2018 ASEE Annual Conference & Exposition
June 24-27, 2018 Salt Palace Convention Center Salt Lake City, UT

Paper ID #23600

How Do Biomedical Engineering Graduates Differ from Other Engineers? Bridging the Gap Between BME and Industry: a Case Study

Dr. Tanya M. Nocera, The Ohio State University, Department of Biomedical Engineering

Tanya M. Nocera, PhD, is an Assistant Professor of Practice in Biomedical Engineering at The Ohio State University. She is focused on developing, teaching and assessing upper-level Biomedical Engineering laboratory courses, with particular interest in improving student technical communication skills.

Dr. Alexis Ortiz-Rosario, The Ohio State University

Alexis Ortiz-Rosario is a assistant professor of practice in the department of biomedical engineering at The Ohio State University. He holds a B.S. in industrial engineering from the University of Puerto Rico Mayagüez, and a M.S. and PhD in biomedical engineering from The Ohio State University. His current position entails teaching measurements and instrumentation courses, leading micro and nano educational labs, as well as mentoring students in their senior capstone projects. His current projects include industry integration in the curriculum, undergraduate professional development, and entrepreneurial minded learning in the classroom.

Amena Shermadou, Ohio State University

Amena Shermadou is an Engineering Education graduate student at The Ohio State University. She received her Bachelors and Masters in Biomedical Engineering from Wright State University, in Dayton, Ohio. Her experience with teaching first-year engineering students has led to research interests in curriculum development, student empowerment and the development of holistic engineers through the collaboration with engineering stakeholders.

Dr. David A. Delaine, The Ohio State University

Dr. David A. Delaine is an Assistant Professor at The Ohio State University Department of Engineering Education. Within this newly formed department he strives to creatively impact society through investigating the intersections of engineering, education, and social need through research on community engagement and collaborative processes within informal learning. He has obtained a Ph.D. in electrical engineering from Drexel University, in Philadelphia, USA and served as a Postdoctoral Fulbright Scholar at the Escola Politécnica da Universidade de São Paulo. Dr. Delaine is a co-founder and past president of the Student Platform for Engineering Education Development (SPEED) and has served two terms as an executive member of the International Federation of Engineering Education Societies (IFEES) as a Vice President for Diversity & Inclusion. He is investigating university-community engagement as empowerment settings and working to further the research agenda of the global community of practice within Diversity and Inclusion in Engineering Education. His research laboratory aims to support an inclusive, global pipeline of STEM talent and to unify the needs of the engineering education stakeholders in order for engineering education to more accurately reflect societal needs. Diversity and inclusion, university/community engagement, informal learning, action research, and student led initiatives fall within the scope of his academic endeavors.

How Do Biomedical Engineering Graduates Differ from Other Engineers? Bridging the Gap between Biomedical Engineering and Industry: A Case Study

Introduction

Biomedical Engineering (BME) is a relatively young discipline in which individuals are trained to solve problems at the interface of engineering and biology. Many students pursuing this field aim for careers in developing new medical technologies. Unfortunately, the BME-to-industry pipeline faces hurdles that appear to be keeping students from pursuing their medical industry career goals. Herein is a brief discussion of the history of BME and the influences that may have created challenges faced by students seeking industry careers. We then present a case study at The Ohio State University (OSU), a large research I university, which evaluates and compares the industry employment potential of students progressing through and graduating from BME. Through this case study, we aim to identify measures that contribute to a gap between BME and other majors, as graduates pursue the industry workforce.

History of Biomedical Engineering

The Biomedical Engineering Society (BMES) defines *biomedical engineering* (BME) as “the bridge between medical and engineering disciplines that provides an overall enhancement of healthcare,” [1]. BME first emerged as a training program in the 1950s, considerably more recent than other engineering disciplines [2-4]. Its rise was initially driven by the National Institutes of Health (NIH) via the awarding of grants to universities to develop BME doctoral programs [2]. Throughout the 1960s and 1970s, a handful of universities began offering BME degrees, but the late 1990s saw the largest surge in new programs, especially at the undergraduate level [2-3]. This surge was in large part credited to the Whitaker Foundation [2, 5], which increased funding for the development of new BME programs infrastructure ($252M), as well as a combined $327M in fellowships and grants to support student and faculty biomedical research (**Figure 1**) [6].

Simultaneously, the United States experienced a national engineering curricula transformation in the early 1990s [7], which was in response to a government funding shift from engineering industry research to engineering science research. This change in engineering education, along with the funding increase by The Whitaker Foundation, likely influenced the development of broad and research driven BME programs and curricula. Today, 115+ BME degree programs have been accredited by ABET [8] (**Figure 2**).

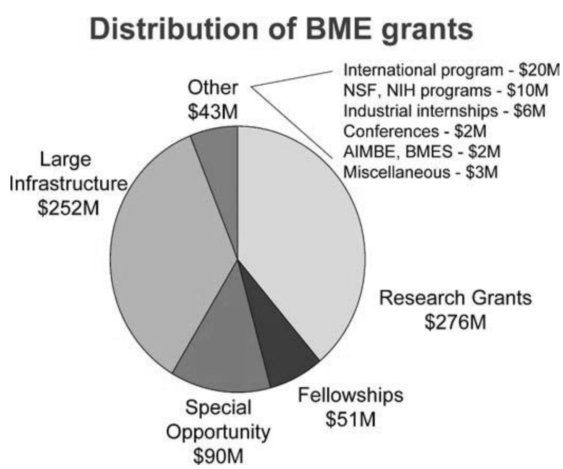

Figure 1: The Whitaker Foundation BME grant funding distribution [6].

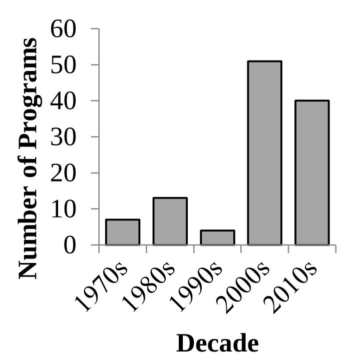

Figure 2: Number of new BME programs accredited per decade.

Challenges within BME

Subsequent to the rising number of BME programs, the Bureau of Labor Statistics reported in 2016 that BME employment is estimated to grow 23% between 2014 and 2024. Despite this predicted trajectory, the identity of the BME field among industry has been of concern to its stakeholders. In particular, the BME curriculum is often rooted in the research expertise of each respective program's faculty. This creates a breadth and diversity in core coursework across different BME programs [9], and likely contributes to the uncertainty industry experiences when attempting to understand the role of BMEs [4]. Additionally, those involved in employment decisions within industry are more familiar with traditional disciplines like chemical engineering (ChE) or mechanical engineering (ME) because their respective core coursework is consistent between universities [4].

There have been indications at The Ohio State University (OSU) that these challenges are affecting BME students in multiple ways. Post-baccalaureate OSU College of Engineering (CoE) alumni surveys have documented that BME graduates believe current undergraduate curricula meets the needs of individuals pursuing graduate or professional school, but lacks sufficient support for those seeking careers in industry. Additionally, many high-achieving students have transferred from BME to other engineering majors, citing difficulty in obtaining BME internships or other support to pursue their industry career goals. Further, BME students express frustration in targeted recruitment and hiring of students from other engineering disciplines, even for positions in which BME skill sets would be more advantageous.

Workshops hosted at recent BMES meetings have identified the leap from university to a career in industry as a continuing national challenge for BME students and alumni. While strides are being made to better utilize industry feedback in the formation of engineering program curricula [10], a more holistic understanding of the factors influencing BME career outcomes is first necessary. This study therefore seeks to identify differences between BME and three other OSU engineering majors (Mechanical (ME), Chemical (ChE) and Materials Science (MSE) Engineering), via analyses of metrics representative of student progression through the university-to-industry pipeline.

Methods

Through quantitative analyses, this paper explores reported outcome metrics for each of four selected majors, Biomedical (BME), Mechanical (ME), Chemical (ChE), and Materials Science (MSE) Engineering. These undergraduate majors were first ABET accredited at The Ohio State University (OSU) during either 1936 (ME, ChE), 1992 (MSE) or 2010 (BME). The selected outcome metrics include 1) *retention and mobility*, 2) *pre-graduation work*, 3) *career outcomes*, and 4) *reported job salaries*. These metrics were chosen from our university's college of engineering annual report because they each represent a facet of a student's progression in the university-to-industry pipeline. Data was extracted from the academic terms of autumn 2012 through summer 2016.

Retention and Mobility

This metrics refers to student transfers out of the initial declared engineering major. There are three student scenarios, in which the student either 1) remains in the same engineering major

(Same ENG), 2) transfers to a different engineering major (Different ENG), or 3) no is longer in the college of engineering (Not in CoE). Values presented in this dataset reflect the average percentage of students in each scenario at the end of summer terms 2013, 2014, 2015, and 2016.

Pre-graduation Work

This metric is defined as any internship, co-op, or engineering related part-time job completed before graduation. Percentages are reported as the number of work offers, normalized by the enrollment size of each major per academic year. Enrollment sizes for 2013, 2014, 2015 and 2016 for each major were, BME = 207, 214, 226, 235; ChE = 470, 544, 620, 642; MSE = 110, 128, 129, 120; and ME = 645, 656, 595, 549.

Career Outcomes

The career outcomes metric is defined as student post-graduation placement in either an industry position or further education. Discussion will focus on industry-related outcomes, rather than graduate or professional school outcomes. Two other graduation outcomes not included were: seeking employment, and other plans. Seeking employment was omitted because its prevalence was consistent across all four majors. The other plans category amounted to < 1% of students, and was therefore deemed irrelevant for this analysis.

Reported Job Salaries

This metric is defined as the student-reported starting salary offered. Analyses include the average starting salaries for post-graduation industry employment for all four majors.

Statistical Analyses

One-way analysis of variance (ANOVA) and a post-hoc Tukey's Honest Significance Difference were used to identify differences across and between observed means for each of the four metrics ($\alpha = 0.05$). Additionally, a regression analysis was performed with the intention of detecting significant correlation between each individual metric and the other three metrics. The regression analysis was either linear (one factor vs. one response) or multilinear (multiple factors vs. one response). All statistical analyses were performed using Minitab 17 Statistical Software (State College, PA: Minitab, Inc.). Results are plotted as averages with standard error bars.

Results and Discussion

Mobility and Retention

Figure 3 shows the percentage of student in each major that were retained (Same ENG), transferred to a different engineering major (Different ENG) or left the college of engineering (Not in CoE). This data is university-documented, and therefore a complete representation of mobility and retention within the four presented majors. For those in the Same ENG category, statistical analysis indicates significantly lower retention rates in BME when compared to ChE or MSE. Further, BME has statistically higher percentages of students who transfer into a different engineering major compared to both ChE and MSE. This metric is particularly interesting, as it points to potential student dissatisfaction with the *biomedical* engineering major, but not with engineering disciplines as a whole. There is no statistical difference in student transfers outside the college of engineering between any of the four majors.

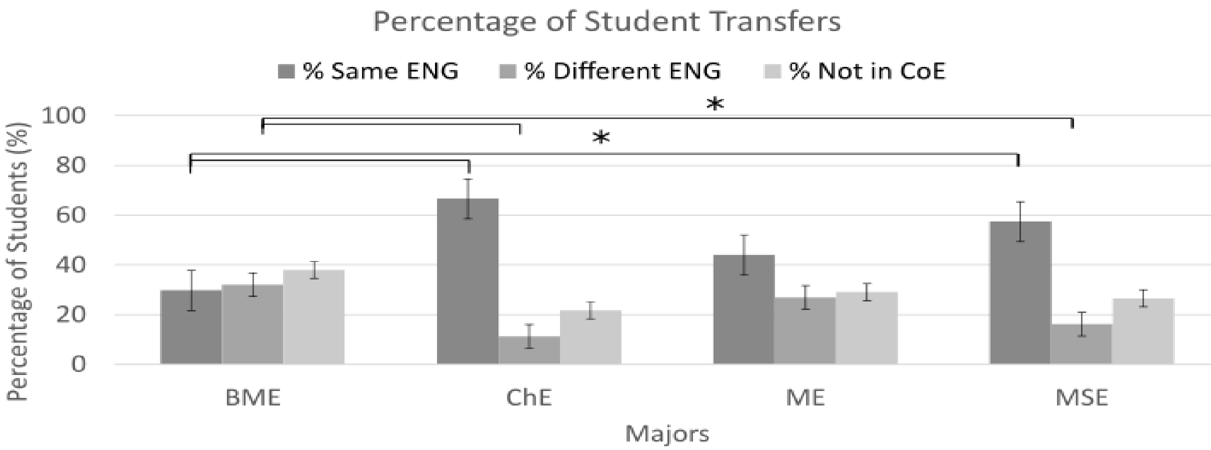

Figure 3: Percentage of student transfer percentages averaged across 2012- 2016. Asterisk indicates significance (p-value < 0.05).

Pre-graduation Work

The number of pre-graduation industry offers made (including internships, co-ops and engineering related part-time jobs), normalized for the number of students enrolled per each respective major, are presented in **Figure 4**. Pre-graduation work obtained without the assistance of OSU's Engineering Career Services is not documented, and therefore may be a limitation in this analysis. ANOVA results indicate a difference in means across the majors ($p < 0.001$), and further post-hoc analyses reveal BME to be considerably different compared to the other three ($p < 0.05$). This result could point towards one of two explanations: either BME students are uninterested in seeking industry-related work prior to graduation, or there is a drastic deficiency in opportunities available to BME compared to the other three majors.

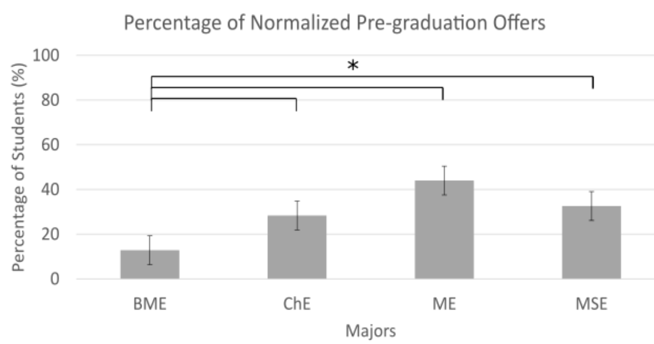

Figure 4: Pre-graduation offers as percentage of students enrolled. Asterisk indicates significance ($p < 0.05$).

Career Outcomes

Average student outcomes for career and further education (i.e. industry and graduate school, respectively) are presented in **Figure 5**. Career outcomes are self-reported by students, and therefore may not be a complete representation of data for this analysis. Statistical analyses revealed a significant difference in the industry outcome means between all four majors ($p < 0.001$). Post-hoc analysis revealed a significant difference in the industry outcomes of BME majors compared with each of the other three majors, as well as between ME and MSE ($p < 0.05$). There was no difference in career outcomes between ME and ChE, or between ChE and MSE. These results indicate a difference among industry outcomes in all majors, but highlight a radically lower industry outcome reported for BME majors compared to the other three majors.

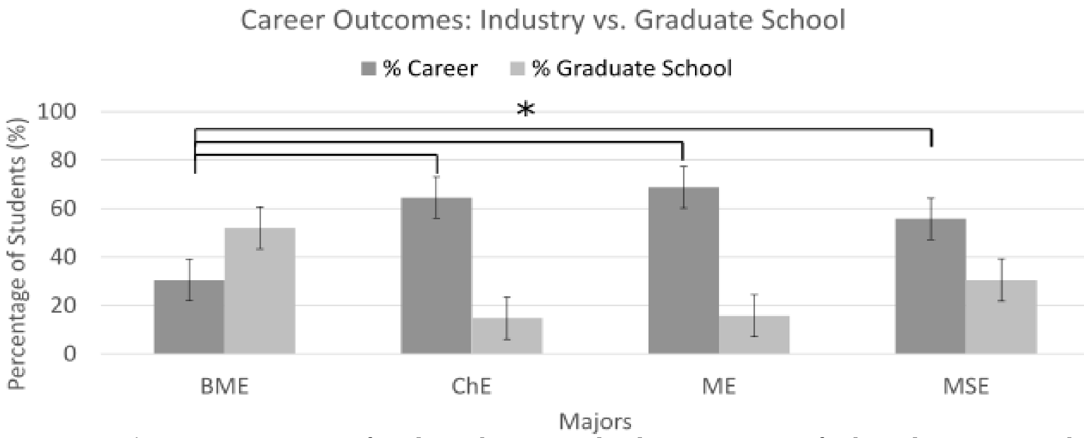

Figure 5: Percentage of students that pursued industry careers or further education in each major. Asterisk indicates significance ($p < 0.05$).

Reported job salaries

The final metric analyzed was the reported salaries of those students that pursued industry after graduation (**Figure 6**). Salaries are self-reported by students, and therefore could be incomplete or askew in this analysis. It was found that BME had significantly lower entry salaries compared to ChE ($p < 0.05$). ME and MSE were not able to be differentiated from BME or ChE. These salary trends are comparable to the National Association of Colleges and Employers (NACE) salary reports. Averaged over the same timeframe as our study (2012-2016), BME bachelor's degree recipients' starting salaries were \$51,003 ± \$7,625 compared to ChE at \$67,714 ± \$1,401 and ME at \$63,464 ± \$1,320 [11], indicating a national discrepancy between BME and the other majors. It is also interesting to note the large standard deviation in BME national salaries. BME salaries have increased by nearly 25%, from \$42,600 (2012) to \$59,057 (2016), while ChE and ME increased by only 3.3% and 5.4%, respectively. While this rapid growth is encouraging for future BME graduates, current students are still experiencing a significant salary gap compared to their peers in ChE and ME. MSE salaries are not reported by NACE.

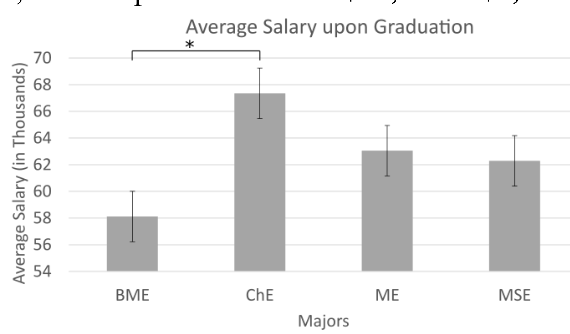

Figure 6 (right): Reported average starting salary for graduating students pursuing industry jobs. Asterisk indicates significance ($p < 0.05$).

Relationships between the Four Metrics

Following individual analyses of each metric, a regression analysis was performed to relate all four measures. Significant relationships were identified between career outcomes and pre-graduation work ($p < 0.001$, $R^2 = 0.85$), as well as between career outcomes and reported job salaries ($p = 0.005$, $R^2 = 0.43$). Additionally, a significant model (albeit with lower correlation) was identified when comparing pre-graduation work and job salaries ($p = 0.042$, $R^2 = 0.26$). Perhaps the most interesting finding was a correlation between average reported job salaries and percentage of students who transferred into a different engineering major ($p = 0.035$, $R^2 = 0.28$). This may provide insight for why many students leave BME in favor of other engineering majors.

Conclusions and Future Directions

This case study seeks to identify potential measures contributing to a gap between BME and industry, relative to three other engineering majors (ME, ChE and MSE), at a large research I university. Analyses of metrics representative of student progression through the university-to-industry pipeline were used to identify differences unique to BME majors. We have found at OSU that BME majors have the highest rate of transfer to a different engineering major, the lowest rate of co-op/internship and career employment offers through Engineering Career Services, and the lowest average self-reported industry starting salary compared to the other majors. Further work is aimed to determine whether these results are generalizable across multiple institutions and/or a potential factor of program youth. Additionally, future directions include *why* BME majors differ from the other engineering disciplines, and *how* that understanding may be used to improve BME industry career outcomes.

References

1. "FAQ's about BME." (2017). Retrieved 2017, from http://www.bmes.org/
2. Benkeser, P. (2006). Benkeser2003_Biomedical Engineering Education. In *Encyclopedia of Medical Devices and Instrumentation*. John Wiley & Sons, Inc. https://doi.org/10.1002/0471732877.emd031
3. Desai, T. A., & Magin, R. L. (2001). Desai_Magin2009 A Cure for Bioengineering? A New Undergraduate Core Curriculum. *Journal of Engineering Education*, *90*(2), 231–238. https://doi.org/10.1002/j.2168-9830.2001.tb00597.x
4. Linsenmeier, R. A. (2003). Linsenmeier2003_What makes a biomedical engineer? *IEEE Engineering in Medicine and Biology Magazine*, *22*(4), 32–38. https://doi.org/10.1109/MEMB.2003.1237489
5. Katona, P. G. (2002). The Whitaker foundation: the end will be just the beginning. *IEEE Transactions on Medical Imaging*, *21*(8), 845–849. https://doi.org/10.1109/TMI.2002.803606
6. Whitaker International Program. (n.d.). Retrieved 2017, from http://www.whitaker.org/
7. Seely, B. E. (1999). The Other Re-engineering of Engineering Education, 1900–1965. *Journal of Engineering Education*, *88*(3), 285–294. https://doi.org/10.1002/j.2168-9830.1999.tb00449.x
8. ABET Accreditation Program. (2017). Retrieved 2017, from http://www.abet.org/
9. Abu-Faraj, Z. O. (2008). Career development in Bioengineering/Biomedical Engineering: A student's roadmap. In *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (pp. 1564–67). https://doi.org/10.1109/IEMBS.2008.4649469
10. Ebrahiminejad, H. (2017). A Systematized Literature Review: Defining and Developing Engineering Competencies. *Proceedings of the American Society for Engineering Education*, Columbus.
11. NACE: National Association of Colleges and Employers (2018). Retrieved 2018, from http://www.naceweb.org/