

Challenges and Opportunities for Recruiting Students to Undergraduate Civil Engineering Programs

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Jon See is the Executive Director for Annual Giving at East Tennessee State University, arriving in November 2015. In this capacity, Jon is responsible for acquiring, upgrading, and renewing contributors to the University. Retired from the U.S. Air Force since 2003, Jon worked at Purdue University since 1997, working in Air Force Reserve Officer Training Corps (ROTC), Information Technology, the College of Engineering, Corporate Relations, and in the School of Civil Engineering. Jon is a graduate of the Community College of the Air Force and Concordia University—Wisconsin. He has a 19-year-old son named Tyler and a dog named Odie.

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Challenges and opportunities for recruiting students to undergraduate civil engineering programs

Abstract

Society needs more civil engineers, with the projected near-term need for civil engineers greater than any other engineering discipline. Ailing national infrastructure and projected retirement rates have led to job projections suggesting that the near-term need for civil engineering graduates is almost double that of any other engineering discipline. This need, combined with other attractive attributes of civil engineering, should make civil engineering a top engineering major at many undergraduate universities.

In spite of the career opportunities readily available to graduating civil engineers, and in spite of the general increasing trend in the number of total undergraduate engineering students, undergraduate civil engineering programs, taken as a whole, have struggled to maintain and grow their numbers. Individually, many undergraduate programs struggle to recruit students to civil engineering, and this poses a major problem not only to individual programs but to the profession itself.

We analyzed a set of civil engineering student surveys to determine the factors, attitudes, and experiences that typically lead students to select careers in civil engineering and found several common responses, many of which can be leveraged to promote the discipline. The data suggest that about one half of our students pre-select civil engineering prior to beginning as first-year engineering students, and that the top reasons for their selection of civil engineering include: a passion for building things; a desire to make a difference; flexible career options; and a love for math and science (which presumably is shared by young engineers of all disciplines).

We present data from another survey carried out with undergraduate students in other engineering majors, as to why students select other disciplines and how civil engineering is perceived. This survey highlights several perceptions about civil engineering among first-year engineers. These include the misperception of civil engineering as a narrow field focused only around bridges, buildings, and roads, as well as the perception of civil engineers earning low salaries.

These student perceptions pose challenges to civil engineering recruiters, but also afford opportunities for clarification and improved recruitment, especially for programs that allow students to select their engineering discipline during their first year of college. We conclude this paper with a set of talking points we have deployed at our own university that directly address the above challenges and opportunities.

Introduction

The need for civil engineers

American infrastructure continues to age and deteriorate, and this supports a continual need for civil engineers in the foreseeable future. The well-publicized 2013 Report Card for America's Infrastructure¹, prepared by the American Society of Civil Engineers, determined that America's

overall infrastructure grade was a D+. The Report Card additionally suggested that an estimated \$3.6 trillion would need to be invested in improving and rehabilitating America's infrastructure by the year 2020.

Civil Engineers will undoubtedly play a key role in this work. The United States Department of Labor's Bureau of Labor Statistics projects that an additional 23,600 civil engineers will be needed by 2024 in large part to meet these demands, an 8.4% increase from 2014^{2,3} (Table 1). This projected number of Civil Engineers greatly exceeds the projections of all other major engineering disciplines and is nearly twice that of the next most in-demand discipline. If civil engineering and environmental engineering job projections are combined (as is the case at many institutions), the demand increases to approximately 30,400 new jobs. This number rises to 129,100 job openings, when considering replacement needs in Civil and Environmental Engineering between 2014 and 2024 (Table 1).

Table 1. Recent enrollment trends and projected job openings. Projected job openings for engineering disciplines over the period 2014-2024, as projected by the United States Department of Labor³, and recent undergraduate enrollment increases for the period fall 2009-Fall 2014, as reported by ASEE⁴. †Summations over disciplines shown in table; ††Summation over all engineering disciplines reported by ASEE, which includes additional disciplines

Engineering discipline	Projected employment change (total number of jobs) ³	Projected job openings due to growth and replacement needs (2014-2024) ³	Recent total (%) increase in total under-graduate enrollment (Fall 2009-2014) ⁴
Aerospace engineering	-1,600	3,200	1,865 (+10.6)
Agricultural engineering	+100	700	1,455 (+45.6)
Biomedical engineering	+5,100	10,900	8,876 (+49.9)
Chemical engineering	+600	10,000	13,763 (+48.1)
Civil engineering	+23,600	106,700	-1,777 (-3.5)
Computer hardware engineering	+2,400	18,400	Not. Avail.
Electrical engineering	+1,800	34,100	18,894 (+25.8)
Environmental engineering	+6,800	22,400	1,094 (+34.4)
Industrial engineering	+2,100	72,800	5,293 (+39.2)
Materials engineering	+300	9,200	1,906 (44.2)
Mechanical engineering	+14,600	102,500	35,238 (41.3)
Nuclear engineering	-700	4,400	-1 (-0.05)
Petroleum engineering	+3,400	13,000	4,239 (105.2)
TOTALS	+56,400[†]	335,500[†]	141,951 (35.2)^{††}

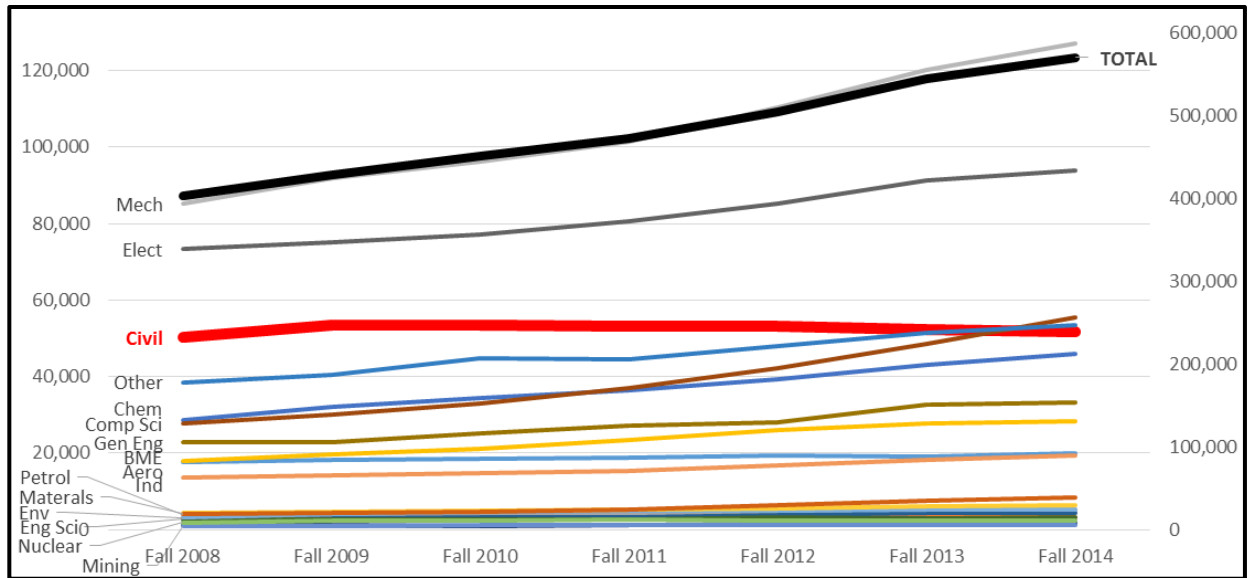


Figure 1. Total undergraduate enrollment for the period 2008-2014, as reported by ASEE⁴. Discipline-specific numbers are presented on left axis, with total enrollment over all disciplines (“TOTAL”) presented on the right axis. Disciplines definitions follow those of ASEE⁴.

Trends in civil engineering undergraduate numbers

Despite these projected demands for civil engineers, an analysis of recent-term enrollment data provided by the American Society of Engineering Education (ASEE) shows that civil engineering undergraduate enrollment has not risen in recent years⁴ (Table 1; Figure 1), in spite of a large overall increase in the number of total undergraduate engineers. *Moreover, during the period 2009-2014, civil engineering is the only engineering discipline to have a major overall drop in enrollment. This enrollment trend, if continued, paired with the projected near-term need for the profession, suggest a looming civil engineer shortage, if not a crisis for the profession.* The enrollment data further suggest that this undergraduate “recruiting problem” is largely – if not entirely – specific to civil engineering. Low enrollments result in logistical challenges pertaining to individual course enrollments. Since resources (including faculty positions and staff support) received by units in a university are often tied to undergraduate student numbers, this does not bode well for CE programs and for the profession as well.

Paper overview

Why are engineering students not choosing civil engineering as their undergraduate major despite job projections being very strong? The goal of this paper is to shed light on this question from preliminary data we have gathered thus far at Purdue University using targeted surveys administered to students both within and outside civil engineering. Such surveys help us

understand student behavior, and some of the insights could be adapted and tailored by individual programs to develop more evidence-based recruiting strategies.

While recognizing that a robust civil engineering recruiting strategy would target young engineers of all ages, we have thus far focused our efforts primarily on recruiting first-year engineering students to choose civil engineering at our school. At Purdue University, we have a first-year engineering program that is designed in part to allow students to make a more informed choice of their engineering major, and first-year students select their engineering major towards the end of this first year. Therefore, at our university, first-year engineers represent a pool of potential recruits for our program; this is not the case, of course, for programs where engineering students must choose their major prior to arriving on campus and are directly admitted to individual engineering schools.

Background

If we are to recruit more engineers to undergraduate civil engineering programs, recruiting strategies should be at least congruent with, if not based on, what has already been studied regarding how and why students select their majors. These findings may be leveraged to develop effective recruiting strategies. Brown summarizes that the leading theories regarding career selection examine personality-occupation “congruence”⁵, and Holland’s career choice model is perhaps the most widely cited⁶. The Holland model examines linkages between personality traits and interests, positing 6 personality types (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional). The model is based on the idea that people ideally search for careers with work environments that match their personality types, which are largely characterized by their interests.

A study by Matusovich *et al.* found strong linkages between value beliefs and students majoring in engineering⁷. In particular, the value of attainment – consistency between the task, in our case civil engineering, and one’s sense of self – was found to be a prominent factor in student engagement and persistence in an undergraduate engineering major. In addition to attainment, other values potentially important in career choice and persistence include cost (of failure or success in terms of resources); interest (enjoyment associated engineering work); and utility (importance of work).⁸

It is somewhat unclear how these career choice theories can be leveraged to improve recruitment to civil engineering, given that every engineering student has a unique personality, and civil engineering is not a good fit for every student. However, one reasonable application of these theories to the development of recruiting strategies is simply that recruiting efforts should aim to portray civil engineering as accurately and fully as possible, so students can make informed and meaningful choices. Importantly, the accurate portrayal of civil engineering includes identifying and correcting misperceptions about the field of civil engineering.

We know much less about how and why students choose individual sub-disciplines of engineering, once they decide to become engineers. In the context of the models presented previously, where students are looking for a discipline that has congruence with their personality attributes, students’ knowledge of themselves and perceptions (if any) of various engineering disciplines will largely shape their selection. Shivy and Sullivan investigated engineering

student perceptions of various engineering majors and found that most (>80%) engineering students claimed familiarity with the work of engineers in many sub disciplines, including civil engineering, but that fewer students claimed familiarity with nuclear, industrial, materials, and petroleum specializations⁹. Their analysis compared perceptions of the sub-disciplines and found that students appeared to distinguish the various disciplines using a unique set of attributes that were different than the usual attributes that people use to distinguish occupations (people, things, data, ideas, gender, and prestige), suggesting that another, unknown set of attributes was responsible for students' perceptions. While these attributes were not identified, civil engineering was found to be perceived most similarly to electrical, mechanical, and aerospace engineering. These disciplines may, therefore, be considered to be the primary "competitors" to civil engineering in recruitment, to the degree that students may feel similarly about these other disciplines, and may therefore be selecting among them for their engineering majors. Mechanical engineering, in particular, is a discipline that has seen large enrollment growth during the recent period over which civil engineering enrollment has declined (Figure 1; Table 1), and it is a plausible hypothesis that students are currently choosing mechanical engineering over civil engineering.

Student perceptions of civil engineering are shaped by the collection of experiences that have occurred prior to the point of decision. The selection process of an engineering discipline (the "how") is therefore likely different between (a) students enrolling in programs that require them to pre-select a major prior to beginning their studies (i.e. directly enrolling in specific engineering disciplines) and (b) students enrolling at engineering schools that have a first-year engineering program, after which they decide their engineering major. In the latter case, experiences during the first-year engineering program can largely shape their decisions; one study at a large Midwestern university with a first-year engineering program found that approximately 70% of students selected a different major at the end of their first year of engineering than they had originally intended¹⁰. Our own marketing survey, described later in this paper, confirms this result (65%), and this is an important conclusion from our work that motivates our focus on first-year engineers.

Various strategies have been proposed in the past to increase the number of students recruited to civil engineering. Proposed activities include enhancing connections to alumni and practicing civil engineers through activities and presentations^{11,12,13}. Another commonly proposed recruiting strategy for civil engineering is to change students' incorrect or negative perceptions of civil engineering¹³, which often are cited as centering on employability and salary.

Unfortunately, little data are available to verify the efficacy of these recruiting strategies, or even the premises on which these strategies are based, such as student perceptions of civil engineering. As such, they remain a collection of what we term civil engineering "recruitment hypotheses". (Note that it is additionally unclear whether these hypotheses can *ever* be tested given the myriad, uncontrollable factors likely involved in engineering major selection, for example the economy, current events, changing generational characteristics, and institution-specific factors).

Nevertheless, as a profession, the booming job projections and waning enrollments presented earlier demand that we try to develop more robust recruiting strategies for civil engineering. This paper may aid in developing these strategies, by presenting analyses of two undergraduate

engineering student perception surveys at our large, public Midwestern university. These surveys provide some insight into students' perceptions of civil engineering, and in doing so highlight both possible selling points for the discipline as well as common misconceptions regarding the discipline. In turn, they suggest talking points for undergraduate programs that may help clarify the discipline, and in doing so, boost enrollment.

Methods

Survey of second-year civil engineers

Surveys were administered to all students taking a second-year seminar course in our civil engineering school that introduces students to contemporary issues in civil engineering. Sophomore students who have declared civil engineering as their major take this class immediately after transitioning out of the university's first-year engineering program. Students had the option of remaining anonymous when filling out the survey, and were given approximately 20 minutes to do so. The survey (Figure 2) consisted of one multiple choice question asking students when they had made their decision to become civil engineers, followed by a list of nineteen possible influences for that decision, presented on a Likert's-scale fill-in form. At the bottom of the survey was a comment section asking what materials students would have liked to have had while making their decision. The fall 2015 class, from which these data were gathered, produced 113 responses.

Civil Engineering Selection Survey

Name (optional): _____

Please indicate approximately when you made your decision to pursue Civil Engineering (CE) as your chosen educational goal (Please check or fill in one circular button)

- Prior to my arrival at Purdue
- While enrolled in the First-Year Engineering Program
- I am currently undecided about CE as my chosen educational goal
- Other _____

Please select the level of importance of the following in choosing Civil Engineering.

	Not Important	Slightly Important	Important	Very Important	Extremely Important
Parents, relatives, or friends	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
High school teacher, counselor, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Professors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other students, peers or friends already in Engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
CE students (e.g. Civil Ambassadors)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Guest/ENGR 131 presentations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Outreach events (e.g. academic fairs, Purdue Family Day, Scholar's Day, MEP/WIEP events)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Purdue advisers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Engineering course	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Self-led exploration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Explain:					
Passion for building things	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Desire to make a difference	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Love of math and science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flexible career options	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Global Programs in Civil Engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hands-on projects (steel bridge, concrete canoe, bridge bust, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How important was salary in making your decision?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other: _____	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What information, material and/or presentation do you wish we had provided to help you make your decision? What could/should we have done differently or better? Feel free to be specific and continue on the reverse, if necessary.

Figure 2. Student survey given to second-year engineering students who have selected civil engineering as their major.

Survey of first-year students and those who selected majors other than civil engineering

We hired the university marketing and media group to conduct a marketing survey on first-year students at our university. The purposes of the survey were threefold: (1) to better understand how students select their engineering major, especially when they do not choose civil engineering; (2) to determine students' perceptions of civil engineering; and (3) to determine marketing messages that would be effective in recruiting more students to civil engineering.

After a set of pilot interviews with 5 first-year engineering students, the full survey was developed and carried out on 24 first-year engineering students who had selected majors other than civil engineering. The survey included questions pertaining both to students' perceptions of civil engineering, as well as questions about their reactions to various possible marketing messages.

The stated major interests of the students involved in the survey were: 35% Mechanical Engineering; 30% Industrial Engineering; 26% Chemical Engineering; 17% Electrical and Computer Engineering; 13% Materials Engineering; 9% Biomedical Engineering; 9% Aeronautical and Astronautical Engineering; and 4% Nuclear Engineering. The total selected majors exceed the survey population because students were asked to select the major(s) that they had either already chosen or were being considered and thus could select more than one major.

At our university, the First-Year Engineering (FYE) program is structured such that engineering students declare an engineering discipline no later than the end of their first year, and begin their coursework in that major during their second year. During the FYE program, all students take a two-course sequence that introduces students to basic engineering concepts such as the design process, teamwork, basic programming, etc. During the first semester of their first year, students are also introduced to various engineering disciplines/schools through a series of short presentations during their classes. These presentations are 20-minute lectures given by each of the available engineering schools (e.g. civil, mechanical, etc.), during which the schools present their respective disciplines and programs, and answer questions from first-year engineering students.

As the civil engineering perception surveys were given in March, the opinions of the students involved in the surveys we report are not those of first-year students entering college, but rather students who have had some degree of exposure – formal and informal – to various engineering disciplines, during their first ~7 months of college.

Salary Analysis

We later present salary data in order to clarify the common misperception that civil engineering salaries are low relative to other professions. Salary data were obtained from two sources: (1) the United States Bureau of Labor Statistics¹⁴ and (2) Purdue University's Center for Career Opportunities, which reports salaries of graduating students from Purdue University.¹⁵ Additionally, data on licensure was obtained from the National Society of Professional Engineers.^{16,17}

The median salary reported by the Bureau of Labor Statistics is a representation of all full-time reporting civil engineers. Purdue University's Center for Career Opportunities collects self-

reported salary data from each discipline’s graduating class. It is assumed that the salaries reported are accurate and a reasonable representation of all of the students in the graduating class. The number of students reporting their salary varied in each discipline because enrollment ranges from 25 to about 200 students. A total of 58 students from the civil engineering graduating class reported their starting salaries for spring 2014; the numbers of students reporting from other majors were: environmental engineering (9), industrial engineering (52), mechanical engineering (149), and agricultural/biological engineering (36).

Results

Survey of second-year civil engineers – why they chose civil engineering

Results from the second-year civil engineering students showed that a majority (55.4%) reported having chosen civil engineering before arriving at university. Slightly fewer (40.2%) chose civil engineering during their freshman year.

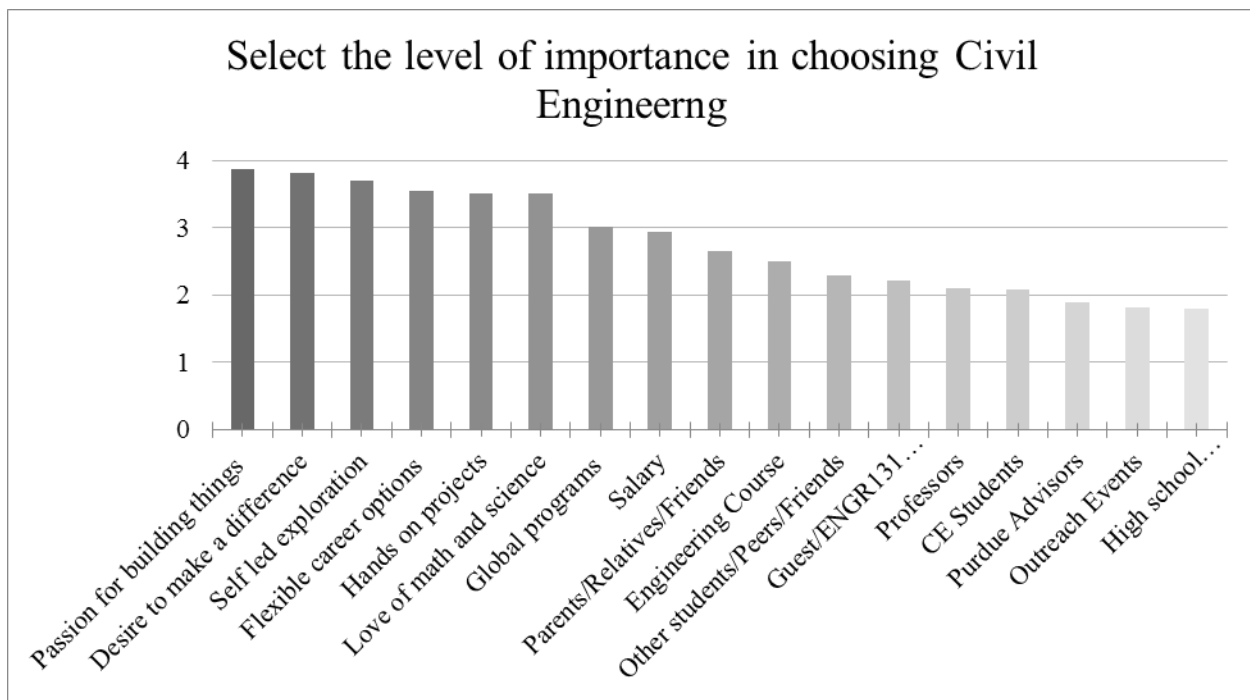


Figure 3. Relative importance of various factors in civil engineering major selection as identified by second-year civil engineering students.

Results from the questions regarding influences on the selection of civil engineering as their major decision, show that students identified most strongly with six influences: passion for building things, desire to make a difference, self-led exploration, flexible career options, hands-on projects and a love of math and science. Least influential were university advisors, outreach events, and high school teachers and guidance counselors. Responses are summarized in Figure 3, with a 0 indicating Not Important and a 4 indicating Extremely Important.

Survey of first-year engineering students who have selected majors other than civil engineering

This survey provided important insights into (a) how and when students select their engineering major and (b) how first-year engineering students who choose other disciplines perceive civil engineering, which can in turn be used to infer why some students are not selecting civil engineering as their major.

Selection of engineering major

Sixty-five percent of first-year, non-civil engineering students said they chose their engineering discipline *after* they arrived at the university, i.e. during their first year as an engineering student. This means that, for these students, perceptions formed during the first year at the university play a significant part in the decisions to choose a discipline. Therefore, the recruitment information that various schools are able to get to students during their first semester at the university may play a significant role in the school selection process (for universities that do not require students to pre-select their engineering major prior to beginning their studies). The selection of engineering discipline after arrival at university may also mean that recruitment rates to various engineering disciplines are highly university-specific, being dependent on students' campus experiences as opposed to their pre-conceptions (which may be more universally shared).

How students select their discipline

First-year engineering students were asked what sources of information were used in deciding a major. They were given their choice of 9 categories, including: word of mouth from family, printed materials (brochures, flyers, etc.), and online routes, like social media or email. Word-of-mouth came in first, with other word-of-mouth categories like "friends & family", "classes and speakers at the university", and "word-of-mouth through friends/classmates at university" receiving 57%, 52% and 52% respectively by the 24 students. About 35% of the students used printed material and an equal number used non-university based websites and online sources. 22% used word-of-mouth from high school staff and 17% used word of mouth from professors and staff at university. Finally, only 13% listed email, 9% listed social media, and 4% listed "other".

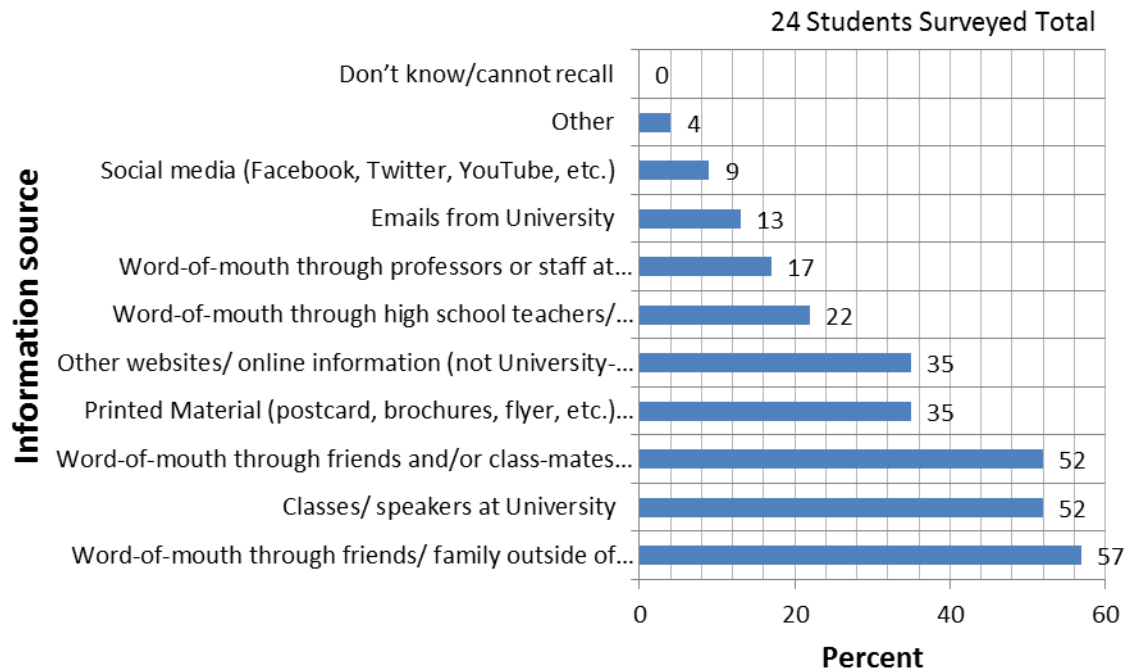


Figure 4. Various factors and information sources used to make engineering major decision (by first-year engineering students who selected disciplines other than civil engineering).

Perceptions of civil engineering

When asked “When you hear 'civil engineering', what are the first thoughts that come to mind?”, the highest number of responses listed bridges and buildings, as illustrated in the word cloud of Figure 5, and generally answered “bridges”, “building”, “construction”, roads”, i.e. the traditional notion of civil engineering, and didn't mention other areas (hydraulics, geomatics, etc.) of civil engineering.

When asked what were thought of as advantages of civil engineering, two main themes emerged. Multiple participants stated that civil engineers “get to see their products finished on a daily basis”, and this was seen as an advantage. Some students also stated that working outdoors was an advantage to civil engineering, and that a smaller proportion of desk work was a positive (some students also listed this as a drawback).

When asked what were thought of as disadvantages of civil engineering, many diverse responses were made. First, outdoor work was again brought up, this time as a negative. Students felt that working outdoors in bad weather was a negative. Next, students felt that civil work was limited to the field of construction, there was little job flexibility, or few new areas of innovation. Employment issues were also mentioned, in the form of both low salary, and limited employment, as an area can only need so many civil engineers. Finally, concerns about a male-dominated field were also voiced.

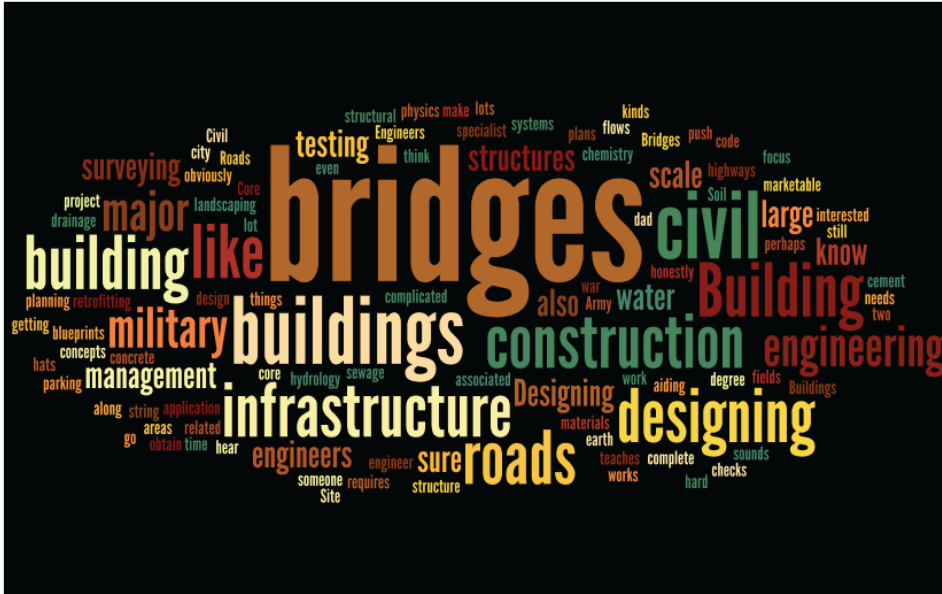


Figure 5. Word cloud showing relative occurrence of first-year, non-civil engineering student perceptions of civil engineering. Text size is proportional to number of word mentions in response to “When you hear ‘civil engineering’, what are the first thoughts that come into your mind?”

Reasons for NOT Considering Civil Engineering
(sample student responses)

- Civil engineering didn't seem as promising as some of the other fields to enter.
- I am not interested in designing/building roads or bridges
- I am not interested in doing soil testing or designing/retrofitting buildings
- I did not know much about it. I learned about Industrial and decided before having an interest in civil.
- I does not seem to have too much math or chemistry(a subject i like) involved.
- I was not interested in the topic
- Infrastructure does not interest me
- It is supposed to be one of the lowest engineering disciplines and it is harder to get good civil engineering jobs than mechanical jobs.
- It never held an appeal to me. I didn't want to design buildings.
- No interest
- Not a high pay and doesn't sound interesting
- Not my thing
- Seems boring
- The thought of being a civil engineer is not appealing to me.
- Working environment is bad

Figure 6. Sample first-year engineering student responses to "Why did you NOT select civil engineering as your major?"

Discussion

The survey results suggest several possible conclusions that can be leveraged to aid university civil engineering programs in recruiting more undergraduate students to their discipline, provided they have students and program configurations comparable to our own. These conclusions fall broadly under two categories: (1) how and why students select their engineering major and (2) how engineering students perceive civil engineering.

Importance of first-year engineering in recruiting

The survey of second-year civil engineering students showed that 55% of them recalled having selected civil engineering as their major prior to beginning university. One recent study showed that approximately 70% of all first-year engineering students select a different engineering major at the end of their first year of engineering than they had originally intended¹⁰; our survey of first-year non-civil engineering students indicated a similar number of non-civil engineering students having decided their major during their first year (65%). These results suggest that perhaps civil engineering students are, as a whole, more sure of their major choice (since fewer civil engineers switch majors during the first year than first-year engineering students as a whole). But more importantly, these results suggest that a substantial number of students are making their major selection during their first year, which suggests that students' first year experiences are very important in their major selection. *In turn, this suggests that activities targeting first-year engineering students are potentially key to increasing or maintaining student recruitment (to all engineering majors), for university programs that have students declare their major at the end of their first year.*

First-year engineering students' limited perceptions of civil engineering

The survey of first-year engineering students from other majors, raised some important perception issues for the discipline of civil engineering. Firstly, civil engineering is perceived in a very traditional, narrow sense: most students still identify civil engineering as being principally about bridges, buildings, and roads (Figure 5). While civil engineers undoubtedly work on traditional infrastructure, this narrow perception ignores many other potentially attractive opportunities in civil engineering, as well as the interdisciplinary nature of even traditional infrastructure projects. Moreover, it could be argued one of the top attributes of civil engineering as a profession are the many and diverse sub-specializations within the field, as well as the interdisciplinary nature of most civil engineering projects. Important sub- and closely related-disciplines of civil engineering include water resources, environmental engineering, air quality, geotechnical engineering, geomatics, materials engineering, architectural engineering, coastal engineering, and transportation engineering (beyond roads). Students in our survey did not volunteer these sub-disciplines as part of their perception of civil engineering, and this suggests that the profession needs to work to expand young engineers' perceptions of the discipline, ideally before they reach college.

In our presentations to first-year students, we now combat this narrow perception by describing civil engineering as "engineering within engineering", to highlight the breadth of the field, and make the argument that this breadth allows students to find their passion within the discipline, even if they are somewhat unsure of the exact area in which they want to specialize. We also

highlight well-known civil engineering mega-projects, such as the Burj Khalifa building in Dubai, as examples of projects where all of the sub-disciplines of civil engineering must be included. We also highlight that many, *if not most*, of the world’s largest engineering firms are civil engineering firms, with the size of these firms being largely a product of the multidisciplinary nature of most large civil engineering projects.

Surveys of first-year engineering students also highlighted some negative perceptions of civil engineering, including: having low salaries; being male-dominated; and requiring work in the outdoors, potentially during times of inclement weather.

Addressing misperceptions of civil engineering

Conversations with freshman students and high school seniors reveal that civil engineering suffers from several misperceptions among potential students in undergraduate engineering programs. Some of the above perceptions of civil engineering can be readily clarified, and we now present some additional information to aid civil engineering schools in clarifying some of these common misconceptions. Several of the most common misperceptions we have observed are discussed below in Table 4 and we present salary information at length in a subsequent section since we have found the low salary perception to be especially pervasive among first-year students, due in large part to civil engineering’s relatively low starting salary.

Table 2. Some common misperceptions of civil engineering that we have observed and possible talking points aimed at clarifying these misperceptions.

Misperceptions of civil engineering	Talking points
“Civil Engineers make a low salary”	While it is true that the starting salaries for civil engineering are lower than other disciplines, civil engineering salaries following licensure are actually much higher than the median salaries for other engineering disciplines. Civil engineers have a licensure requirement because the projects they work on are critical to public safety and health. (http://www.asce.org/licensure/). Additionally, a civil engineering degree can be leveraged for more lucrative work (e.g. petroleum industry or engineering/project management). One point that might be made is that we find civil engineers have chosen our discipline out of a “desire to make a difference” rather than “salary”, but this should not be taken to mean that you do not make a good salary as a civil engineer.
“Civil Engineering is just about bridges, buildings, and roads.”	Of course civil engineers build bridges, buildings, and roads, including the most impressive feats of engineering on the planet such as the Burj Khalifa and the Golden Gate Bridge. But this is just a small subset of what civil engineers do. Civil engineers also provide clean water for humans and ecosystems, restore natural habitats,

	protect coasts from flooding, design solar and wind farms, create bike share programs, bore tunnels, design wetlands to clean stormwater, design airports, and the list goes on and on. Civil Engineering is a very broad discipline with numerous sub-disciplines. Most large civil engineering projects – even bridges, structures, and roads – involve many of the civil engineering sub-disciplines because they function as <i>systems</i> , not just as structures (using examples such as Burj Khalifa & Panama Canal).
“Civil Engineering is a luddite profession, and does not use technology like other disciplines”	Many universities can readily leverage their civil engineering research to dispel this myth; as civil engineers, we use UAVs to inspect bridges, and drive robots to inspect pipelines; perform computational fluid dynamics modeling to model water currents; use mass spectrometers to measure chemical concentrations; perform laser scans to map buildings and cities in 3-D; and run autonomous underwater vehicles to photograph dams. Additionally, civil engineering software can be highlighted, such as Building Information Modeling (BIM), AutoCAD, Civil 3D, etc.

Low Salary Perception

According to the Bureau of Labor Statistics, the median annual wage for all civil engineers was \$82,050 in May of 2014 [ref. 14; Table 2]. During that same month in 2014, Purdue University reported that the average *starting* salary of civil engineering graduates was \$55,105.¹⁵ Table 3 shows a comparison of median salaries and reported average starting salaries for several engineering disciplines.

Table 3. Average starting salaries and median salaries for various engineering disciplines. “PL” denotes “post-licensure”.

Engineering Discipline	Average Starting Salary ¹⁵	Median Salary ¹⁴
Civil engineering	\$55,105	\$82,050 \$99,000 ^{PL}
Environmental engineering	\$55,291	\$83,360
Industrial engineering	\$58,865	\$81,490
Mechanical engineering	\$62,010	\$83,060
Agricultural engineering	\$57,175	\$71,730

As a career in engineering progresses, more expertise is gained and salary increases. Based on the salary information listed above, the increase in salary for civil engineers is nearly 49%. Environmental engineering is the only discipline which showed a more significant increase. The

average starting salary for environmental engineers increased by 51%. While industrial, mechanical, and agricultural engineering showed a salary increase of 38%, 34%, and 25%, respectively, the increases were less significant.

Licensure plays a key role in salary increase for civil engineers. A Professional Engineering license (PE) allows a civil engineer to sign and seal engineering documents for private or public projects. A PE, or a “Professional Engineer”, is respected as an ethical and competent public servant. In order to obtain a license from a particular state’s licensing agency, an engineer must complete a four-year engineering degree from an accredited program, pass two thorough state-specific exams, and complete four years of engineering work under a licensed professional engineer¹⁶. To maintain the professional engineering license, a PE must complete continuing education requirements as prescribed by the state they are licensed in. The annual mean salary for licensed engineers is \$99,000 which is \$15,000 more than the overall median salary presented in Table 2.¹⁷

Positions for civil engineers exist in both the private and public sector. Most civil engineers work in the private sector in engineering consulting services (46%) and nonresidential building construction (5%). State (13%), local (11%), and federal government (4%) civil engineers make up the public sector. The remaining civil engineers work in other industries¹⁴. Table 3 shows the median annual wages for civil engineers in these industries.

Table 4. May 2014 Median Annual Wage for civil engineering sectors¹⁴

Civil Engineering Industry	Median Annual Wage
Engineering Consulting Services (46%)	\$81,830
Nonresidential Building Construction (5%)	\$74,030
State Government (13%)	\$78,330
Local Government (11%)	\$85,820
Federal Government (4%)	\$90,340

Conclusions

This work was motivated by recent, declining enrollment trends in undergraduate civil engineering programs nationally. This trend is all the more perplexing given the booming job projections, and deserves serious consideration by the profession. Preliminary data presented in this paper suggest that universities with first-year engineering programs offer potentially fertile recruiting grounds for undergraduate students, with a large percentage of students deciding their engineering discipline during their first year on campus. This is likely welcome news to many undergraduate civil engineering schools for whom resource limitations render daunting the task of recruiting pre-college students to civil engineering.

The limited survey results presented herein, as well as numerous discussions with undergraduate students and alumni, suggest that civil engineering suffers from a set of misperceptions among prospective undergraduate recruits that could be collectively deemed an “image problem”. Many students misidentified civil engineering as a narrow, traditional discipline closer to the field of construction engineering than civil engineering. Students have also identified low salaries with

the profession of civil engineering, which is largely a consequence of the low *starting* salaries for civil engineers, relative to other engineering disciplines.

It seems clear that, for programs that employ a centralized (and non-discipline-specific) first-year engineering program, the first year of college is not too late to impact students' decisions regarding major. As previously stated, our program surveys show nearly half of students haven't yet made up their minds by the time they reach college and Rodriguez-Simmonds and our own marketing survey agree that 65-70% of students ended up selecting a different major than they had originally intended. This represents a significant opportunity to provide information to students and encourage them to consider their options and make decisions in an informed manner.

Perhaps as noteworthy as when/where to provide this information, is how to provide it. Or specifically, how to allow students to discover it. Our survey to second-year students who chose civil engineering, indicated "Self-led Exploration" was one of the top influencers for their decision. This was introduced by Rodriguez-Simmons *et al*¹⁰. It is worth noting that 5 of the top 6 influencers listed were attributes of the person and/or civil engineering, while self-led exploration is really a method of discovery. Today, all civil engineering programs provide information on their websites, but this is not nearly enough. Programs should seek to leave relevant, timely, and dynamic "breadcrumbs" for students to follow. This is why our table of talking points above, includes some references for students to dig deeper.

We hope that by providing a spotlight on this important issue of undergraduate student numbers in civil engineering will lead to continued study of this problem as it relates to the health of civil engineering as a whole. More studies and data are needed, and it is important for programs at institutions across the country to communicate and share successes (and failures) in recruitment measures. While we understand that civil engineering programs are different and may need different measures locally to be effective, it is useful to learn from peer program experiences. It is critical to bring our considerable academic resources to bear on the somewhat mundane matter of recruiting to identify more people who possess passion and potential to turn this tide of low enrollments. It is only by multiplying our effectiveness (and our numbers), that we can ever hope to improve and rehabilitate America's infrastructure and address important societal needs.

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