance [28,29].

1.2. A Brief Historical Overview of the BME Department in Greece

The Department of Biomedical Engineering was founded in 1985 as the Department of Medical Instruments Technology at the Technological Educational Institute (TEI) of Athens, Greece. It was then renamed the Department of Biomedical Engineering T.E. in 2013, and it received its current name and University status in 2018 with the founding of the University of West Attica (the transformation and union of the TEI of Athens with the TEI of Piraeus). In the academic year 2019–2020, the department offered a 5-year study program, while in 2020–2021 it offered a unified and indivisible postgraduate degree (integrated master's). The Department of Biomedical Engineering is the only department in Greece that offers comprehensive undergraduate and postgraduate studies also considering that the field of biomedical engineering can now be thought of as an independent scientific subject based on the fusion of the engineering sciences with life and health sciences. To date, approximately 1850 graduates and 800 active students are counted in the department.

2. Materials and Methods

2.1. Administration Structure of the Department

The Department of Biomedical Engineering is divided into two sectors: (i) Sector A: Biosciences and Biomedical Informatics and (ii) Sector B: Biomedical Technology. In addition, three individual research laboratories have been established: (i) the Laboratory of Medical Image and Signal Processing (MEDISP) (ii) the Laboratory of Radiation Physics, Materials Technology and Biomedical Imaging (AKTYBA), and (iii) the Smart Hospital Research Laboratory (SHRL). The permanent academic staff is composed of twenty-six (26) members in total and their specifications are summarized in Table 1.

Table 1. The academic profile of the staff. The academic status as well as the principal studies are numerically indicated.

Academic Staff Of The Department			
Academic Status in the Department	Number of Members	Principal Studies of the Staff	Number of Members
Professor Emeritus	3	Physics	8
Professors	6	Electrical engineering	4
Associate professors	8	Biomedical Engineering	7
Assistant professors	4	Biology	1
Technical staff	2	Chemistry	2
Secretariat members	3		

2.2. The Curriculum of the Department

The department offers a 5-year study undergraduate educational program (10 individual six-month semesters) including 76 separate courses (49 mandatory courses and 27 courses of choice) accompanied by a mandatory diploma thesis of expertise and optional clinical practice (three months in duration). English-language courses are also offered for incoming ERASMUS students from countries, such as Spain, France, Austria, Germany, Romania, Portugal, Poland, Hungary, Turkey, Italy, and China.

The department also offers MSc and PhD studies. The MSc studies involve two MSc programs. The first one is entitled “Advanced Systems and Methods in Biomedical Engineering”. It focuses on modern and emerging biomedical technologies. The official language of the program is Greek. The second one is entitled “Biomedical Engineering and Technology”. It provides an intensive introduction to the field of biomedical engineering for graduates with relevant engineering and/or health sciences backgrounds who wish for a different career than one in the biomedical engineering sector. The official language of the program is English. Both the MSc programs are three academic semesters in duration (1.5 years). The first and the second semesters involve lectures, whereas the third semester involves the diploma thesis. The Ph.D. studies program is a minimum of 3 years in duration, guiding students towards research for the production of new knowledge in any aspect of biomedical engineering.

2.3. Data Content and Analysis

Numerical data were obtained from the Secretary Department, particularly concerning the student database over the past 30 years (duration period 1989–2019) for analysis using descriptive statistics. During this period, the department had 1845 graduates and currently has 1082 active students. Data were provided in terms of the (i) diploma degree, (ii) duration of studies, and (iii) indication of gender. Personal information was excluded from the datasheet. Data analysis was carried out by dividing the total duration (from 1989 to 2019) into five-year sub-periods, which correspond to six different periods. The Student's t-test was used to identify any statistically significant differences.

3. Results and Discussion

The number of graduate students as well as the graduation grade (average value $\pm$ standard deviation, maximum and minimum values) for different time periods from 1989 to 2019 are provided in Table 2. In the majority of cases, the maximum and minimum graduation grades were obtained by male students with the exception of the last period, 2015–2019, where the maximum grade was obtained by a female student (grade: 8.6). This finding is probably due to the higher number of male students compared to female students (approximately 76–82% per year of education) resulting in an increased probability of males to achieve higher grades. However, it should be noted that in recent years, the number of female students has increased due to the new requirements of the biomedical industry to recruit biomedical engineers for specialized tasks, which has created new job descriptions, such as personnel dedicated to educating healthcare specialists in the optimal utilization of complex biomedical systems, such as MRI and ultrasound systems and personnel collaborating with healthcare professionals during surgery for the installation of implants, such as pacemakers, valves, etc. The maximum and minimum grades, from the establishment of the department until this day, were 9.3 and 5.4, respectively. The mean value grade, from the establishment of the department until this day, is 6.5. There was also a decrease in the average graduation grade during the period of 2005–2014, as shown in Figure 1. There was a radical change in the university entrance examination process in Greece after 2000, which had a crucial impact on the knowledge level of students in physical sciences (e.g., physics, mathematics, and chemistry) and their corresponding inability to meet the requirements during their studies in engineering departments. The first generation of students of that period began to graduate after 2005 and this may be a major factor that affected the gradual decrease in the graduation grades in 2005–2014.

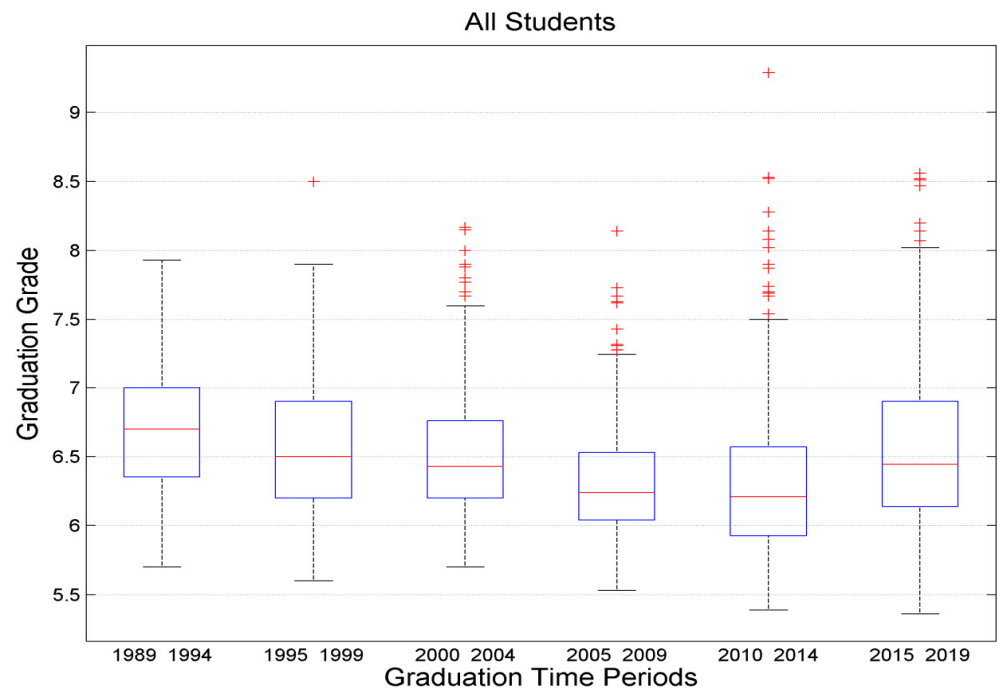


Figure 1. Boxplots present the graduation grade for different time periods from 1989 to 2019.

Table 3 provides the number of graduate students based on their diploma grades. Three levels of grade range were studied: Good [5.0–6.5), Very good [6.5–8.5), and Excellent [8.5–10.0]. The average diploma grade was 6.46 with an average of 6.7 years taken to graduate. Females presented better performance than males in terms of both diploma grades (6.58 against 6.43, respectively ($p < 0.001$)) and duration of studies (6.02 years against 6.86, respectively ($p < 0.001$)). Only seven students so far have graduated with “Excellent” grades (>8.5) after 4.3 study years (average value), which is very close to the normal time taken to graduate.

The majority of students (59%) graduated after 7.4 study years with an average diploma grade of 6.1, while approximately 41% of students graduated after 5.7 study years with an average diploma grade of 5.7. A point worth noticing is that female students tend to graduate faster and with better performances as compared to the aforementioned department’s average values (6 study years with an average grade of 6.6). Female students mostly have “Good” and “Very Good” grades. On the other hand, the majority of male students (61%) graduated after 7.5 study years with “Good” grades. Figures 2 and 3 also show, for almost all graduation years, that females (a) accomplished higher average grades than males (with the exception of 1990, 1994, 1997, and 2017) and (b) graduated earlier than males. Another significant outcome is the increase in the required study years for graduation in recent years for both males and females. Finally, Figure 4 illustrates the number of graduated students and their average diploma grades according to the number of study years required for graduation.

Both numbers decrease over time when students are late in obtaining their degree or, in other words, in order to obtain their degree, students decide to “sacrifice” their degree grade. The most cost-effective degrees seem to be those that correspond to 5–6 study years for graduation.

Table 2. The number of graduate students as well as the graduation grade (average value $\pm$ standard deviation, maximum and minimum values) for different time periods from 1989 to 2019.

	1989–1994		1995–1999		2000–2004		2005–2009		2010–2014		2015–2019	
# graduate students	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)
	148 (81.8)	33 (18.2)	151 (76.6)	46 (23.4)	314 (76.9)	89 (23.1)	337 (81.0)	80 (19.0)	309 (82.1)	71 (17.9)	155 (76.7)	61 (23.3)
	181		197		386		422		397		262	
Graduation Grade mean value $\pm$ standard deviation	6.68 $\pm$ 0.46	6.78 $\pm$ 0.49	6.52 $\pm$ 0.47	6.64 $\pm$ 0.50	6.51 $\pm$ 0.46	6.54 $\pm$ 0.47	6.31 $\pm$ 0.39	6.42 $\pm$ 0.41	6.30 $\pm$ 0.55	6.46 $\pm$ 0.52	6.48 $\pm$ 0.59	6.80 $\pm$ 0.66
Max Min	7.93 5.70	7.93 5.90	8.50 5.60	7.90 5.80	8.17 5.70	7.88 5.76	8.14 5.53	7.67 5.62	9.29 5.39	8.14 5.53	8.52 5.36	8.56 5.64

M: male, F: female, Bold text accounts for the highest and the lowest values for each period.

Table 3. The number of graduate students based on their academic grading (Good, Very good, and Excellent). The average value (and standard deviation) of the degree grade and the corresponding number of study years are also provided.

	All			Male			Female		
	# Graduates (%)	Degree Grade Avg $\pm$ Std	Study Years Avg $\pm$ Std	# Graduates (%)	Degree Grade Avg $\pm$ Std	Study Years Avg $\pm$ Std	# Graduates (%)	Degree Grade Avg $\pm$ Std	Study Years Avg $\pm$ Std
All Grades [5.0–10.0]	1845 (100)	6.46 $\pm$ 0.51	6.70 $\pm$ 2.76	1465 (79.4)	6.43 $\pm$ 0.51	6.86 $\pm$ 2.84	380 (20.6)	6.58 $\pm$ 0.52	6.02 $\pm$ 2.36
Excellent [8.5–10.0]	7 (0.38)	8.63 $\pm$ 0.29	4.30 $\pm$ 0.49	6 (0.41)	8.65 $\pm$ 0.32	4.17 $\pm$ 0.41	1 (0.26)	8.56 $\pm$ 0	5 $\pm$ 0
Very Good [6.5–8.5]	757 (41.0)	6.93 $\pm$ 0.38	5.74 $\pm$ 2.40	568 (38.8)	6.91 $\pm$ 0.37	5.87 $\pm$ 2.57	189 (49.7)	6.97 $\pm$ 0.40	5.35 $\pm$ 1.75
Good [5.0–6.5]	1081 (58.6)	6.12 $\pm$ 0.22	7.36 $\pm$ 2.81	891 (60.8)	6.11 $\pm$ 0.23	7.51 $\pm$ 2.82	190 (50.0)	6.17 $\pm$ 0.21	6.68 $\pm$ 2.68

M: male, F: female.

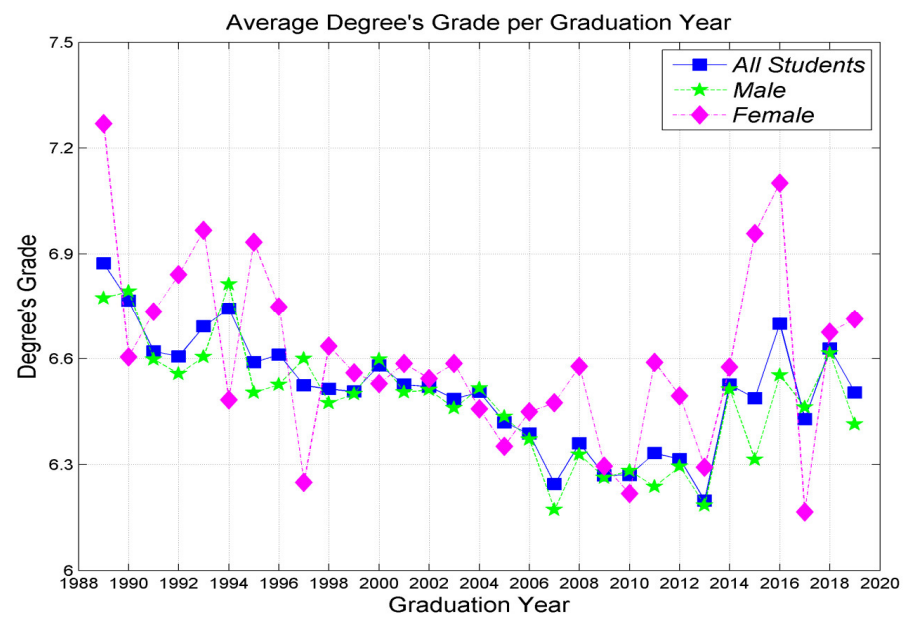


Figure 2. Average degree grade according to graduation year. Blue, green, and magenta colors correspond to the total number of students, males, and females, respectively.

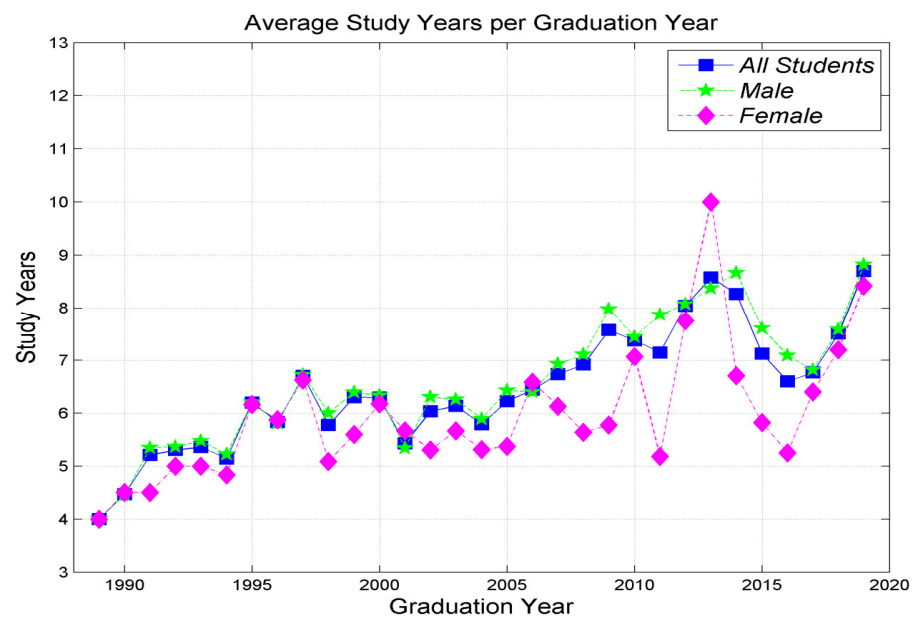


Figure 3. Average required study years for graduation per academic year. Blue, green, and magenta colors correspond to the total number of students, males, and females, respectively.

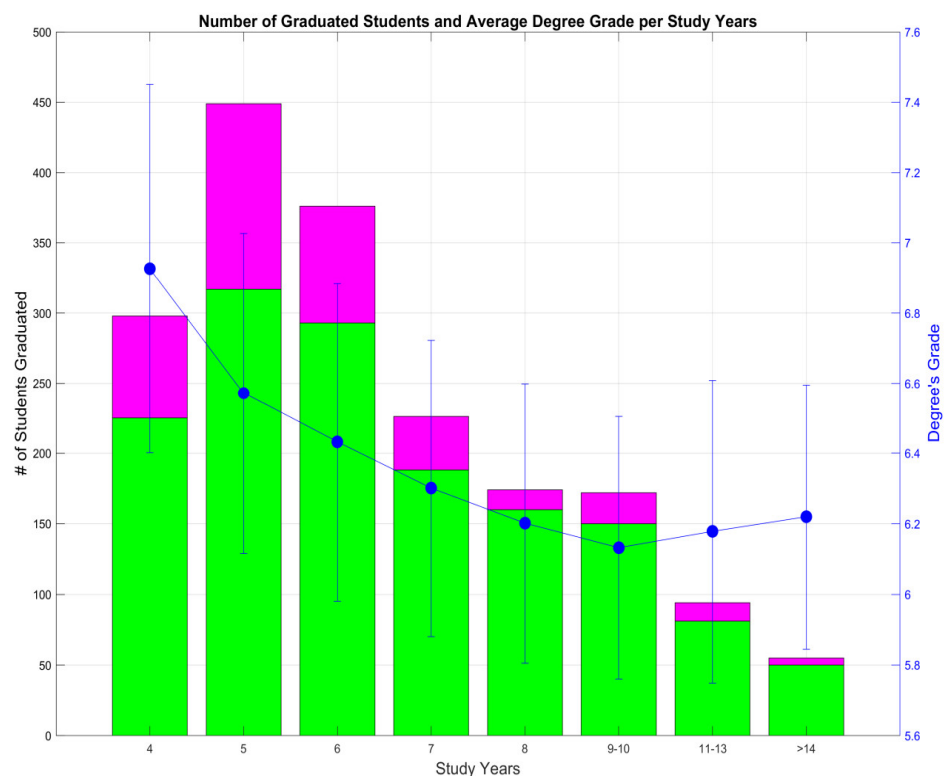


Figure 4. Double y-axis (y-y) plot showing the number of study years required for graduation. The left y-axis accounts for the number of graduated students. Green and magenta colors correspond to the portion of male and female students in the bar plots, respectively. The right y-axis accounts for the average degree grade as illustrated in a blue line/dot variation in the graph along with the corresponding error bars.

4. Conclusions

This article presents the student outcomes of the undergraduate Biomedical Engineering department in Athens over the past 30 years (period 1989–2019). Based on the student database, the main conclusions are as follows. (a) The average grade value of all time was estimated to be approximately 6.5; (ii) the majority of students (59%) graduated after 7.4 years with an average grade of 6.1, while approximately 41% of students graduated after 5.7 years with an average grade of 5.7; and (iii) the most cost-effective degrees seem to be those that correspond to 5–6 years for graduation.

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