
GC 2012-5626: ENGINEERING EDUCATION AROUND THE WORLD: A STUDENT PERSPECTIVE

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Engineering Education around the World:

The student experience from the students' perspectives

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Abstract—This study highlights the undergraduate experience in engineering training in a sample of countries. Student respondents provide their unique perspectives on their choices, opportunities, attitudes, and aspirations.

Keywords—engineering education; United States, Brazil, Trinidad and Tobago, India, Australia; student perspective

I. MOTIVATION

The student experience in engineering training varies greatly from one university to another, not only within the US, but also around the world. The structures, practices, and cultures of engineering training that differ between nations and regions create unique environments¹ in which engineers learn and grow. Each country's policymakers, the United States included, could benefit from understanding, analysis, and comparison of engineering systems besides their own. Through its collaborations with students internationally, the Student Platform for Engineering Education (SPEED) presents a paper that takes a broad look at the differences between engineering education systems from the perspectives of the students being trained within them.

The authors first present an overview of some common models and characteristics for undergraduate training structures. We note differences along the dimensions of curriculum, teacher qualifications and practices, connections with industry, and infrastructural support in the school. As the literature provides few examples of comparative analysis of student development from the student perspective, we then employ case study methods to fill this gap in the extant body of work. Case studies provide depth to the picture of engineering education across the spectrum: Brazil, Australia, the United States of America (USA), India, and Trinidad and Tobago (T&T) are included as examples of the varied ways in which engineers are prepared to address industry and development challenges around the world. SPEED's connections to students around the world provide a data source for student feedback in all of these contexts. As part of the

case studies, the paper highlights individual reports from students who are in or have recently experienced engineering training in each country. A student from each country is asked the same general questions about his/her experiences navigating the university engineering training system. We find that numerous themes that emerge from students' descriptions of their experiences are common between the five environments represented.

Understanding the variety of goals, approaches, and outcomes of engineering training in different nations provides a sense of the variety of other possible policy tools. Students, educators, and policymakers looking to shape their engineering training can benefit from the successes and pitfalls of other systems. And, as the global mobility of the engineering workforce increases, it is vital for employers and educators to understand the background of employees and students who might join them; the student perspective in an international and comparative context is a voice that provides user feedback on engineering training.

II. RESEARCH QUESTIONS

How can we characterize the student experience of undergraduate engineering training from the students' own perspectives?

More specifically:

- What factors do students choose to highlight in their descriptions of their personal experience?
- What general factors do students cite as beneficial or detrimental to their experiences?
- What components of the institutional training delivered are highlighted? What components outside the official system are highlighted?
- What are some commonalities between diverse national engineering and education environments?
- What aspects may characterize unique national environments?

III. CONCEPTUAL FRAMEWORK

This section provides an overview of the some of the major debates in engineering structures today, a background for the components of engineering training that might be highlighted

1 Downey, G.L. & Lucena, J. (2005). National identities in multinational words: engineers and 'engineering cultures'. *International Journal of Continuing Engineering Education and Life Long Learning*, 15(3): 252-260.

in the student perspective on their experiences. In addition, we highlight notable developments in the countries that are represented in our student sample.

The major elements of engineering training that are often highlighted in the literature include the curriculum content provided in undergraduate programs, the identity of the student who accesses undergraduate engineering education and how s/he gets in, the professors in the engineering faculty, and opportunities to connect with industry. To this, we add the broad component of the purpose of engineering education, intimately related to a university's structure. First and foremost, though, we describe the few pieces of research done focusing on the engineering student perspective in the university experience.

One of the most comprehensive was created and administered by the state of Texas². Students were given numerous categories of Likert-scale and multiple-choice questions on a survey that investigated the characteristics of their training they saw as important and the quality of training in those realms that was delivered by their universities. Researchers asked about a thorough and specific set of skills and constructs taught in both 2- and 4-year engineering courses. Smaller survey work has been done to understand engineering student retention³ and choice of career⁴. While these studies discern important patterns in student responses to the characteristics identified as important by professors and policymakers, they do not emerge from the student perspective.

A. Prototypical models

National policymakers create, support, and view engineering training institutions for different purposes. In varying geographic regions, cultures, resources, and practices; different colonial histories, national allies, and populations; and different development goals, economies, and technology environments all lead to and indicate different purposes for education. Some nations built their engineering training systems to serve a more vocational/technical focus, while others focus on practical, R&D preparation, and still others focus on scientific training of advanced theorists.

The French system of *Grandes Ecoles* is seen as highly theoretical, grown out of the military and civil service traditions. Elsewhere in Central Europe, German engineering training grew out of a similar start with high-prestige academic training of state engineers. This then translated to an earlier

adoption of using these same methods for training engineers for the private sector⁵.

Even in recent years, as established engineering traditions vie for new positions in a more interconnected world, policymakers are considering re-conceptualizing their approaches but still exhibiting key differences based on their traditional structures. Lucena and coauthors describe major differences in three regions⁶. The United States had an established system of engineering education organizations (e.g., ABET) overseeing a training regimen closely connected to industry and oriented towards hands-on learning inputs. Europe, as an emerging unified identity, has wrestled with combining established, prestigious systems of engineering training including strong theoretical components with more diverse national partners and demands for continental mobility. And, Latin America has had to straddle traditions coming from Europe and America. Brazil, as it refined its model under a national framework, consciously considered the French model for engineering education against models that grew organically out of local structures and political negotiations.⁷

Researchers in science education also recognize possible differences in pedagogical approaches based on different cultural and political structures.⁸ Beyond broad cultural differences, though, more specific dimensions of engineering training are frequently raised as the major areas that policymakers can shape to train engineers.

B. Curriculum: theory vs. practice

In the curriculum, balance must be struck between theory and practice. Engineering as a discipline struggles to find the ideal mixture of theoretical training, practical experience, and the essential but even more challenging classes that combine both. Increasingly, debates around quality and adherence to widely-accepted standards serve to create a consensus around how much theory and how much practice is needed in the engineering curriculum. Accreditation efforts and increased connectivity between training programs reflect broader pushes for more national education standards in general and coherence in engineering in particular (in Australia^{9,10}, for example).

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- 2 The Texas Higher Education Coordinating Board [THECB]. (2010). Engineering Student Surveys. Accessed from THECB [<http://www.thecb.state.tx.us>] December 1, 2010.
 - 3 Anderson-Rowland, M.R. (1997). Understanding Freshman Engineering Student Retention through a Survey. American Society for Engineering Education Conference.
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C. *Students: accessibility vs. quality vs. flexibility*

Another major set of concerns to balance is in the profiles and numbers of students to admit. Despite concerns about the numbers of students going into engineering, there are still significant differences in the proportions of students who are women or under-represented minorities in the US or in other countries who enter or stay in engineering fields.

Brazil's engineering education system exemplifies the dilemma—trying to balance high-quality student applicants with a desire to have the diverse population represented in the national body of engineers. Brazil's system includes a small cadre of high-prestige engineering programs with very competitive admissions. However, there is a huge difference in the perception of quality between programs, in particular between highly-regarded public universities and newer private programs, some of which cater to non-traditional students. In addition, the last decade has seen Brazil's higher education system trying to grapple with racial and socioeconomic quality through a controversial quota system. Such challenges of recruitment, quality, and diversity are reflected in educational developments around the world.

A huge number of students are studying abroad¹¹. Concerns about the migration of human capital often focus on the loss of STEM workers from both high- and low-income economies. These fears are added to the overall worry that there are not enough students entering or persisting in STEM fields to answer the needs of industry, innovation, or development.

D. *Teacher qualifications and practices*

The training of engineering professors faces challenges of balancing competing needs as well. Research training, usually through traditional doctoral programs, is juxtaposed with industry experience as an important qualification for those who are training engineers. In addition, there is a growing recognition that even engineering professors need to have pedagogical training.

In a recent qualitative survey of students, faculty/deans, and industry, students provided a characterization of their "ideal" professor.¹² The top characteristic of professors that students reported they were looking for was "inspiring/motivating". Beyond this, students sought an educator who was prepared knowledgeable, including with practical real-world knowledge, as well as someone committed to teaching and helping, someone who is an effective communicator, and a person of integrity. Overwhelmingly, the top priorities for students have to do with the professor's leadership by example and his/her

communication of learning. Overwhelmingly, EE stakeholders note that this is lacking in the professoriate.

E. *Connections with industry and university infrastructure*

Finally, the connections at the institutional level between the university and relevant industry partners as well as the physical resources of the university are important characteristics. Some universities have reshaped their infrastructure to facilitate more connections with industry, looking at either off-site involvement with industry (through required internships/apprenticeships) vs. on-location (innovation centers/hubs).

Policymakers and employers are concerned about both having enough engineers¹³ as well as new employees having the necessary skills¹⁴. While policymakers recognize that engineers need more hands-on training, administrators debate whether this industry experience should happen before graduation or whether the school setting should be for theoretical preparation followed by graduation to actual practice. These unsettled debates provide a backdrop for the student perspectives on the engineering training they receive.

IV. SAMPLE

Data for this study come from a sample of SPEED members, officers, and affiliates. Respondents were chosen as a convenience sample first approached through a broad call for participation within the SPEED network and second through the contacts of involved SPEED members. Respondents are therefore a highly-involved group of high-achieving engineering student leaders.

The Indian respondent has facilitated multiple workshops with SPEED and its affiliate organizations and is now looking to apply to graduate programs outside of India. He has completed his bachelor's degree and worked in industry in numerous locations in India. He served as SPEED's Indian outreach officer.

The Australian respondent has also facilitated multiple workshops with SPEED and affiliate organizations and is currently enrolled in a doctoral program in Australia. His research focus is related to engineering education. He is SPEED's current president.

The Trinidadian respondent is connected to a highly-involved (former Vice President) American SPEED member. The respondent currently attends graduate school in the Northeastern United States.

The American respondent is also connected to the former SPEED Vice President and attends graduate school in the United States.

Comparative Education, 24 (3).
10 Webster, J. (2000). Engineering Education in Australia. *Int. J. Eng Ed*, 16(2): 146-153.
11 Organisation for Economic Co-Operation and Development. (2007). *Education at a Glance 2007: OECD Indicators*.
12 Morell, L. & DeBoer, J. (2011). The ideal engineering professor. In *Multiple Stakeholder Perspectives of Higher and Engineering Education*, Macmillan (India).

13 Walden, S.E. & Foor, C. (2008). "What's to keep you from dropping out?" Student Immigration into and within Engineering". *Journal of Engineering Education*, 97(2): 191-205.
14 Wooldrige, A. (2006). The battle for brainpower. *The Economist*, October 5, 2006.

The Brazilian respondent has facilitated workshops with SPEED and led his own local student organization. He is currently a master's student in an engineering field as well as the internal affairs officer of SPEED.

A. Limitations

The students sampled are necessarily part of the SPEED network, and so are a non-representative group of engineering students. They are interested in thinking about issues of engineering education already, so their perspective raises external validity concerns and may not be generalizable to many other groups of students in their home countries.

In addition, these engineers are an international group. They have traveled and/or studied abroad, and they are connected to an international student group. As we use a qualitative approach in our work, we will not attempt to generalize findings here but instead to generate hypotheses to test in future follow-up work (see *Future Work*).

V. METHODS

While we provide an overview of some of the important factors making their way into academic and policy debates about engineering education, the methods we employ for gathering student perspectives are necessarily inductive. We ask students very broadly to describe engineering training in a particular country. Then, we look across and within responses to understand themes that emerge from the student voices.

A. Interview protocol

The semi-structured interview protocol was distributed to each of the five respondents via email. It was nearly unstructured. This was employed in order to elicit responses unbiased by the types of questions asked about the students' experiences. The questionnaire follows:

"Tell me about the university engineering training in <respondent's country>. What are some defining characteristics of the system? What about your experience in undergraduate training? How did you navigate the route from undergraduate to <current position>?"

Brackets ("< >") indicate where questioning was specific to the student respondent.

B. Grounded theory, emergent themes

The idea of using the student perspective as a way of conceptualizing and prioritizing engineering training structures is novel. Because of the dearth of literature on this area of study, we employ a qualitative framework to begin to generate hypotheses about the factors that comprise the student perspective of their experiences in engineering training. Grounded theory provides the basis for this work, as a large amount of information was gathered, and broad characteristics then emerged as themes.

In order to not influence participant response by having prescribed categories to which to respond, a small number of

open-ended questions were provided to each respondent. The questions were only tailored to each respondent's country name and the name of their current degree. Answers were collected by the authors in the form of text-based email responses. The length of the responses varied by participant and question.

Data coding and categorization were completed by the authors. The responses were scanned for the specific mentions of educational components are categories of educational factors. Specific factors coalesced around bins or categories of responses, and emergent themes were identified and named to describe the larger construct they refer to from the student's point of view. We compare and contrast the structures and characteristics of the engineering education system from the student perspective(s).

The themes consolidated from the five cases in our sample are noted in the two results sections that follow. The first results section details themes that are common and run through the five respondents' perspectives and the second section details themes that emerge for individuals.

VI. RESULTS: EMERGENT THEMES

Characteristics that emerged from looking across the varied student respondents coalesced around four important issues. First, the student's own pro-active engagement was an important facilitator of the student's experiences. Second, the students described an orientation towards practice in their training. Third, all of the students paid close attention to describing *who* participates in engineering education and how to get into training programs. And, finally, the motivation of the individual students was described.

A. Role of student's personal initiative

One of the major themes to emerge across student responses was the emphasis on the role of the student's own initiative in creating key opportunities in that student's training process. Even students coming from highly-ranked training programs note that important curricular and extra-curricular activities arose from their own attentiveness to seeking out such opportunities. They note that some of their best experiences come from seeking out enriching activities in the social or co-curricular sphere.

For example, the "best experience" of the Indian respondent was "the opportunity in various areas to participate and explore", including his work as student body president and coordinator with local industry.

Because of these experiences, students were able to supplement the official training that they received by seeking out the opportunities that might have been part of a more "comprehensive" training program. These components of a complete engineering education organically transpire for some students even if they are not systematically offered, as student look for and find clubs, internships, or mentoring partners to fill their needs.

This may be a characteristic of the students included in this initial round of interviews. The students involved with SPEED are necessarily self-starters, so much of their engineering education life may be characterized by creating space for their own individual opportunities.

B. Existing orientation towards practice

In the balance between theory and practice, students tend to describe a practical orientation in their courses. Some industry connections exist everywhere, through school or otherwise. In each response, the theme emerges of opportunities for practice or at least a notion on the part of students that this is needed. The students had all found chances to connect with industry, and all described some kind of connection that existed within their universities.

However, the converse is also true; research is not emphasized for undergraduate students. It is not taught. While the respondents are all in graduate programs, it was personal connections, a passionate personal desire, or an internship experience that actually led the students to find their ways into an advanced degree program.

C. Access: who gets into engineering and how

As current or recently graduated students, respondents are quick to note the official process they had to navigate to reach their current position. More specifically, they describe the accessibility or lack thereof in the engineering education system. They note the requirements for rigorous exams (Brazil and India), the funding mechanisms (Australia), and the overwhelmed student perception of engineering as a possible measure and way of life upon entering college (US and Trinidad).

Students also discuss the identity of the engineer, understandably focusing attention on their own identity as well as that of their peers. They note the discrepancies in access—based on geography and local industrial contexts (Brazil), race/ethnicity, SES, and gender (Australia), and prior educational experiences (USA).

D. Motivating factors

Respondents pointedly note the prestige of the field. Engineering is seen as a highly-valued, respected, prestigious field, attracting high-performing students, parental pressure, and a concern about reputation. Students readily mention the factors that push them to participate in this field.

The motivating factors for entry and persistence in the field are early all intrinsic. Students want to adhere to parental ideas about prestigious work; they want to go through the “trial by fire” (Trinidadian respondent) and show that they could become an engineer; or, they are innately interested in the topic. They have a personal sense of obligation (US respondent) or a broadened sense of obligation to family (Indian respondent).

E. Curriculum overload and rigidity

All of the students mentioned the limitations that the size and strict application of the curriculum placed on their flexibility and development. According to the Australian respondent, there were “rigid course requirements, every subject defined without opportunity to explore outside degree program”. The Trinidadian respondent described the overwhelming set of classes, a result of the need to meet (sometimes competing) demands of industry, international accreditation, and freedom for student choice.

VII. RESULTS: NATIONAL DIFFERENCES

While some emergent themes are shared across the student respondents, other themes appear within a student’s individual perspective and could perhaps be more reflective of the unique national environment to which that student is exposed.

A. Teacher quality

Not all of the respondents discuss teacher practices or qualifications, and when they do, they may be positive or negative. The Trinidadian respondent described in detail a highly cohesive curriculum that employs scaffolding, student-centered and student-delivered pedagogy, and other best-practices teacher methods.

In contrast, the American response deplores the lack of foresight in teacher hiring:

“Faculty are hired for research, but they end up being bad teachers...[schools are] investing in one professor rather than hundreds of students” (US respondent).

The Australian respondent notes that since teachers are hired for research, they are far removed from the necessary practical exposure that industry experts would have.

B. Structural differences between schools

Brazil and India are both characterized as having engineering institutions widely varying in quality and highly unequal. In Brazil, this hierarchy is a strong public/private dichotomy (public having higher quality), noted in overview also.

In India, the quality structure is also distinctly hierarchical, varying notably by three levels. There, the distinction in prestige translates directly into more or less student-centered teaching practices and more or less opportunities for hands-on, laboratory-based experiences.

C. Pre-college preparation

Some respondents mentioned the lack of training they had prior to college. In particular, the American respondent discussed the lack of preparation received in high school and the confusion of not even knowing “what an engineer does” upon entering the program. The Trinidadian respondent described the notable difference and difficult transition from high school even to the first class in the engineering program.

D. Some programs notably more theoretical

Some of the programs exhibited a much higher level of focus on theory. In Brazil, the student noted that, even for him (admittedly more interested in theory), he felt the need for universities to be more connected with companies:

"It would be great to get more contact with practical fields and see better where I can apply my skills. I think that it's not hard contact companies to open doors to students to learn more about the process and to be interested to join in the company." He notes that even with the focus on theory, this has not translated into production of scientific research for the country, perhaps since training in research methods and practice do not accompany the theoretical focus (see above emerging theme on practical orientation).

While the US respondent did have a lengthy industry/academic combined experience, the respondent describes this as "unique", noting that most American programs are not as job-oriented. The core curriculum and subsequent electives provided a good education, but the focus was not on job preparation.

E. Some programs very job-oriented

In contrast, some of the programs are described as highly job-oriented. The Trinidadian respondent describes how growing and dominating local industries need more engineers, and so the education system is tailored to produce engineers for those jobs, ready to work. In India, students are prepared for the "jobs they want".

According to the Australian respondent, his training was "a positive experience, both from an educational and social perspective. After completing my degree I felt well equipped to being working as a graduate engineer." Again, he noted the major need for engineers voiced by industry in the country.

VIII. IMPLICATIONS

We find that students highlight experiences that changed their own understanding of the relevance of the engineering skills they learned in the classroom—a hands-on project that was meaningful, an internship where concepts finally "clicked". We also find that, while students note the systematic opportunities in place for developing engineers, the most useful opportunities are a result of student-initiated action. Students report that they have found the best learning opportunities of their own volition, outside of the traditional lecture hall, whether because they are not readily available or because they are more meaningful since students sought them out. The implications of our paper call for a more systematic incorporation of useful, hands-on learning activities and the formal incorporation of student feedback in the structure of engineering student development generally.

A. Contribution

This paper is unique not only in its international perspective, but in its emphasis on the student experience and

the student perspective in these different environments. Our paper adds an important perspective to the "student development" track.

B. Future Work

As a result of this initial exploratory, qualitative work, we can begin to generate categories of interest and hypotheses as to what might explain students' application, persistence, and success in engineering disciplines.

In the future, we will again use grounded theory to examine the broad themes that emerge about what dimensions students use to characterize their educational experiences in undergraduate engineering training. We can expand the sample to include students from other countries as well as students with varying degrees of success.

With more data from longer responses, we can apply other qualitative analysis tools to conduct content analysis and identify and show a more detailed structure of response themes and details.

Finally, we hope to generate areas of questioning that can become a survey and augment current surveys. We can test hypotheses generated from our initial work on regional differences in how students might characterize their educational experiences. Work can then include a larger sample of students from a sample of countries, and we will distribute a survey built from this initial inductive work.

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