Chapter 1

Students' Demographics in Postgraduate Engineering Education: The Case of International Students

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Abstract

Engineering was informally viewed as skills that were passed down from engineers who were mostly European immigrants. As times changed and development occurred, these engineering skills were integrated into the curriculum to train engineers to meet the regional economic need in various countries of the world. As a result of various needs of people and of the international community, internationalization of higher education has gained interest recently. In an attempt to unravel this, there must be an understanding of their demographic characteristics, enrolment, and support. In this demographic study, postgraduate engineering international students were the study group and data from the National Science Foundation (2018) was used in this study. Data was collected from graduate students and post doctorates in science and engineering (GSS). This research is a demographic study of doctoral and postdoctoral non-tenure researchers in engineering education. Findings from the study revealed that there was more male enrolment than female in postgraduate programmes. It was also found that among all the race groups, the whites were also high in terms of enrolment in

postgraduate engineering programmes. Findings revealed that the most profound primary source of support for full-time students is nonfederal support. This study recommends that gender consideration be intensified in engineering disciplines to ensure gender equality.

1. Introduction

In the United States, engineering was seen informally as skills that were passed down from engineers who were mostly European immigrants. As times changed and development occurred, these skills were integrated into the curriculum to train engineers to meet the regional economic need. Historically, as a result of the land-grant schools under the provision of the Morrill Act of 1862, engineering education had expanded rapidly in the United States (Marcus, 2005). Afterwards, engineering was integrated into the academia and a four-year curriculum was adopted for a degree course in engineering. In the 21st century, as a result of the massive advances in science and technology and global competition, there is a need to have a workforce that is scientifically oriented and technically proficient which necessitates international students to pursue engineering education. Also, the vitality of the innovation economy in the United States depends on the presence of a highly educated technical workforce and this can only be maintained by retaining international students. For this reason, a major component of the workforce consists of engineers, engineering technicians and engineering technologists.

As a result of various needs of people and of the international community, internationalisation of higher education has recently gained much interest. International students are individuals enrolled in higher education institutions; they are on temporary student visas and are non-native English speakers (Stevens, Emil, & Yamashita, 2009). The need to have international education might be influenced by various factors such as access to better educational facilities, need for global exposure, personal preference,

prevailing conditions etc. International students come from various backgrounds, and they have various experiences. They also bring to the fore various skills and level of the English knowledge (Bektas, 2008; Sovic, 2009). However, in the pursuit of their education, they are constrained with enrolment, support mechanisms, racial bias, language difficulties, acclimatizing to a new environment, new ways of learning and new people who they might not have met before. This is in line with the findings of Lu (2001) who revealed that major areas of concerns for international students in the United States are communication/language, financial issues, socio/cultural issues, psychological/personal, housing, food and health issues.

Some reports from the scientific community have described the effect of demographics on the future of science and engineering workforce (National Science Foundation, 2006). Also, it was revealed that science and engineering have been primarily the domain of white males (National Science Foundation, 2006). It has been observed that a large proportion of the US population is composed of minorities (Barton, 2003). In an attempt to unravel this, there is a need to understand their demographic characteristics, enrolment, and support. This study seeks to ascertain the demographic characteristics of international students and analyse their primary source of support and primary mechanism of support.

2. Literature Review

Engineering education in the early years of the United States was patterned after the English system of apprenticeship. According to Seely (2005) an apprentice is engaged in his work with the help of an experienced surveyor, draftsman or machinist to learn the trade. The apprenticeship model could not keep up with the demand for engineers as the United States rapidly grew and expanded in the 1800s. The approach of most American universities historically has been the classical college model of instruction to teach courses like Philosophy, Greek, Latin and classic literature and to award a Bachelor

of Arts degree. Such an instruction model was not enough to provide the type of engineers needed for a progressing country.

The first engineering programme in the United States was established in 1802 by Congress. The aim of this programme was to train engineers on military and civil engineering principles. The educational programme was made formal in 1917 by Colonel Sylvanus Taylor on the model of the French Ecole Polytechniqe with much emphasis on mathematics and science (Grayson, 1977) After that, universities began to offer engineering coursework during the first half of the 1900s.

For more than 50 years, the United States has made remarkable discoveries in technology as a result of innovation which has culminated in economic prosperity for the nation and social well-being for the citizens. This agrees with the argument of Charles Vest when he maintained that for America to achieve prosperity and security, there must be the discovery of new scientific knowledge and technological potential through research, and a drive for high-end sophisticated technology at a pace faster than anyone else (Vest, 2006). Such a drive to make discoveries, to innovate continually and support sophisticated industries has expanded the engineering knowledge base in the United States.

With the world evolving from different epochs tagged as industrial revolutions, there has been profound influence on engineering education. Engineering education was basically crude and lacked the necessary drive for massive industrialization but as humans interacted more with the environment and for survival, they wished to gain more mastery which resulted in the evolution of various technologies. Engineering education as a discipline evolved as a result and contributed to national development in the country.

Recently, there has been increasing concern for the shortfalls in the number of American students pursuing engineering and other technical courses in the United States (National Academies of Sciences Engineering and

Medicine, 2017) and the diversity among those venturing into engineering discipline (Buccheri, Gurber, & Bruhwiler, 2011; National Academy of Sciences National Academy of Engineering & Institute of Medicine, 2010; National Research Council & National Academy of Engineering, 2014). This might have sparked the increased attention on internationalisation of students in engineering education.

International students across various disciplines impact universities in the United States. Academically, they are a major part of research universities and are seen to be highly vital to innovation in the United States. With international students enrolling in research universities, it is a pointer to the fact that international students are picking up the pace of innovation in the United States and they are essential to the research capabilities of the universities.

Also, as a result of the quality of domestic students, international students are attracted to United States universities. As a result of increasing numbers of international students in advanced studies, it has been proven that programmes should be made better, for which funding is needed. By virtue of their studies, international students pay full tuition fees, and they need to show proof of financial support before gaining entry into the university. Once a student is admitted, more revenue is generated for the university for a certain number of years depending on the type of programme (undergraduate or postgraduate). By injecting billions of dollars to the United States economy each year, international students are a vital source of revenue. From money spent on tuition fees, food, clothing, travel, textbooks, research etc., the United States has benefited extensively.

3. Data and Methods

Data was collected from graduate students and postdoctorates in science and engineering (GSS). The survey of graduate students and postdoctorates in science and engineering (GSS) is an annual census of all academic institutions in the United States and its territories (Guam and Puerto Rico) granting

research-based masters' degrees or doctorates in science and engineering or selected health fields, as of the autumn of the survey year.

The survey data was collected through coordinators at eligible institutions. Coordinators were assigned by their institution and were responsible for identifying all GSS eligible units, collecting the requested data, and submitting the data to the survey contractor. Coordinators were provided with access to the GSS Web survey to report aggregate counts on enrolled masters and doctoral students, postdocs, and NFRs in each eligible unit, as of the fall term of the academic year 2018. Reporting was done by the coordinator uploading a file with requested data to the GSS website, which automatically aggregated the data and populated the cells of the Web survey instrument for each eligible unit. Alternatively, coordinators could also manually enter data into the Web survey. Hard copies of the survey worksheets and GSS-eligible code lists were also mailed to the institution coordinators as reference. The Web survey was the primary mode of data submission. Based on the review of respondent data and explanatory comments provided by the respondents, follow-up telephone calls were made, or e-mails were sent to clarify responses, if needed.

3.1. Data Processing

All data submitted by institution coordinators was reviewed to ensure that data fields were complete, and that data was internally consistent. Data that substantially different from previously reported data was flagged for review by the survey contractor. If additional information or corrections were needed, institution coordinators were contacted by telephone or e-mail and asked to correct and resubmit the survey data.

3.2. Estimation Techniques

The survey method used in this study is a census of eligible units; therefore, weighting for sampling is not applicable.

Imputation rather than weighting is used to adjust for unit non-response; imputation is also used for item non-response.

3.3. Research Design

This research is a demographic study of doctoral and postdoctoral non-tenure researchers in engineering education.

3.4. Target Population

The survey target population of this study was the academic institutions in the United States and its territories (Guam and Puerto Rico) that grant research-based masters or doctoral degrees in science, engineering and health (SEH) fields. This population includes branch campuses, affiliated research centers and health facilities, and separately organized components, such as medical or dental schools, schools of nursing, and schools of public health.

3.5. Sampling Frame

The sample size in 2018 included 19,592 units at 715 academic institutions in the United States that granted research-based master's degrees or doctorates in SEH fields.

3.6. Sample Design

The GSS is a census in which eligible academic institutions are identified primarily through integrated postsecondary education data system (IPEDS)

4. Findings and Discussion

4.1. Demographic Characteristics

The results exhibited in Table 1 show graduate programmes categorized into institutions, schools and units. These findings are categorized into variables such as gender, ethnicity, visa type, and nature of studies.

- *Gender*: Table 1 reveals that out of the total number of all graduate students (163301), the number of males were 121935 (74.7%) while females were 41366 (25.3%). To categorize these further into masters and doctoral programmes, 75.3% of the masters' students were males while 24.7% of the masters' students were females. For doctoral students, 73.9% were males while 26.1% were females. The result implies that there was more male enrolment in postgraduate programmes than females. This is in line with the findings of the National Science Foundation (2006) which maintained that science and engineering have been primarily the domain of white males. The view of Blickenstaff, (2005) also supports this result, maintaining that women with advanced degree are widely underrepresented in STEM fields of which engineering is a part. This might be attributed to the assertion that engineering is often viewed as a discipline for the male gender and until recently, the bulk of the profession has always been dominated by males.
- The inequality in the ration of males to female shows that a high percentage of the entire student demography is males. There are now various concerns to make the discipline more gender friendly and ensure that females are attracted to ensure gender parity. With more males involved in postgraduate engineering disciplines, making the case for gender balance is important. Limited numbers of women in academic STEM disciplines causes great stress on scientific creativity (National Academy of Science, 2007) and results in a shortage of professionals (Kuenzi, 2008).

4.2. Ethnicity

- *US Citizens:* Out of the total number of all graduate students, 47.0% were United States citizens. Table 1 indicates more master's students than doctoral students. It is observed that 51.4% of the population are master's students while 41.2 are doctoral students. It is important to note that a PhD is one of the highest levels to be attained in

terms of academic hierarchy and people mostly start a PhD for professional advancement in academia. Being a United States citizen offers immense opportunities for further studies along doctoral and masters' lines. There are wide opportunities for studies in the country, a conducive environment and infrastructure that is critical to ensure a smooth academic journey. Hence, the high number of postgraduate students that are United States citizens is justifiable in light of this. Also, the number of enrolments for PhD might not be as high as for master's degrees for permanent residents because people might be enthused more about a PhD just to secure a job in academia or for career advancement.

- *Other ethnicity and race*: among the other races considered, the whites were also high in terms of enrolment in postgraduate engineering programmes. Table 1 shows 29.1% of all graduate students are whites. High up the hierarchy are Asians (6.7%). This agrees with the findings of UNESCO Institute for Statistics (UIS) (2014) which reveals that Central Asia has the highest number of international students with the number of its citizens schooling abroad increasing from 673,00 in 2003 to 156,600 in 2012. Other ethnicity and race include Hispanic or Latino (4.9%), black or African American (2.5%), unknown ethnicity and race (2.3%), more than one race (1.5%), American Indians or Alaska Natives (0.1%). This result is in line with the findings of Verbik and Lasanowski (2007) who maintained that the United States is the leading destination for international students. This result is also in line with the findings of Barton (2003) who maintained that since the beginning of the 21st century, a larger proportion of the United States population will be composed of minorities such as blacks, Hispanics, Native Americans etc. Hawawini (2011) also supports this result when he revealed that the impetus for internationalisation in United States continues to gain momentum and the population of international students in the United States has increased steadily from 1940 until present.

- Since the mid-20th century, international student mobility has experienced an increase. The mobility of international students is a strong index of globalization or internationalisation of higher education (Kehm, 2005). International students' presence has been on the increase in the United States and as a result of their presence, they are an important component of diversity. As a result of the increase in the population of international students in the United States, it makes a significant contribution to the personality of the institution and its financial status. With the majority of international students paying full tuition fees, their importance cannot be understated. International students of various races and ethnicity are also vital to research in universities. They are seen to be important to innovation in the United States. This is in line with the findings of Chellaraj, Maskus, and Aaditya (2008) who argued that a 10% increase in international graduate students will culminate in 4.5% increase in patent application. International students in engineering and technology do not outperform domestic students in dissertation awards and patent application; they only complement them Matloff (2013). Also, the findings of the Institute of International Education (2015) revealed that from the vast majority of respondents worldwide, 74% of the respondents chose the United States as their destination of choice for higher studies. This agrees with the result from this study. This also confirms the findings of the OECD (2018) which revealed that the United States is the top destination of choice for international students, whose numbers grew by 7.1% since 2015. This agrees with the findings of Chow (2015) who maintained that the United States remains the major destination for international students.

International students have an increasing presence in many universities in the United States and with their presence they are an important component of diversity of thought. As a result of diversity, they are important for reshaping academic discipline and the entire university community. A walk across

any university campus in the United States speaks volume about the presence of international students and it has become a source of pride for universities to have great diversity.

- *Visa type*: It is important to bear in mind that if you want to take a postgraduate course in the United States and you are not a citizen, you will need to have a student visa in place before your arrival. Table 1 reveals that 53.0% of all graduate population were temporary visa holders. This implies that international students were more numerous in terms of enrolment compared to United States citizens. We also see that 58.8% of the doctoral students, and 48.6% of the master's students, had temporary visas. One of the challenges that international students face in the United States is a cumbersome and exhausting visa process and this implies that only those with determination succeed in gaining entry into the United States universities.
- *Nature of studies*: The postgraduate programmes in the United States afford some degree of flexibility for students and people can decide to work at their own pace. This might be necessary due to various concerns such as job demands, family duties and other considerations. Hence, there are options for full-time and part-time programmes. From the results in Table 1, we see that 73.8% of all graduate population are full-time while 26.2% are part-time students. This might be as a result of the reasons previously mentioned. Similarly, 87.3% of the doctoral students are full-time students while 12.7 are part-time students. 63.6% of the master's students are full-time students while 36.4% are part-time students.
- *First time in United States*: Table 1 also shows that 38,565 students are first time students in the United States. From the results, 27,784 students out of the masters' cadre are first time students in the United States while 10,801 in the doctoral cadre are first time students in the United States.

Table 1: Demographic characteristics.

		All graduate students		Masters students		Doctoral students	
Type		**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
	Institutions	328	45.9	320	44.8	227	31.7
	Schools	340	41.6	328	40.1	235	28.8
	Units	2,246	11.5	2,016	10.3	1,338	6.8
	All graduate students	163,301	100.0	93,064	100.0	70,237	100.0
Sex	Male	121,935	74.7	70,039	75.3	51,896	73.9
	Female	41,366	25.3	23,025	24.7	18,341	26.1
Ethnicity and Race	U.S. citizens and permanent residentsa	76,770	47.0	47,813	51.4	28,957	41.2
	Hispanic or Latino	7,939	4.9	5,436	5.8	2,503	3.6
	Not Hispanic or Latino						
	American Indian or Alaska Native	211	0.1	140	0.2	71	0.1
	Asian	10,863	6.7	6,758	7.3	4,105	5.8
	Black or African American	4,035	2.5	2,618	2.8	1,417	2.0

		All graduate students		Masters students		Doctoral students	
Type		**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
	Native Hawaiian or Other Pacific Islander	75	*	45	*	30	*
	White	47,447	29.1	28,993	31.2	18,454	26.3
	More than one race	2,460	1.5	1,519	1.6	941	1.3
	Unknown ethnicity and race	3,740	2.3	2,304	2.5	1,436	2.0
Visa type	Temporary visa holders	86,531	53.0	45,251	48.6	41,280	58.8
Nature of study	Part time	42,780	26.2	33,836	36.4	8,944	12.7
	Full time	120,521	73.8	59,228	63.6	61,293	87.3
First time		38,565	23.6	27,764	29.8	10,801	15.4

Source: *National Science Foundation (2018).*

Table 2: Primary source of support for full-time students

	All graduate students		Master's students		Doctoral students	
Institution	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Federal	21,961	13.4	3,591	3.9	18,370	26.2
DOD	4,346	2.7	1,255	1.3	3,091	4.4
DOE	2,191	1.3	302	0.3	1,889	2.7
HHS	3,271	2.0	240	0.3	3,031	4.3
NIH	2,615	1.6	135	0.1	2,480	3.5
Other HHS	656	0.4	105	0.1	551	0.8
NASA	703	0.4	157	0.2	546	0.8
NSF	8,159	5.0	832	0.9	7,327	10.4
USDA	325	0.2	90	0.1	235	0.3
Other	2,966	1.8	715	0.8	2,251	3.2
Nonfederal	53,424	32.7	15,758	16.9	37,666	53.6
Institutional	44,127	27.0	13,544	14.6	30,583	43.5
Domestic	7,294	4.5	1,672	1.8	5,622	8.0

	All graduate students		Master's students		Doctoral students	
Institution	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Foreign	2,003	1.2	542	0.6	1,461	2.1
Self-support	45,136	27.6	39,879	42.9	5,257	7.5

** = value < 0.05%.*
DOD = Department of Defense; DOE = Department of Energy;
HHS = Department of Health and Human Services;
NASA = National Aeronautics and Space Administration;
NIH = National Institutes of Health;
NSF = National Science Foundation;
USDA = Department of Agriculture.
a Ethnicity and race data are available only for U.S. citizens and permanent residents.
b Funding data are available only for full-time students.
NOTE: Percentages may not add to total because of rounding.
SOURCE: National Center for Science and Engineering Statistics,
Survey of Graduate Students and
Post doctorates in Science and Engineering, 2018.

4.3. Primary Source of Support for Full Time Students

The cost of higher education in the United States increases on a yearly basis and many students find it challenging to support themselves across their programme. With postgraduate studies in the United States, there are a series of support programmes for students. From the data in this study, some of the primary sources of support for full-time students include federal support, support from the departments of defense and energy, National Aeronautics and Space Administration; National Institutes of Health; National Science Foundation; and United States Department of Agriculture. Table 2 indicates that the most profound primary source of support for full-time students is nonfederal support (53,424). Apart from this primary source of support, self-support is next in line. Most of the postgraduate students supported themselves using their own means (27.6%). This might be attributable to the fact that the US economy provides them with the opportunity to support themselves using their own means. Other prominent means of primary support for full-time students are institutional support (27.0%) and federal support (13.4%). Other sources of support are the DOD (2.7%), DOE (1.3%), HHS (2.0%), NIH (1.6%), Other HHS (0.4%), NASA (0.4%), NSF (5.0%), USDA (0.2%), Domestic (4.5%), foreign (1.2%), others (1.8%).

4.4. Primary Mechanism of Support for Full-Time Students

Table 3 contains data on the primary mechanism of support for full-time students. Most higher education institutions in the United States have various primary mechanisms of support for students which include fellowships, research assistantships, teaching assistantships, and traineeships. Other types of support include self-support and other types. From the results, it is seen that the most prominent source of support is other types of support (33.8%). Under this support mechanism, self-support (27.6%) is the major primary mechanism of support for full-time students. It is important to note that postgraduate studies require support for successful study. Postgraduate studies are often done by those who have the wherewithal to support themselves

throughout the educational process. With reference to the data in Table 3, more master's students (42.9%) engage in self-support compared to doctoral students (7.5%). This might be because a master's degree might be less capital-intensive than a doctoral degree. Other primary mechanisms of support for full-time students include research assistantships (23.5%).

Doctoral students have more support (45.6%) in terms of research assistantship than master's students (6.9%). This puts them primarily in the line of research. With the two-pronged need to support research in higher education and the need to support students throughout their programme, research assistantship is important. Also, there are teaching assistantships (9.3%) to encourage students to develop their teaching skills and also earn money to support themselves throughout their educational journey. More doctoral students (14.8%) are involved in teaching assistantships than master's student (5.2%).

Fellowship is also a primary mechanism of support for full-time students (6.1%) and traineeships (1.0%). Fellowships provide a basis to start a career or significantly improve one's career and make impressive contributions to one's academic profile. While on fellowship, the individual works with professionals along engineering lines, receives mentorship, enhanced training opportunities, networks and makes connections in the field which can lead to further opportunities and better career choices. There are different types of fellowships depending on various factors such as discipline. Doctoral students have more primary mechanisms of support for full-time students in terms of fellowship (11.7%) compared to master's students (1.9%).

5. Conclusion and Recommendation

The findings of this study should be carefully interpreted because it was a demographic study focusing only on international postgraduate engineering students in the United States. Thus, generalizing beyond this group of international students is limited. Future studies should consider an analysis

Table 3: Primary mechanism of support for full-time students.

	All graduate students		Master's students		Doctoral students	
Support Mechanism	**number**	**Percent**	**Number**	**percent**	**number**	**Percent**
Fellowships	9,971	6.1	1,752	1.9	8,219	11.7
Research assistantships	38,457	23.5	6,404	6.9	32,053	45.6
Teaching assistantships	15,259	9.3	4,858	5.2	10,401	14.8
Traineeships	1,557	1.0	536	0.6	1,021	1.5
Other types of support	55,277	33.8	45,678	49.1	9,599	13.7
Self-support	45,136	27.6	39,879	42.9	5,257	7.5
Other	10,141	6.2	5,799	6.2	4,342	6.2

Source: National Science Foundation (2018).

of other groups. The study considered the demographics of postgraduate engineering students using international students as a case study. It is important to note that there is an intensified effort on internationalisation of students in the United States because of the various advantages it confers on the country. Numerous among such is diversity. With diversity amongst various students in the universities in United States, it has strengthened academic processes and research. It has also resulted in the increase of revenue for the government which has consequential benefits for the country as a whole, the citizens and their social well-being. The United States has been a top choice of destination for international studies and this might be attributed to the quality offered in terms of education and the presence of necessary infrastructure critical to the overall success of students. This study found that there is a wide gender gap between males and females. This must be critically addressed and concerted action should be taken to encourage gender equality in engineering disciplines. There is a minority presence in the demography although this a low. This study therefore recommends that gender consideration be intensified in engineering disciplines to ensure gender equality. Also, there should be increased attention given to enrolment of international students in the United States.

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