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Motivations of Women Participating in a Technology-Based Social Entrepreneurship Program

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ABSTRACT

Academic programs focused on engineering entrepreneurship are growing in number and popularity at American universities. However, the fields of engineering, entrepreneurship and technology-based entrepreneurship struggle to recruit and retain female students: a historic and endemic failure at obtaining gender-balanced participation. Understanding the motivations of women engaged in such academic programs can influence recruitment and retention strategies and lead to the creation of transformative learning environments and entrepreneurial ecosystems. This study investigates the motivations that women have for participating in the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Penn State. In this five-year study, females from diverse academic majors cited the following to be their top motivations for participating: a) becoming a global professional; b) making a difference; and c) applying theory learned in school to address a problem. In contrast, males cited 1) making a difference 2) participating in an exciting real-world project and 3) applying theory to address a problem, as their top motivations. Studying the motivations and perceptions of enterprising women and men provides compelling insights to help make academic engineering entrepreneurship programs more appealing to both female and male students.

Key Words: Women, Entrepreneurship, Humanitarian, Social, Service Learning, Motivations, Gender Equity

INTRODUCTION

Historically, significant discrepancies have existed between the numbers of female and male engineering students that matriculate and complete academic curricula at both the undergraduate and graduate level [1]. In 2010, females accounted for 18.1% of all engineering undergraduates, the largest population of women since 2002 [2]. Women received 22.6% of all engineering masters' degrees in 2010 but the number has seemingly plateaued in recent years after rapid growth from 2000 to 2008. Role models for females in engineering are also lacking, with women representing just 13.2% of tenured and tenure-track faculty in US universities in Fall 2010 [2].

Balanced participation of genders is also not common in the field of entrepreneurship. While one study concluded that girls are less likely to want to start a business in the future [3], another study found no significant differences between male and female motivations for entrepreneurial activity [4]. Compared to men, many more young women claim that their future career plans would prevent them from engaging in entrepreneurial activity [5]. Lack of participation in entrepreneurship by females impacts the recruitment pool and demographics for academic programs at the university level. Several approaches have been pursued to combat the low enrollment of women in engineering and entrepreneurship programs. These include mentorship initiatives, community-building exercises, targeted advertising, and hiring greater numbers of female faculty members [6–9]. Additionally, research conducted on youth attitudes towards entrepreneurship and engineering has shown that many students (male and female alike) believe careers in both fields can benefit from college education that offers diverse courses covering business expertise and technical skills [5][8] [10].

Humanitarian engineering and social entrepreneurship are not viewed in popular discourse as common engineering specializations at American universities. However, academic and co-curricular programs that engage engineering students in creating appropriate technology-based solutions for resource-constrained environments are rapidly emerging across the country. Such programs often incorporate a significant entrepreneurial component to ensure sustainability of the emergent ventures. "Ventures," in this context, refer to for-profit enterprises, non-profit organizations, or even organizational models intended to address a problem in a sustainable and scalable manner. The specifics of humanitarian engineering programs vary by university, but they collectively attempt to leverage business solutions to address global inequities—such as those related to food, health, and energy—by working collaboratively with developing communities. Concentrations of such programs include innovation, social entrepreneurship, and context-driven design, and they often employ the pedagogy of service learning [11]. These programs have had greater success than most traditional engineering programs at attracting and retaining female participants [12]. However, while several

research studies focus on the impact of such programs post-involvement, few of them explore the student motivations for initial participation [13] [14].

This study seeks to understand the motivations of women who participate in the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Penn State. The HESE program attracts consistent participation from female students in engineering and other colleges. In the program, students and faculty from all disciplines develop sustainable and scalable solutions for global challenges. One of the program's goals is to change the perception of engineering to a profession that is directly involved in improving the lives and livelihoods of individuals in resource-poor environments. The quest is for solutions with the four hallmarks of sustainability – they must be technologically appropriate, environmentally benign, socially acceptable and economically sustainable. Several of the program's entrepreneurial ventures have leveraged external seed funding to develop enterprises that have impacted a few million people. A common element amongst most successful teams is that they included a significant number of female students with multiple years of academic engagement.

Understanding the motivations for women's participation in such academic programs and ventures is critical to determining how universities can draw women to engineering programs and retain them until the successful completion of their studies. The findings of this study can help faculty advisors better understand what female students may want out of their educational programs and careers. Finally, publishing the motivations of female students may incentivize professional women to inform others about unique emerging opportunities in their fields. This study also seeks to investigate why female non-engineering students are participating in HESE. Understanding the perspective of non-engineering majors will allow educators to better engage them in collaborative efforts. Such organic collaboration can strengthen the venture team, while gradually changing the perception of entrepreneurs and the engineering profession. Furthermore, including the perspective of male students elucidates the differences between them and their female counterparts. Studying male motivations also helps guide how to continue attracting students of both genders and all majors.

This article starts with a review of the current literature on women's participation in engineering, entrepreneurship and humanitarian-focused programs. The research methodology, including the data collection and analysis methods, is discussed next. Demographics and motivations of students that have participated in the core teams of HESE courses/ventures over the last five years (2009-2013) are presented. The motivations of male and female students, as well as STEM and non-STEM students, are discussed so that comparisons can be drawn between these sub-groups. Relevant quotes from female students are interspersed in the discussion to capture nuanced perspectives in the students' own words.

BACKGROUND

While more women are entering the STEM fields than ever before, there is still a large gap between the number of women and men enrolled in STEM fields as undergraduates. The gender disparity is further aggravated at the Masters and Doctorate level [15]. These low enrollment numbers subsequently bias the number of women working as professionals in the STEM fields. According to a study by the American Association of University Women (AAUW), by 2018, the top-growing jobs in the U.S. will "require significant scientific or mathematical training" and having more women professionals in the STEM fields will "maximize innovation, creativity, and competitiveness" in America [15]. Women are integral to the STEM fields and consequently the national engineering culture must change to encourage the retention of, and dispel the bias and stereotypes about, women in STEM fields [15].

Attracting women to engineering has been a problem since its inception. Despite extensive research into why female students leave engineering, there is a lack of consensus on the reasons [16]. Commonly reported reasons for retention failure include low self-efficacy [17], a lack of academic confidence [18], unsatisfactory guidance by faculty [19], and diminished ability to establish a community within engineering [7]. It has also been discussed that mission statements of engineering programs are tailored towards males, and may create negative attitudes about the inclusion of women within engineering environments [20]. The structure of coursework inherent to engineering also does not appeal to women and it has been suggested that a truly inter-disciplinary engineering curriculum, drawing from the liberal arts, could attract more women to engineering [21]. At the same time, in a study at the Colorado School of Mines, women engineers were found to comprise more than half of the participants in engineering projects focused on humanitarian problems [9]. By emphasizing concern for the needs and wellbeing of resource-constrained communities around the world, Humanitarian Engineering brings a wave of change to the perception of the engineering profession [22].

Universities, professional bodies, and governmental agencies have long sought to bring diversity into engineering programs by increasing outreach to women. Despite spending hundreds of millions of dollars to promote the engineering profession to young people, it was found in 2002 that the majority of efforts were fruitless. The major problem cited was a lack of consistent information regarding the nature of work done by engineers resulting in general misunderstanding of who engineers are, and what characterizes a successful engineering candidate [23]. Similar attitudes exist throughout the United States, leading to minimal desire among female students to pursue an engineering degree at the undergraduate level. Out of over 1.4 million junior-level students that took the Preliminary SAT/National Merit Scholarship Qualifying Test in 2011, 17.8% of the male students listed engineering as their future major in college, the highest of any discipline. Conversely, only 2.8% of female students listed engineering as their intended major [24].

The National Academy of Engineering (NAE) conducted a seminal study that attempted to discern how recruiting messages can most effectively attract interest from diverse populations. While examining the current perceptions of engineering among the US population, focus groups were conducted with young women to discuss the issue of career choices. An overarching conclusion from young females in the group was that while women had equal potential as men to become engineers, "'girls that like things that boys tend to like' (e.g., video games, cars and vehicles, building things) were more likely to become engineers than 'average girls' (e.g., girls who want to be veterinarians, lawyers, doctors, fashion designers, teachers, or otherwise want to 'work with people.')" [8]. In its groundbreaking book, "Changing the Conversation", the National Academy of Engineering (NAE) strongly encourages the engineering community to adopt the following messages to describe the work of an engineer:

1. Engineers make a world of difference.
2. Engineers are creative problem-solvers.
3. Engineers help shape the future.
4. Engineering is essential to our health, happiness, and safety.
5. Engineers connect science to the real world [8].

Painting a more comprehensive picture of an engineer's knowledge base, professional work and global impact will enable K-12 students and the larger population to rethink and redefine engineering in a more inclusive manner. The goal is to diverge from the singular story of engineers as math and science-loving nerds that build cars and video games. Instead, programs like HESE strive to create a multi-faceted conceptualization of engineers as innovators and problem-solvers striving to make the world a freer, fairer, friendlier and more sustainable planet. The idea is to champion, with a sense of humility, the notion that engineering is a mindset for addressing global challenges. In that quest, students can 'make a world of difference' and 'shape the future' while they are still in college, by engaging in relevant academic programs.

Over the past two decades, entrepreneurship education programs have grown significantly in terms of both number and popularity [25]. However, entrepreneurship remains another global field in which women are under-represented. Females have been repeatedly found to have lower entrepreneurial self-efficacy and lower entrepreneurial intentions [10][26]. According to the 2010 Global Entrepreneurs Monitor report on Women Entrepreneurs Worldwide, women had higher entrepreneurial activity than men in only one of the 59 economies surveyed. Few economies even had equal numbers of male and female entrepreneurs [27]. While statistics abound regarding the number of professional females participating in entrepreneurial activity, there is little research about gender dynamics of entrepreneurship in university settings [25]. However, women entrepreneurs have garnered significant attention from news sources and scholarly publications alike on the current status of females starting and managing businesses [28][29][30].

"Social Entrepreneurship", defined as sustainable value creation that focuses on large-scale transformational benefit for marginalized populations in resource-constrained environments, has become a buzzword in academic and global development communities [31]. Engineers are considered to be "naturally skilled at innovation" and engaging in social entrepreneurship enriches their education while enhancing their inherent inventiveness [32][33]. The problem-solving nature of engineering students makes hands-on projects extremely beneficial to their knowledge growth [34]. Channeling students' energies towards social problems can fulfill academic goals while concurrently developing their professional skills and providing experiential learning in how to achieve sustainable global impact. Despite its great potential, the literature on social entrepreneurship education is essentially non-existent. Service learning literature is vast but the majority of it focuses on program evaluation rather than student motivations [35][36]. A shift must occur to focus on why students choose to engage in service-learning, as that will dictate how to design new academic programs, or evolve current ones, tailored to the wants and needs of students and partnering communities. Research has shown that motivations are comprised of academic self-efficacy, attributions, intrinsic motivation, and achievement goals [37]. Motivations provide valuable insight into the student as a whole, and understanding student motivations will enable academic institutions to optimize their educational experiences.

HESE CURRICULAR MODEL

The Humanitarian Engineering and Social Entrepreneurship (HESE) program has evolved from students working together in a student club, to a series of course-based efforts, to include a formal certificate program in Engineering and Community Engagement and the form the Social Entrepreneurship cluster (specialization) in the intercollegiate minor in Entrepreneurship and Innovation. The goal in creating the Certificate program was to institutionalize a program that would engage engineering (and other) students in employing their academic training to bring about sustainable change in marginalized communities. The certificate is optional, but all HESE students are involved with technology-based social ventures in conjunction with partnering academic and community organizations. The ventures are multi-year endeavors that are tightly integrated into students' academics. Students work in cross-functional multidisciplinary teams on the design, testing and commercialization/implementation of their ventures. The courses offer real-world integrated engineering research and design experiences, and cover a range of topics, from problem formulation through venture scale-up and performance assessment, depending on where the particular venture is in its lifecycle [38].

All HESE ventures utilize skills and knowledge from various disciplines - engineering, agriculture, medicine, business, social sciences, etc. The academic model of student engagement engages students and faculty mentors across campus in these ventures in various formal and informal ways from the sub-credit to multi-credit levels [38]. Students participate with different degrees of engagement including honors thesis research, focused courses, embedded projects, commissioned assignments, volunteer efforts, etc. The core teams, responsible for the system integration of the ventures are housed in a 2-credit course titled "Projects in Humanitarian Engineering" (EDSGN 452). Every venture has its own section and it is open to undergraduate and graduate students from all disciplines. All the core team students concurrently enroll in a common one-credit seminar class titled "Design for Developing Communities" (EDSGN 453). This seminar course grounds students enrolled in EDSGN 452 and other related courses in the basics of humanitarian engineering, user-centered design for extreme affordability, social entrepreneurship, systems thinking, travel and fieldwork, and related issues.

A number of engineering and other classes participate in the ventures alongside the core team. For example, a junior-level bioengineering class of 56 students works on the design of the inexpensive biomedical devices for at elemedicine venture. The class is divided into eight teams and each team is assigned a different device. At least one student from each team serves as the context lead and attends the EDSGN 453 seminar class. Students participating by way of honors thesis, commissioned assignments, or volunteer effort are also required to register for the seminar class. The seminar talks are streamed live for students from other campuses and professionals mentoring the teams. Comprehensive assessment of the model has been conducted and it was found that at all levels of participation, students gained global awareness and their experiences have made them more culturally conscious, and more prepared to confront real-world challenges in the future. The women that participated in this study were engaged in six different ventures over the five years of data collection. Since the nature of the ventures fundamentally impacted the recruitment and engagement of students, these ventures have been discussed in brief.

Mashavu: Networked Health Solutions

Mashavu is a telemedicine system that connects medical professionals in developing countries with individuals living in rural areas through the use of relatively simple yet innovative technology. The smart-phone based system sends a patient's medical history and vitals to a healthcare professional that responds with a recommended course of action within twenty minutes. Mashavu operators charge customers a small fee per consultation, thereby making the venture economically sustainable and creating an additional revenue stream for the rural communities [39][40]. Since July 2011, Mashavu is a cash-positive venture operating in Central Kenya. HESE teams continue to

expand the scope of operations by developing low-cost biomedical devices, refining the operational models, and scaling operations across regions.

WishVast: Building Trust and Social Capital using Cellphones

WishVast is a cell-phone-based business networking system that harnesses the pervasiveness of cellphones in developing countries to optimize resource utilization and facilitate people-to-people trade, with the ultimate goal of alleviating poverty. WishVast allows its users to join groups of local relevance to exchange information, meet new people based on shared interests, and build trusting relationships [41][42].

EssentialDesign: Appropriate Technologies

EssentialDesign projects focus on the development of appropriate infrastructure technologies that are socially, environmentally and economically sustainable. These include projects related to: housing, water and wastewater systems, energy, and agricultural systems. Current ventures include low-cost greenhouses, solar food dryers, rainwater harvesting systems and ceramic water filters [43].

iSPACES: Rethinking Science Education + Design of Innovation Space

The iSPACES venture has two components: 1) Understanding barriers to science education and developing effective science education programs and 2) designing of an affordable and sustainable Innovation Space where people from various walks of life can converge to rapidly prototype innovative products that meet their unique needs and preferences. A key feature of this space is access to various kinds of connectors and structural elements that collectively form a full-scale "LEGO® set" for innovators [44][45][46].

Project Prerana: Rural Supply Chains + Educational Systems to Empower Women

Prerana is an information platform that utilizes multimedia educational modules. These modules allow the user, regardless of their literacy level, to access relevant knowledge that will help them improve their ability to attain basic daily needs and that of their families. Prerana accomplishes this through improving users' prospects of attaining employment or through helping them improve the skills necessary in maintaining successful employment [47].

HESE Projects in K-12 Education

Engineering students serve as effective partners, role models and mentors to K-12 teachers and their students. HESE students work on technology with K-12 teachers, students and retirement

communities with the goal of motivating students to use their mathematics, science, business and social studies skills to build functional bench-top agricultural systems for various customers.

DATA SOURCE AND ANALYSIS

The population used for this study includes all students enrolled in the common HESE seminar class, EDSGN 453: Design for Developing Communities, between 2009 and 2013. To be eligible to work on HESE ventures, all students regardless of their major must enroll in the EDSGN 453 course once. This course counts as an elective course for most students. Students from the Hershey College of Medicine and Dickinson School of Law are not required to officially register for the class. All students enrolled in the course write weekly blogs to reflect on, and chronicle, their academic, professional, and personal journeys throughout the semester. Beyond acting as a component of final grades, these blogs are intellectually challenging and thought-provoking, and ensure that students remain actively engaged in all aspects of the course. Students gave written permission for their blog posts to be used for research purposes. Blog posts from 204 of 305 total students enrolled in EDSGN 453 class from 2009-2013 were used for this study.

The study focused on students' initial blog assignment that included two questions: 1) Why did you enroll in this course? and 2) How do you envision this course making you a better student? The blogs of all students (male and female) were analyzed to determine recurring themes. The authors subsequently coded each blog for occurrence of each theme. Analyzing the blog posts was the most efficient way of collecting data for this study. While individual interviews would have yielded richer data, it was not realistic to schedule a large number of interviews with busy students during the first week of class. Individual interviews would also leave room for bias, as motivated students would be more likely to schedule interviews. The sample was fundamentally biased because the students self-selected to participate at a higher level of engagement in the HESE program. The majority of the students included in the study continued on, or intend to continue, with the certificate program in Engineering and Community Engagement or the minor in Entrepreneurship and Innovation with an emphasis on Social Entrepreneurship. After analysis, the significance of differences between males' and females' motivations was calculated using a chi-square test. Corresponding p-values < 0.05 were determined to be significant.

STUDENT DEMOGRAPHICS

Over the course of five years, we have seen an increase in the total number of overall participants in EDSGN 453, the HESE seminar class required in order for students to work on one

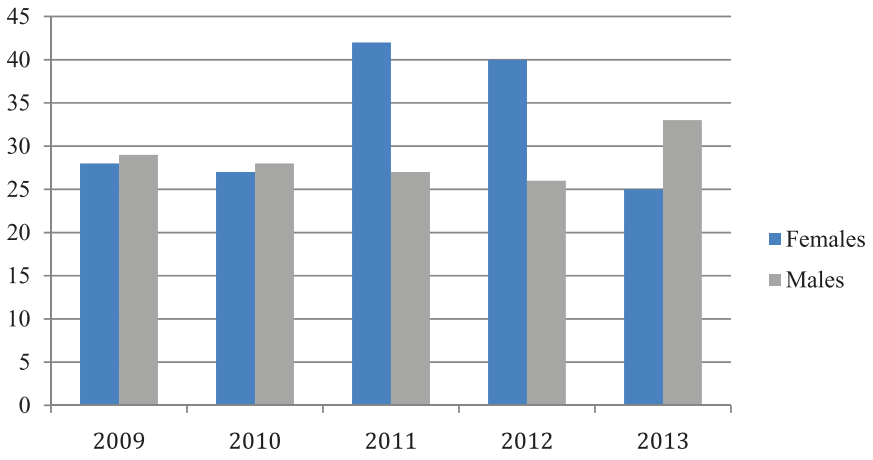

Figure 1. Students Enrolled in HESE, 2009–2013, (n=305).

of the various ventures that are integrated into the EDSGN 452 class. As shown in Table 1, the percentage of women enrolled from the College of Engineering has been relatively steady over the last five years, hovering close to half of the total number of enrolled participants. The initial drop from 2009 to 2010 can be attributed to a rising enrollment of non-engineering females. Data from 2013 is unique for several reasons. Lower total participation can be attributed to fewer venture offerings due to faculty changes. As the program and all the courses were formalized, there was a paradigm shift towards fewer ventures with more rigor, higher quality, and operations in multiple countries. Further, the lower percentage can be attributed partially to the medical students; for the first time three male medical students were selected to work on the Mashavu

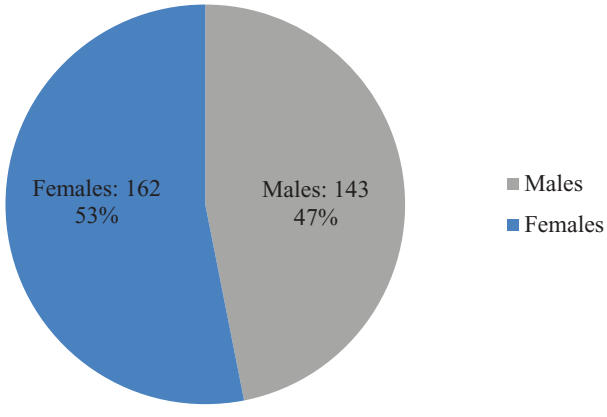

Figure 2. Total Student Participation in HESE, 2009–2013, (n=305).

Semester	Total Participants	Females	Males	Percent Females enrolled	Percent Males enrolled	Total Females Enrolled from the College of Engineering	% Females from the College of Engineering (From Total Female)
Spring 2009	57	28	29	49%	51%	16	57%
Spring 2010	55	27	29	49%	51%	12	44%
Spring 2011	69	42	27	61%	39%	20	48%
Spring 2012	66	40	26	61%	39%	19	48%
Spring 2013	58	25	33	43%	57%	16	64%

Table 1. Distribution of Female Participants from 2009–2013 (n=305).

project whereas all previous participants from Hershey Medical College were women. Finally, it must be noted that HESE does not pro-actively recruit women, and instead recruits all students regardless of gender.

As shown in Table 2, almost half (48.8%) of all female HESE participants come from the College of Engineering, the largest percentage of any academic college. The total undergraduate student

College	Total # Students Enrolled	# of Males Enrolled	# of Females Enrolled	%Female Students (n=162)
College of Engineering	166	85	81	48.8%
College of Agricultural Sciences	20	2	18	11.1%
College of Information Sciences & Technology	17	14	3	1.8%
Eberly College of Science	17	7	10	6.2%
College of Earth and Mineral Sciences	15	6	9	5.5%
Smeal College of Business	14	10	4	2.5%
School of International Affairs	12	2	10	6.2%
Hershey College of Medicine	10	4	6	3.7%
College of Health & Human Development	7	1	6	3.7%
College of Liberal Arts	7	4	3	1.8%
College of Education	5	2	3	1.8%
Dickinson School of Law	5	2	3	1.8%
College of Communications	4	2	2	1.2%
College of Arts and Architecture	3	1	2	1.2%
Penn State Staff, non-student	1	0	1	1%
Intercollege Degree	1	0	1	1%
Division of Undergraduate Studies – undecided	1	1	0	0%

Table 2. Distribution of HESE Students by Discipline, 2009–2013 (n=305).

enrollment in the College of Engineering at the University Park (main) campus is about 10,000, of which 18.6% are women. A small fraction of engineering students participate in the HESE program. The College of Engineering also offers certificates or minors in Engineering Design, Engineering Entrepreneurship, Engineering Leadership Development, Product Realization, and International Engineering. The College of Engineering also represents the college from which the most participants (regardless of gender) are joining HESE. In 2011, HESE expanded its networks to include the Penn State College of Medicine, which enables medical students to work on Mashavu, the telemedicine venture in Kenya. For the first time, in 2012, HESE partnered with the Penn State Dickinson School of Law (DSL) to form the International Sustainable Development Projects Law Clinic, which enables law students to work on diverse legal aspects of the ventures.

Differences in enrollment by college may result from variations in advertising schema. Since HESE is housed within the College of Engineering, many more HESE recruitment opportunities exist for engineering students as opposed to students enrolled in other colleges. Additionally, faculty champions from outside of the College of Engineering play a major role in attracting students from their colleges to the program. HESE provides information about the program for as many academic advisors as possible, and some individuals promote the program to their students more than others. HESE is an extremely demanding program with intense results-oriented coursework, a required faculty-led fieldwork experience in a developing community, and expectation of an original publishable manuscript. It attracts a specific cadre of students who are interested in social value creation and international development.

RESULTS AND DISCUSSION

Motivations for Participation

Student blogs were analyzed through various demographic lenses in terms of motivations for participation in the HESE program including: Motivations of all participants regardless of major (Table 3); Motivations of all participants from the College of Engineering (Table 3); Motivations of all participants with a science/engineering (STEM) major (Table 4); Motivations of all non-STEM participants (Table 4). The authors examined the motivations for participation of STEM and non-STEM students in order to draw conclusions regarding why students outside of sciences and engineering decide to participate in HESE.

Table 3 shows that females' strongest motivation for participation across all majors is becoming a global professional followed by making a difference, and participating in an exciting, immersive real-world project. For male students, the strongest motivation to enroll in HESE is making a difference.

	All Majors					Engineering Majors				
	Male (n = 95)		Female (n = 109)			Male (n = 59)		Female (n = 58)		
Motivations	**Percent**	**Number**	**Percent**	**Number**	χ^2	**Percent**	**Number**	**Percent**	**Number**	χ^2
Motive 1- To become a global professional	34.7	33	65.1	71	18.7**	37.3	22	56.9	33	4.51**
Motive 2 - Make a difference	63.2	60	56.0	61	1.09	61.0	36	50.0	29	1.44
Motive 3 - Apply something learned in school (theory) to address a problem/help someone	48.4	46	45.9	50	.13	50.8	30	53.4	31	.079
Motive 4 - Participate in an exciting immersive real-world project	52.6	50	55.0	60	.11	59.3	35	58.6	34	.006
Motive 5 - Specific interest in the subject matter of a venture (i.e. global health, science education, etc.)	31.6	30	44.0	48	3.36	16.9	10	37.9	22	6.48**
Motive 6 - Work in multi-disciplinary teams; learn from other majors	38.9	37	43.1	47	.36	39.0	23	50	29	1.44
Motive 7 - Engage with and learn from other cultures	33.7	32	33.0	36	.009	32.2	19	34.5	20	.068
Motive 8 - Interest in travelling	44.2	42	30.3	33	4.24**	50.8	30	41.4	24	1.06
Motive 9 - Engage in research	5.3	5	7.3	8	.366	3.4	2	8.6	5	–

** indicates $p < .05$; χ^2 not calculated for $n < 5$

Table 3. Motivations for Participation among All Students and Engineering Majors.

	Engineering + Science (STEM) Majors					Non-STEM Majors				
	Male		Female			Male		Female		
	(n = 79)		(n = 82)			(n = 16)		(n = 28)		
Motivations	**Percent**	**Number**	**Percent**	**Number**	χ^2	**Percent**	**Number**	**Percent**	**Number**	χ^2
Motive 1 - To become a global professional	35.4	28	64.6	53	13.7**	31.3	5	66.7	18	4.45**
Motive 2 - Make a difference	60.8	48	52.4	43	1.13	75	12	66.7	18	-
Motive 3 - Apply something learned in school (theory) to address a problem/help someone	48.1	38	51.2	42	.156	50	8	29.6	8	2.02
Motive 4 - Participate in an exciting immersive real-world project	41.9	41	56.1	46	.286	56.3	9	51.9	14	.159
Motive 5 - Specific interest in the subject matter of a venture (i.e. global health, science education, etc.)	26.6	21	43.9	36	5.28**	56.3	9	44.4	12	.732
Motive 6 - Work in multi-disciplinary teams; learn from other majors	38.0	30	47.6	39	1.51	43.8	8	29.6	8	2.02
Motive 7 - Engage with and learn from other cultures	31.6	25	34.1	28	.114	43.8	8	29.6	8	2.02
Motive 8 - Interest in travelling	46.8	37	35.4	29	2.19	31.3	5	14.8	4	-
Motive 9 - Engage in research	2.5	2	8.5	7	–	1.25	2	3.7	1	-

** indicates $p < .05$; χ^2 not calculated for $n < 5$

Table 4. Motivations for Participation among STEM and non-STEM Majors.

Male and females cited the majority of motivations at similar rates including: making a difference, applying theory, participating in an exciting real-world project, working in multi-disciplinary teams, and engaging with other cultures. Statistically significant differences existed between male and female motivations regarding 1) becoming a global professional and 2) interest in travel. Many more women than men cited an interest in catalyzing their careers through participation in the course. On the other hand, men discussed how the class was a good opportunity to travel. Male engineering students in particular were interested in travel (50.8% cited travel). This may be attributed to study abroad opportunities being limited by engineers' strict curricular requirements.

The authors explored the motivations of STEM-majors versus non-STEM majors (Table 4). In order to leverage major-specific skillsets, it is critical to understand why these groups choose to participate. Both male and female non-STEM students more often cited interest in the subject matter of ventures as a motivator than students in other ventures. This could indicate that students are choosing to engage in ventures that encompass topics related to their desired future career. The interest in becoming a global professional remained as the top motivation for female non-STEM students and students of both genders were motivated by the opportunity to make a difference.

Becoming a Global Professional

In today's globalized society, it is of critical importance that students gain practical experience as early as possible, and the HESE program is one way by which this can be accomplished. For students, applying their classroom knowledge to a real world project can catalyze their path to becoming a global professional. They are able to make a sustainable difference in a community but also add this experience to their résumés and discuss it in future interviews. Across all majors and subgroups, women listed becoming a global professional as their motivation for enrolling in HESE at significantly higher rates than men. Gaining the skill set and confidence that the phrase "global professional" implies may help women strongly establish themselves in fields traditionally dominated by men. While men certainly expressed interest in engaging in the real-world and beneficent aspects of the projects, women consistently stated that HESE projects represented what they want to do for the rest of their lives.

The motivations of female students in HESE align significantly with the positioning messages suggested by the NAE Changing the Conversation publication [8]. Combining humanitarian efforts, entrepreneurship and technological innovation brings to life the field of engineering as suggested by the NAE. Many students leave the field of engineering during, or immediately following, college because their aspirations of 'connecting science to the real world' and 'shaping the future' are smothered by rigid educational regimens. The onus is on educators to create multi-dimensional educational environments that provide students compelling opportunities to realize the full potential of the engineering discipline and mindset.

Included below are student quotes that reflect women's desire to become global professionals.

"The types of entrepreneurial endeavors we'll be engaged with in [this class] reflect relatively closely what I hope to do with my career. I've always been interested in small businesses and non-profits because I find value in the stake that each individual places in the organization as a result."

"After my involvement with the Essential Design course last semester I knew that these are the types of projects I am passionate about. I think this course will help me to understand the global economy and market place better. Learning how to be an engineer in a developing country and how their needs are different from those in the developed world. I hope to become a well-rounded engineer with unique experiences. I want to not only be considered by a future employer as an engineer, but as a person with a passion for her work, someone that seeks unique and adventurous opportunities, and someone ready to tackle any challenge or adversity."

"Because I have limited experience in communicating across different majors and across other countries this is going to be a great learning experience for me that will help in all of my future endeavors as an engineer for the rest of my life. I am planning on being employed by the government to some extent and there it is pertinent that I know how to effectively communicate with all different kinds of people because otherwise I personally would never be able to accomplish much."

"As a potential engineer, I look forward to the real-life global experience these ventures will offer, as well as the hands-on and cross-discipline practice I'm sure to get. I also believe that this is where the industry's major sustainable growth lies, given trends in global population."

"As mentioned in the first seminar, this class does the work that is actually being done by humanitarian international organizations. I want to learn how to think and create in a "constrained" environment because, if I can help it, I will be involved in this type of work for the rest of my life."

"Helping out" vs. "Making a sustainable difference"

"Making a difference" was a fairly common theme, with approximately 60% of both males and females citing it as a motivation. Upon further analysis, the authors realized there was a difference between individuals wanting to "make a difference by helping out" and those who wanted to "make a sustainable and/or entrepreneurial difference." Over half of the students were specific in that they wanted to make a sustainable and/or entrepreneurial difference. The HESE program strongly focuses

	All Majors				
	Male		Female		
	(n = 95)		(n = 109)		
Motivations	**Percent**	**Number**	**Percent**	**Number**	χ^2
Motive 1 - Make a difference by helping out	44.2	42	24.8	27	8.57**
Motive 2 - Make a sustainable / entrepreneurial difference	18.9	18	31.2	34	4.01**

** indicates $p < .05$; χ^2 not calculated for $n < 5$

Table 5. Motivations of "Helping out" vs. "Making a Sustainable Difference".

on entrepreneurial solutions to pressing global issues such as food security and lack of access to health care in sub-Saharan Africa. Students recognize the difference between leading social change through sustainable long-term solutions versus "helping out" in an ad-hoc manner (more akin to volunteering). Several students discussed how their venture (and their contributions to it) had the potential to do more than just "help out" the communities, demonstrating that students want to engage in ventures where the fruits of their hard work will create self-sustaining systems. Further evidence can be found in the long hours and hard work students contribute over the course of the semester in HESE classes. Their efforts are fueled by a passion to create impactful change in the subject area of their venture. A few quotes from the blogs of female students capture this sentiment and are highlighted below:

"The project as a whole is interesting to me because (like many other participants here) I am interested in helping someone lead a better life. I see this as a golden opportunity to learn the 'how-to's of social entrepreneurship. I am acutely aware of the problems I see and have seen in my homeland, but finding sustainable solutions is an uphill task. I hope this project will school me better in being able to find them, design tools to successfully implement them and help communities chart their own path toward a better quality of life."

"Many times I have wanted to make a difference but never known how, but now I have the ability to change lives in a different part of the world. The best thing about this project is that it is built for sustainability, which means that what I'm doing will (hopefully) last forever. I think that's something to be very proud of...I will be more thoughtful and understand working in different cultural contexts, with different people."

"By enrolling in this course, I now have the opportunity to design using the knowledge I have gained so far and apply it to a real-life situation. I had never really done so in my

previous semesters. It was all just solving word problems in textbooks. Thanks to HESE, I can gain valuable experience in solving problems that test my abilities in being inventive and sustainable."

Multi-disciplinary Teamwork

The ability to work on multi-disciplinary teams was a motivating factor for approximately 40% of all students in every category. Students of both genders value working with students in a variety of backgrounds because they know it will benefit them in the future. This information signifies that the program is effective in terms of its cross-campus outreach efforts. Female students from College of Agricultural Science make up the second largest group of participants followed by the College of Information Science and Technology and the School of International Affairs. The focus on humanitarian issues is attractive to non-STEM students, especially those who want to work in the international arena after graduation. Allowing students to collaborate on creating innovative, tangible and sustainable solutions to global issues facilitates the engagement of students and breaking down of barriers between the sciences and liberal arts. Our findings corroborate with a study from Tufts University, where inter-disciplinary collaboration between the liberal arts, engineering, and the hard sciences was found to have long-term positive effects on female participation [6]. Students desire a forum to learn how to collaborate with their peers rather than compete, as they know it is a skill they must hone before entering the post-collegiate work environment.

"...one of the most vital things I have learned by working on this project is that life is multi-disciplinary and therefore education should be as well. The world does not exist in a vacuum and the more versatile you can become as a person, educator, citizen, business, etc. the more of an impact you will have on the world (which I would view as the ultimate goal). By redefining who I am and opening myself to new ways of thinking and interacting I have found an effective way to bridge the gap not only between disciplines but between people, countries, and cultures. That in short (or not so short) is why I enrolled in this course. I am confident that my continued involvement with Mashavu will enhance myself not only as a student but as a global citizen. I have already seen the ways in which working in multidisciplinary teams has challenged my notions of how to do things."

"I see this course making me a better student and engineer. One reason for this is because of the teamwork that we will all be involved in. As a whole this project is the largest team I have ever worked on, and being a part of it and having to communicate between all of the different factions will enhance my communication and teamwork skills...the teams for

this project are very multi-disciplinary, this is a good experience for me to learn more about other people and how my field can benefit from them and vice versa."

"I wanted to be a humanitarian and I wanted to be a scientist… I never thought about engineering, but wanted to learn from the experience. And I fell in love with the concept that we would be traveling to a country in Africa and actually implementing what was taught in class. Thus I realized that I HAD to enroll in the course."

Interest in a Specific Project

Female STEM majors were (Table 6) more motivated than men by specific interest in the subject matter of the venture. Mashavu: Networked Health Solutions is one of HESE's most well-developed ventures, with over five years of research and development efforts and more than 500 students participating in its evolution. A telemedicine system that aims to connect patients in rural communities with access to health care professionals, Mashavu epitomizes the multi-disciplinary nature of the HESE program. The knowledge and competencies needed to bring the system to fruition are extremely diverse, and require active participation from almost every discipline. The creation of the web application that connects patients to health care professionals needs computer scientists. Designing user and operator training requires students with education backgrounds. Privacy and liability concerns prompted the recruitment of a legal team. Electrical and biomedical engineering students are needed to develop the low-cost biomedical devices. Pre-medical and medical students facilitate patient interactions and conduct clinical assessment on-the-ground in Kenya. Business students are needed to develop the business model to ensure economic sustainability. However, that represents only a small sampling of the diversity of the Mashavu team. Students from eleven different colleges and over 50 majors have participated in this venture since 2009. Females consistently comprise the majority of students working on the Mashavu venture

	Engineering + Science (STEM) Majors					Non-STEM Majors				
	Male		Female			Male		Female		
	(n = 79)		(n = 82)			(n = 16)		(n = 28)		
Motivations	**Percent**	**Number**	**Percent**	**Number**	χ^2	**Percent**	**Number**	**Percent**	**Number**	χ^2
Motive - Specific interest in the subject matter of a venture (i.e. global health, science education, etc.)	26.6	21	43.9	36	5.28**	56.3	9	44.4	12	.732

** indicates $p < .05$; χ^2 not calculated for $n < 5$

Table 6. Motivation of Specific Interest in the Subject Matter of a Venture.

Although projects in the HESE program are technology-based and include different aspects of engineering design, they draw students from diverse majors because the ventures encompass issues of global health, access to education, and agriculture. For many students in the general sciences, their future career relates to the application of science to challenges in other disciplinary areas. Irrespective of major, 44% of all female participants indicated having a specific interest in a HESE venture as a motivation for participation.

It must be noted that the specific ventures that the students worked on did not necessarily correlate with their majors. For example, a civil engineer preferred to work on a healthcare-related venture than an infrastructure-related one, or a biomedical engineer preferred to work on a biodiesel system, an astrophysics major was one of the leads on an agricultural venture while a philosophy major did a phenomenal job leading the business strategy for a telemedicine venture! For some students, their preferred venture was aligned with their personal interests while others took a more practical stand and joined ventures that would give them an edge in their chosen professional domain. To the latter, projects like Mashavu can be especially appealing to students interested in public health or pursuing further study in topics like biology, biomedical engineering, or medical school. But this desire to engage in careers with humanitarian components is not unique to a small group of students. Those currently attending college - the Millennial generation (also nicknamed Generation G for Generosity) [48] - are inspired to combine their passion to do good in the world with their professional pursuits [32]. Social ventures can be an opportunity for students to delve into their passions in a way that no other class provides. Selected quotes portray female student's passion towards the intersection of their chosen ventures with their planned careers.

"With Mashavu's computer-based system, I believe that the project is a perfect marriage of IT work and humanitarian engineering."

"Being that I am a student in Science, and ultimately my goal is to become a doctor, I was going through a period in which I wanted to help those who need it right away. Given that I am still in college that was not possible, except volunteering at a hospital or something…I believe that this course will really allow that to happen, especially if I can go to Africa…. Having this experience would help me combine my dreams of becoming a humanitarian doctor, but at the same time let me learn from the perspective of engineering; thus, improve my interaction with engineers, since different fields are always diverging to meet common goals."

"As an IST major, I've always wanted to apply my education in technology into a career where I would be helping others in need. I feel passionate and motivated to explore new opportunities that coincide with my future career plans."

"Sometimes, for myself at least, it is hard for me to envision how slow and small advances in research, studying math theorems, etc. actually helps to benefit anyone out there in the world. This course, the Mashavu project, and all of the other projects as well, will hopefully serve as tangible ways to illustrate that engineering, technology, and specifically bioengineering for Mashavu are important and helpful on a global scale."

"I thought that there was more Humanitarian work in becoming a doctor or scientist than becoming an engineer. When I saw the crossover between the world of science, engineering, and humanitarian work come together, I realized there were endless possibilities."

"The Wishvast program closely mirrors how I plan to apply my business knowledge in a career, in that it underscores connections between fields and offers a real world opportunity to create social change. I believe that this course will help to make me a more well-rounded student and challenge me to use the types of critical thinking skills that I'll need in my career."

"The types of entrepreneurial endeavors we'll be engaged with in EDSGN 497C reflect relatively closely what I hope to do with my career. I'm also fascinated by other cultures, so although I've had no prior experience with Kenya in particular, I'm looking forward to the chance to learn more. I tend to approach my business degree through a liberal arts mindset and interest. In my opinion, it's crucial to consider the values of one's company as a top priority, to question one's perspective and assumptions of the market and ensure that business is conducted with respect. I'm hoping that this focus will bring a new dimension to the Wishvast team."

"As engineers I feel like we are taught that the big advances are what make the big differences, and big advances are defined as new and exciting ventures. What I have heard over the past few days is that there is such a disparity between what I thought innovation was to what it really is, and there is a difference between what makes a big difference for powerful people and what makes a big difference for this world as a whole. Knowing this difference will definitely make me a better civil engineer."

Perception of engineering

Engineering is not traditionally seen as a field with a strong ethic of care, an attribute that often repels women from the field [22]. However, the integration of humanitarian work into engineering education broadens the stereotypical views held by outsiders regarding the profession. Women want to gain practical experience, work collaboratively on impactful projects and have found they can do so through engineering as a result of engineering and entrepreneurial service-learning programs [49]. HESE has successfully moved away from the demographics of most professional engineering programs and closed the gender divide that typically permeates the field. We postulate that this is a result of the emphasis on humanitarian issues, a common finding among service-learning programs.

Through this study, we are realizing that female participants in HESE are drawn to more than the humanitarian aspect of the program. The program provides a space where students can think innovatively and make a lasting impact on a community while simultaneously catalyzing the students' personal transformation into global professionals. Additionally, the academic program provides a space where passionate students effectively redefine engineering in their minds as a field welcoming to all, where students regardless of gender, major, or semester standing can work together to change the world. Females resist engineering because they do not see the field's potential for 'shaping the future' or why it is 'essential to our health happiness, and safety' [8]. However, women may reconsider their views on the engineering profession when programs like HESE demonstrate a whole new world of collaborative engineering and real-world impact to them. The students greatly value the opportunity to expand the bounds of their academic majors and extend the reach of their scholarly work. Here are a few quotes that capture this sentiment:

"The idea of this being an engineering class is intimidating because I don't have a technical or mechanical background at all. The combination of humanities and engineering is one I've never really considered or seen in any other program or class, but its a combination that makes so much sense."

"As an engineering student, I feel like almost all of my work is geared strictly towards math and science. Thus, the exposure to these other disciplines will be really advantageous for me. The last time that I had a class on World Cultures, was probably in high school. And all of those classes were taught using a text book. This class seems to be more interactive, and I am really looking forward to learning facts and ideas about a culture that I probably would not have had the opportunity to do so."

"As far as the project making me a better engineering student, I think it can only help me to learn things that I am currently not aware of at all. Being a Health Policy and Administration major, I have never been involved in an engineering project, and I am fairly naive in the subject. I am willing to learn how projects are designed and brought together from the bottom-up and the top-down. I hope to walk away from this class having an idea of how engineers approach and accomplish projects."

"So far in my academic career being an engineer, I have only solved problems by crunching numbers into a calculator, scratching down the answer and submitting it for points. Sure it improved my technical problem solving skills but when it comes to being innovative and thinking on the fly, I am lacking quite a bit, mostly because I haven't had the chance to use them. By deciding to join HESE, I can now train those skills and learn to be resourceful, make the most out of so little."

CONCLUSION

This paper discussed the motivations of women engaged in an engineering program focused on the development of technology-based enterprises that prioritize social value. Though the sample size is small, the students involved in the study represent passionate undergraduate and graduate students seeking unique opportunities within engineering curricula. Our data indicate that female students enrolled in the program are primarily motivated to work on such entrepreneurial ventures because they believe the experience will help them become global professionals. Other high-ranking motivations include making a difference and applying theory learned in school to address a problem or help someone. For many students, the ventures represent a trial run for their desired post-collegiate careers. For others, the ventures are an avenue towards creating sustainable impact. The opportunities provided by HESE and similar academic programs – multi-disciplinary teamwork, ethical decision-making, systems thinking, global engagement, development of an entrepreneurial mindset, practical real-world experience, introduction of broader skill sets and exposure to diverse subjects - all have the potential to contribute to students' future success. Further, incorporating such elements into engineering curricula may help to attract and engage more women in the fields of engineering and entrepreneurship, both of which are in great need of gender balance.

To promote balanced enrollment in engineering and entrepreneurship programs, engineering education must evolve. Female students emphasized their interest in leveraging their engineering education to become global professionals who can address complex challenges in multi-disciplinary teams. The students were clear in their motivations of participating in HESE – to actually build sustainable and scalable systems that live on, take a life of their own, and solve problems for lots of people. In essence, these students want to be social innovators and entrepreneurs and are challenging educators to design educational experiences and entrepreneurial ecosystems to enable them to pursue their passions. The publication of "Changing the Conversation" has catalyzed an exciting dialogue regarding mechanisms for marketing the engineering profession, specifically to women. However, our data and experiences suggest that it is not enough to just discuss ways that engineers can make a world of difference. While strategic messages will attract a more diverse population to engineering, they will not necessarily engage, retain and accelerate women towards their ultimate professional goals. Engineering education must also be re-conceptualized in the minds of educators. Traditional engineering classrooms do not systematically meet the diverse needs and wants of today's students, nor are they a sufficient introduction to the evolving nature of the engineering profession in the interconnected global economy. Radical innovation, the kind of step-change thinking that changes the world, stems from radical collaboration. Such collaboration must go beyond electrical engineers working with mechanical engineers. Instead, electrical engineers need to be comfortable working

with social scientists, business professionals, chemists, philosophers and also with people with little or no formal education.

When discussing how we must educate the Engineer of 2020, Charles M. Vest, president emeritus of Massachusetts Institute of Technology said, "My primary advice regarding engineering education is that making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus is more important than specifying curricular details" [50]. Engineering educators and students need to co-create such transformational learning spaces. In this quest, a convergence of concepts, disciplines, cultures, and epistemologies can help develop an enabling framework for passionate students and faculty to break down the barriers amongst them, and between them and the collaborating communities [51]. Engaging women in these innovation processes is a fundamental pre-requisite for transforming the perception of the engineering profession and finding sustainable solutions to compelling global problems. The successful operationalization of these learning spaces and innovation processes is contingent on the ability to understand and align them with the motivations of students, particularly women and other underrepresented groups. This study illustrates that the motivations of female students to engage in technology-based social entrepreneurship programs like HESE are fairly sophisticated and nuanced. Females desire impactful engineering experiences that prepare them for careers as global professionals. Simultaneously, they want to contribute significantly to specific projects while collaborating with diverse populations of students and communities alike. These multi-faceted motivations provide a compelling snapshot of the professional 'coming of age' of female engineers and entrepreneurs.

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