To Change the World: Student Motivation for Pursuing a Degree in Agricultural or Biological Engineering

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Abstract

Demands for food, water, energy and healthcare continue to increase along with the increasing world population while the resources available to meet these demands remain limited. An innovative workforce capable of designing creative solutions to these problems is needed. Agricultural and biological engineers focus on food, water, energy and healthcare systems and will play a pivotal role in meeting these challenges. However, public awareness of these fields and their impact on society is limited. The objective of this study was to assess undergraduate student understanding of Agricultural Engineering (AE) or Biological Engineering (BE) degree programs and identify key motivating factors to pursuing a degree/career in these fields.

Sophomore AE and BE students enrolled in a course on the engineering properties of biological materials were the focus of this study. At the beginning and end of the semester, students submitted definitions in their own words to describe their chosen major (Agricultural Engineering or Biological Engineering) and explained their motivation for pursing a degree in this field. The information gathered suggests both student definitions of their chosen major and motivations for pursuing a career in this field are closely tied to opportunities to positively impact society.

The findings of this study can be used to guide student recruitment strategies to increase enrollment in these fields. Recruitment efforts should highlight the many ways agricultural and biological engineers positively affect the world. In addition, instructional techniques can be adapted to meet the unique characteristics and motivations of students enrolled in AE or BE degree programs. For example, course instructors can connect theoretical course content to real-world examples. Meeting the challenges of a growing world population will require broadening participation in agriculture and biological engineering. Promoting the potential of these fields to solve real-world challenges related to food, water, energy and healthcare will help inspire the next generation of agricultural and biological engineers to meet these needs.

Introduction

The fields of agricultural and biological engineering represent a distinct facet of engineering applied to living things (1). Growing from agricultural engineering in the early 1900s, programs now include a variety of disciplines including biomedical, food, and power and machinery (2). The central professional organization for agricultural and biological engineering, the American Society of Agricultural and Biological Engineers (ASABE), provides the following definition for these disciplines:

> *'the discipline of engineering that applies engineering principles and the fundamental concepts of biology to agricultural and biological systems and tools, ranging in scale from molecular to ecosystem level, for the safe, efficient and environmentally-sensitive production, processing, and management of agricultural, biological, food, and natural resources systems. Agricultural and Biological Engineers collectively ensure that the*

world has the necessities of life including safe and plentiful food, clean air and water, renewable fuel and energy, safe working conditions, and a healthy environment by employing knowledge and expertise of sciences, both pure and applied, and engineering principles to design devices, equipment, and materials for the production, processing, and management of agricultural, biological, and natural resources systems.'

This broad definition highlights the many ways – including food, energy and equipment design - in which agricultural and biological engineers have a positive impact on the world. These attributes resonate well with the career motivations of undergraduate students. The majority of students currently in the postsecondary system represent a generational cohort defined as the Millennial Generation (3). This population is particularly motivated by opportunities to save the world and improve society (4).

Engineering undergraduate students represent a unique subpopulation of postsecondary students. Prior work has identified common factors that specifically influence engineering student motivation for pursing an engineering degree (5; 6). Student motivations include both intrinsic (psychological or behavioral) and extrinsic (social good, financial, mentor or parental influence) factors with the greatest influences including intrinsic motivations followed by social good and financial motivations (5; 7). Similarly, the life aspirations of engineering students include 'inventing something new,' 'making a difference in the world,' and 'achieving financial security' (6).

Gender also affects student career aspirations. A survey of over 1,200 undergraduate engineering students found male students were more likely to list inventing something new and achieving financial security as life aspirations while female undergraduates reported making a difference in the world as a life aspiration (6). Gender differences were also noted in the motivation of engineering undergraduates. For instance, one study reported that intrinsic psychological motivations were less common in female students (8). The same study identified a connection between student activities and motivations. Engineering undergraduates that participate in Engineers Without Borders (EWB) were more likely to include 'helping others' in their motivation for pursuing a career in engineering (30% of responses) while students that did not participate in EWB rarely mentioned 'helping others' as a motivating factor (11% of responses) (8).

The design and implementation of engineering education and outreach efforts often overlooks student motivations and aspirations. Alignment with student motivations should be the foundation of outreach efforts and undergraduate curriculum (7). Specifically in agricultural and biological engineering, the application of engineering principles and the fundamental concepts of biology is an essential component of the profession's definition (ASABE) and clearly align with student motivations. However, across the board, current engineering education largely focuses on mastering the engineering sciences with little attention paid to technology transfer or humanitarian engineering (9). Showing students the connection between social issues and engineering within the curricula may help broaden participation of female and minority students (8; 10). Helping students develop an engineering identity by connecting their personal values to the practice of engineering can encourage students to persist in engineering (11). In addition, undergraduate engineers should be exposed to the breadth of engineering practice beyond teaching just the fundamental engineering skills (11).

This paper describes the motivations of undergraduate students pursuing degrees in AE or BE. These results may be used to guide student retention efforts through alignment of teaching and recruiting methods with prominent student motivations. In addition, general marketing of these fields should highlight factors identified in this study.

Methods

The focus of this study were AE and BE students enrolled in a sophomore level course on engineering properties of biological materials. The course covers a range of properties including moisture content, viscosity, and modulus of elasticity. Students learn the unique characteristics of biological materials and their applications to engineering design. The course is typically a student's first experience applying engineering thought processes to coursework through hands-on laboratory activities. The students' prior experience included the more prescribed problems in the freshman introduction to engineering courses. Throughout the semester, students worked together in teams of three to four to complete laboratory activities focused on client-based industry scenarios that have been shown to improve student engagement (12).

During the first week of class, students completed a 'Lab Certification Worksheet'. The certification worksheet included the following questions:

- Define agricultural engineering or biological engineering (choose according to your major) in your own words.
- What is your motivation for studying AE or BE (minimum of three sentences, no wrong answers)?

At the end of the semester, students responded to a 'Laboratory Departure Worksheet' intended to model an exit interview. Students provided feedback on their laboratory teammates (distribution of work load, ability to learn/teach each other) and the work environment (available instrumentation, lab management by instructor). In addition, students responded to the following questions related to their personal growth throughout the semester:

- What have you learned (big picture) as a result of participating in this lab?
- In what ways, if any, has your motivation for studying AE or BE changed?
- Define your major (AE or BE) in your own words.

Informed consent was obtained for this study (IRB # 20150815495 EX) and placed in a sealed envelope to be opened at the end of the course to ensure that there was no impact to student scores or treatment. In this course, 48 of 64 students consented to participate in the study of which 29 students were male and 19 students were female. The gender representation of the consenting students (60% male; 40% female) closely aligned with the overall class gender distribution (61% male; 39% female). Qualitative analysis of the data from the 'Lab Certification Worksheet' and 'Laboratory Departure Worksheet' consisted of reading the collected student work and using a grounded theory approach. The grounded theory process allows for the analysis of qualitative data with respect to a specific population (13). In this case, the specific population was undergraduate students pursuing degrees in either AE or BE. After reading all of the student responses, consistent themes in the responses were identified as codes. In addition, the student motivation data was coded according to the six motivational factors identified in the APPLES study (5). Instances corresponding to the identified themes were identified and quantified during the analysis of the collected student work.

Results and Discussion

The objective of this study was to identify key motivating factors that lead undergraduate students to pursue a degree in AE or BE and find trends in how undergraduates describe these fields. The information gathered suggests both student definitions of their chosen major and motivations for pursuing a career in this field are closely tied to opportunities to positively impact society. This result aligns with prior research on the motivations of engineering undergraduates to have a positive impact on their world and craves connection to real-world problems. However, financial motivations were absent in student responses, which suggests the population of students pursuing these degrees differ from engineering undergraduates as a whole.

Student motivations for pursing a degree in AE or BE were coded into six categories defined in the APPLES study (Figure 1). The motivation codes included: Financial (opportunity to make money/have a good career), Parental (parent is in a similar field or encourages pursuit of this field), Social Good (potential to positively impact the world, society or individual people), Mentor (someone in their life encouraged the student to pursue this field), Intrinsic Psychological (personal enjoyment and/or skill in science, math or engineering topics), and Intrinsic Behavioral (personal enjoyment and/or skill in building or designing). Student responses were most often coded as Social Good (79% of responses) or Intrinsic Psychological (79%). None of the student motivations were coded as Financial and only three students mentioned Parental (2%) or Mentor (4%) factors influencing their motivation to pursue a degree in AE or BE.

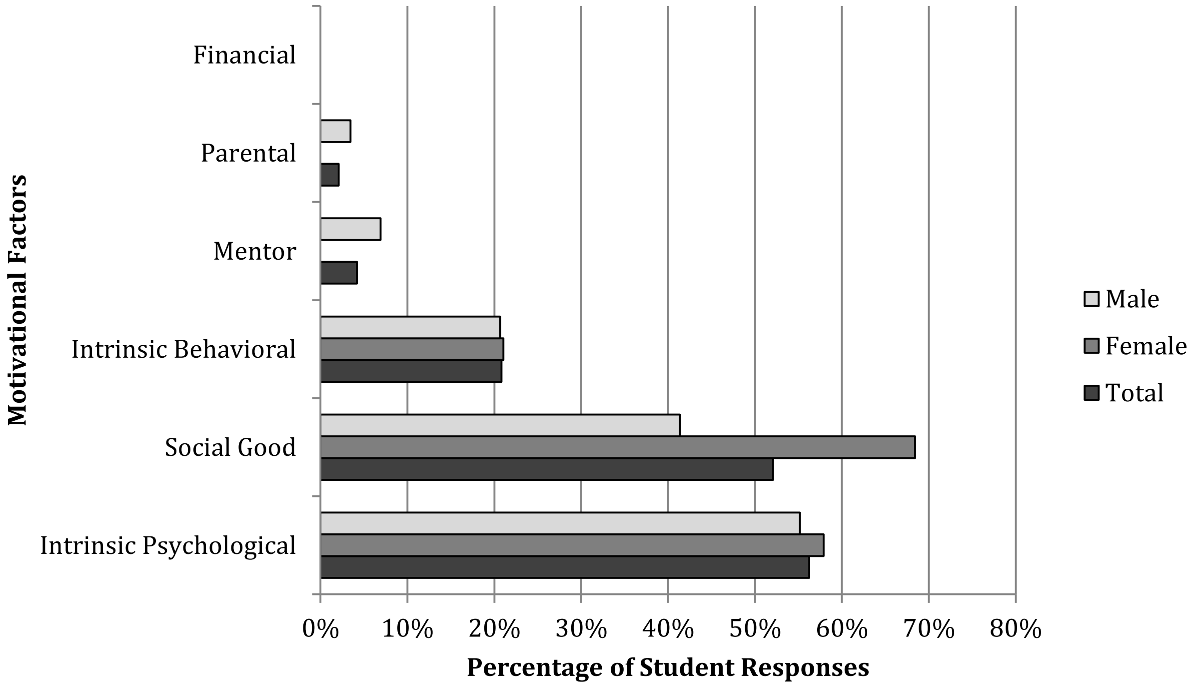

Figure 1: Frequency of thematic codes in reported student motivations for pursing a degree in Agricultural Engineering or Biological Engineering.

Some of the student motivations coded as Social Good reflected their enthusiasm for science and engineering (Intrinsic Psychological). For example, students commented:

> *'My motivation for studying* [BE] *is that I have always had a passion for the biomedical side of science. I hope to do research in viruses and diseases to help better society.'*

> *'I really like the idea of working with living systems using engineering, biology (my favorite science subject), and mathematics. I also like the thought of me in the future helping out the community by doing something I enjoy.'*

However, many students focused solely on their potential to positively impact the world. These sentiments were evident in following responses:

> *'I want to study* [BE] *because I have my heart set on helping the human race. I want to be able to make some impact on the world that will improve quality of life for all those that I know and love.'*

> *'My main motivation is to do all I can to help others... What motivates me is doing everything in my capacity to positively impact someone's life every day.'*

> *'I want to improve the quality of life for people, and I do not think there is any other better place to do that than* [BE]. *By directly improving peoples' health, it will be easy to achieve my goal of helping people by being a bio-systems engineer.'*

Separating student motivations by gender revealed that a higher percentage of female students (68%) mentioned Social Good as a motivating factor as compared to male students (41%). The difference between Intrinsic Psychological motivating factors was small with 58% of female responses compared to 55% of male responses. Only male students mentioned a parent or mentor contributing to their motivation to pursue a degree in AE or BE. One student noted the role of his parents in choosing to study engineering:

> *'My personal motivation for studying* [AE] *is my parents; both of my parents don't use college degrees in their line of work. Growing up I was told I would go to college so I could have a better job and more opportunities than people without one.'*

At the end of the semester, student responses suggested only moderate changes in motivations for pursing the degree programs. Many students responded that their motivations had not changed over the course of the semester (27%) or had increased (27%). Students identified academic success as a key contributor to increased motivation. For example, one student who reported an increase in his motivation noted,

> *'I am actually more interested than before, since I was actually good at this stuff and enjoyed doing it'*

The next most common responses related to a broader understanding of the concepts related to agricultural and biological engineering (23%), an expanded understanding of the breadth of the fields (21%), or a discovery that a certain aspect of the fields was not a good fit for the student (19%). Students appreciated gaining a broader working knowledge of the different areas of these broad fields, for example,

> *'This class exposed me to the different emphasis areas offered – which sparked some new future ideas. If anything it helped me appreciate all the areas offered.'*

Only 6% of the students stated that their motivations for pursing a degree in AE or BE had decreased. An additional 6% of students responded that they were or had changed majors during the semester. Often the decrease in motivation was linked to a perceived disconnection between course content and their passions or career interests (7; 9). One student that noted that his motivation had 'probably decreased' during the semester explained the change by stating:

> *'a lot of topics in my classes are starting to seem obscure and strange.'*

Student definitions for agricultural or biological engineering were collected at the beginning and end of the semester. The definitions were analyzed to better understand the relationship between their motivations and choice of major (Figure 2). The following codes were used to aggregate student definitions: Solving Problems, Social Good, Math/Science, Design, and Creativity. The frequency of the codes in student definitions was determined from the beginning of the semester responses (Pre), end of the semester responses (Post), and repeated responses (Both) which indicated that responses from the same student matched the given code at both the beginning and end of the semester. The most common theme in all three categories was problem solving (55%). The application of math or science skills was the next most common definition at the beginning of the semester (38%). At the end of the semester, the second most common theme of student definitions was social good (38%).

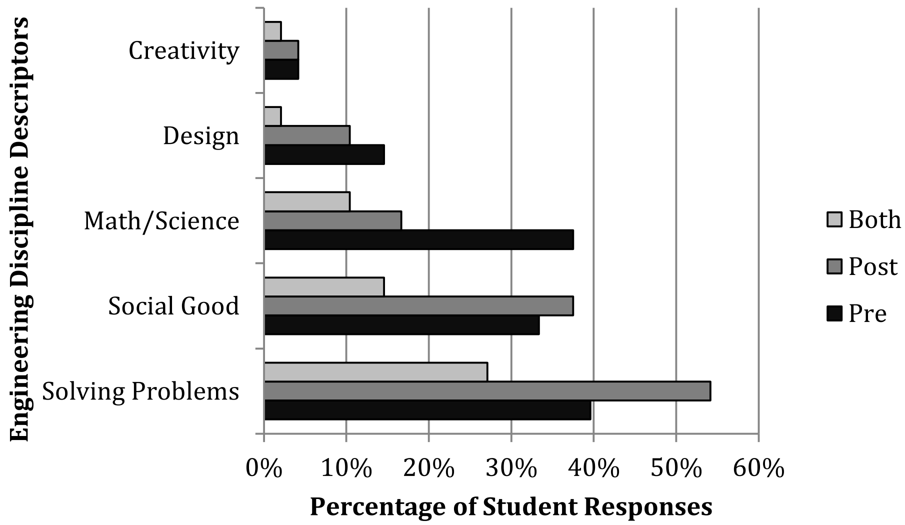

Figure 2: Frequency of thematic codes in student definitions of Agricultural Engineering or Biological Engineering at the beginning and end of the semester.

The frequency of students describing their engineering field as related to solving problems (+14%) or affecting social good (+5%) increased at the end of the semester. Students were less likely to include math/science (-21%) or design (-12%) in their definitions at the end of the semester.

Students often combined problem solving with social good in their definitions, for example:

> *'Biological Systems Engineering is the process of solving problems related to biology using our understanding of scientific principles, math, and engineering for the benefit of society.'*

Some students limited their definitions to focus on just the topics of the course (engineering properties of biological materials) during which responses were collected. One student defined their major by stating,

> *'Biological Systems Engineering is the study of engineering properties of biological materials in order to solve a problem involving a biological system to better society.'*

A similar trend was identified when male and female student responses were analyzed separately (Figure 3). The most common themes in the collected responses for both male and female students included solving problems and social good. Female students (55%) were more likely to include 'problem solving' in their definitions than male students (41%). The female students again connected problem solving directly to the larger picture of having a positive impact on the world.

'[Biological Engineering] *means solving problems that affect living organisms. It's making the world a better place to live in.'*

Male students (16%) were more likely to include 'design' in their definitions than female students (8%). This difference may be due to the larger number of male students identified as agricultural engineers and the focus of the discipline on machine design.

'Agricultural Engineering… is the science and math behind designing and testing equipment and processes used in agriculture.'

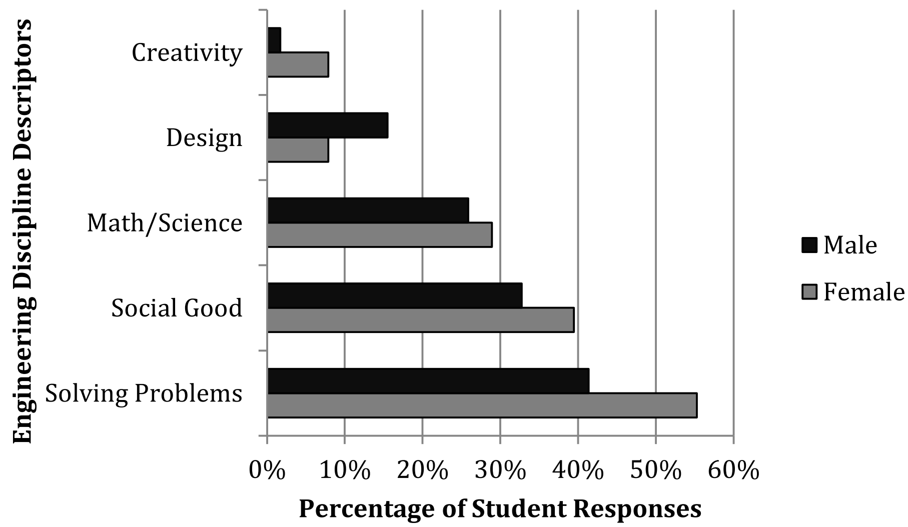

Figure 3: Frequency of thematic codes in reported student definitions of Agricultural Engineering or Biological Engineering separated by gender.

The results of this study suggest that AE and BE students have similar motivations as compared with the general engineering student population described in the literature. However, a stronger connection with social good was identified, particularly amongst female students. In addition, an absence of financial motivations was noted. The findings of this work can be used to guide the design of student retention and recruiting efforts. For example, youth outreach programs that highlight engineering advancements for the common good could increase interest in the discipline. A good example is the American Society of Civil Engineers that has been using the Future City competition to spur interest in their discipline. At the college level, incorporation of real-world scenarios related to poverty, hunger, and malnutrition could help contextualize foundational engineering content to retain students. Further work is needed to better understand the connection between student motivations and persistence in AE and BE degree programs.

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