



Article Engineering Students' Concepts of Humanitarian Engineering and Their Identity Development as Humanitarian Engineers

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Abstract: Humanitarian Engineering extends engineering practice to provide a focus on addressing social inequities and contributing to sustainable development for all. This study investigated undergraduate engineering students' concepts of Humanitarian Engineering and motives to be Humanitarian Engineers as they acquire knowledge and skills and build a professional identity as engineers who can work in complex socio-technical sustainability contexts. Qualitative data were collected from an open-ended survey of 46 engineering students followed by semi-structured interviews with ten students at a U.S. university. Survey data provided individual characteristics that conceptualized and guided interviews to explore key relationships among participants' concepts of Humanitarian Engineering and motivations. A central idea of a "Humanitarian Engineer" identity emerged, influenced by various motivations. Students envisioning themselves as Humanitarian Engineers were associated with socio-cultural background, motivation to practice engineering skills, and desire to travel. A value-related motivation, the desire to help others, appeared as a strong catalyst for developing students' professional identities and empowering a possible future self as Humanitarian Engineers. To support sustainability education in engineering demands, initial motivation factors associated with student Humanitarian Engineer identity development are researched to support potential future practice and career development.

Keywords: humanitarian engineering; professional identity; sustainable development

1. Introduction

There is a growing interest in cultivating Humanitarian Engineers who can play a significant role working on sustainable development [1]. Ever since the establishment of the first national Engineers Without Borders (EWB) in 1982, Ingénieurs sans Frontières in France [2], for the purpose of offering humanitarian or development assistance supported by engineering and technology, the number of organizations with similar missions has increased. This includes independent EWBs in other countries, Engineers Against Poverty in 1998, Engineers for a Sustainable World in 2001, and Engineering for Change in 2009 [3]. The "Engineering for a better world" report from UNESCO in 2003 highlighted the importance of engineering, which contributes to technical capacity-building in developing countries [4]. This growth captures engineering's engagement in larger global efforts aligned to both the UN 17 Sustainable Development Goals (SDGs) (e.g., building a living economy, fair distribution, and staying within planetary boundaries) established to end poverty and bring about a more sustainable future and the Sendai Framework for Disaster Risk Reduction, which outlines priority targets to reduce existing disaster risks and prevent new ones.



Citation: Park, J.J.; Park, M.; Smith, J. Engineering Students' Concepts of Humanitarian Engineering and Their Identity Development as Humanitarian Engineers. *Sustainability* **2021**, *13*, 8845. https://doi.org/10.3390/su13168845

Academic Editor: Firoz Alam

Received: 12 July 2021 Accepted: 4 August 2021 Published: 7 August 2021

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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). From these organizations and agendas, Humanitarian Engineering (HumEng) has emerged. We use Humanitarian Engineering (capital H and E) to refer to specialized areas of practice involving humanitarian response and community development, to differentiate from humanitarian engineering (lower case), which can apply to engineering that has an impact on society (which, it can be argued, is all engineering).

Related terms including Engineering for Developing Communities [5], Global Engineering [6], and Development Engineering [7] are used for emphasizing long-term global community development. As a term, HumEng refers to immediate humanitarian action responding to disasters as well as community development, both domestically and internationally [5], although definitions of HumEng vary across time and region.

For instance, Shekar and Drain [8] stated that Humanitarian Engineers need to be aware of how to develop solutions that can impact developing countries while considering social–cultural issues. These ideas highlight the importance of Humanitarian Engineers' ability to learn about cultures and engineering practices. In terms of developing such sensitivity to social–cultural issues alongside engineering expertise, engineering educational systems occupy an essential position in preparing the next generation of Humanitarian Engineers. Socio-technical thinking is fundamental for a successful intersection between sustainable community development and engineering [9].

Fila et al. [10] also emphasized the importance of empathy to think socio-technically, where empathy was defined as one's ability to understand and share others' emotions and feelings. They highlighted the need for experiential learning to gain appropriate understanding, which can be achieved through direct engagement with users or at least through specifying user groups and evaluating existing and proposed design solutions when user engagement is inappropriate or unavailable. To address the need to develop socio-technical perspectives for engineering students, practice-based learning related to HumEng has been adopted to promote students' career readiness [11]. This learning approach is seen in many of the formal minors and majors connected with this area that are now being offered in higher education [12].

This work explores engineering students' conceptualization of sustainability and HumEng through their motivations and identity development in HumEng undergraduate courses. The next section will explore the key existing literature, first on motivations for HumEng and then professional and engineering identities. The research methods and analysis approaches will be outlined followed by results that emerged from the data. Finally, a discussion will be derived from the results, providing insights for both education and the area of HumEng broadly.

2. Background and Literature

2.1. Humanitarian Engineering Motivations

In general, the overall objective of sustainability education is to achieve positive societal and environmental impact through creative, appropriate, and sustainable engineering practices. Student engagement in HumEng offerings at higher education is often linked to interests in social responsibility [13] and connectedness [14], sustainability [1], and global [6] and professional [11] competencies. These areas are commonly explored through a range of curriculum approaches including problem-based learning (PBL), service-learning (SL), and study abroad. In addition to curriculum and content, student and professional motivations have been explored but to a lesser extent. Bielefeldt and Canney [13] found engineering students engaging in optional EWB-USA initiatives had more positive socially responsible attributes compared to those who did not take part. However, students taking part in EWB-USA activities were coming into experiences with higher and more positive attributes, and this related to a higher frequency of service participation while at school. These findings from the USA are echoed in other countries with similar educational contexts. A study by EWB-Australia (EWB-A) explored the motivations of students at multiple universities in Australia to engage in the optional HumEng initiatives that EWB-A delivers, including short-term study abroad experiences, volunteering, and final year SL

R&D projects [15]. From a list of predefined motivations, value alignment was found as a primary motivation. Other than that, males were more likely to identify career and personal development motivations than females, who had greater motivations around social connectedness. A study of one university program in Australia found that students engaging in optional HumEng offerings had higher levels of previous community or volunteer work before and while at university when compared to the overall engineering student cohort [16]. The study also found students involved in HumEng were more likely to be domestic and have English as their first language, while the percentage of female students was higher than the overall cohort, although not significantly so.

While HumEng programs emphasizing the human dimensions and impacts of engineering have been shown to increase female participation, a lack of this, unrealized expectations, or being unable to make connections between engineering and social impacts can lead to motivations to leave engineering work or studies. For example, Rulifson and Bielefeldt [17] identified a greater number of women motivated to "help people or society" leaving engineering studies compared to students with less motivation to have a social impact. Reasons for students' departure included "unsupportive environments, decontextualized technical courses, and curricular difficulty". Litchfield and Javernick-Will [14] found female EWB-USA members were also more likely to become disillusioned with community development in engineering work once in the workforce and express challenges finding personally meaningful work. This highlights that providing offerings and opportunities related to HumEng and human dimensions of engineering is not enough to enhance the diversity of the engineering profession and career pathways. Instead, role models are required for students and graduates to be able to construct a career trajectory that meets their motivations, interests, and identity as professional Humanitarian Engineers.

2.2. Engineering Identity as A Professional Identity

For professional identity related to engineering, there have been various perspectives regarding what factors should be considered to develop engineering identity. Rottmann et al. [18] reported that professional engineering identity is composed of technical mastery, collaborative optimization, and organizational innovation. According to Eliot and Turns [19], the professional identity development of engineering students is associated with the acquisition of technical knowledge and skills and work experiences that are organized around a particular professional identity development because sense-making has a role of connecting external expectations and actions to internal evaluations to consolidate professional identity. Pierrakos et al. [20] reported that engineering students form their initial professional identity based on working with engineers or having real-world engineering experience. They found that taking STEM classes, participating in engineering activities, and organization and interaction with engineering faculty members were also positive factors that influenced students' professional identities.

In terms of the imperative aspect of social engagement, Dannels [21] found that the professional identity development of engineering students is influenced mainly by disciplinary knowledge and social conceptualization (e.g., social, creative, and interactive disciplines). His perspective on engineering professional identity is aligned with Huff et al. [11], who examined how engineering students consolidated their professional identities as engineers while being involved in community-based activities. He argued undergraduate engineering students' professional development should accompany their identity development as engineers who are socially connected professionals. He reported that the design experiences within community engagement ignited participants' own identity-thinking when they realized the engineering professions' role to fulfill socially connected communal goals, and community engagement is often practiced within HumEng domains such as Engineers Without Borders (EWB).

From the research above, it can be seen that motivations and professional identity impact professional practice and career pathways. When developing educational pathways to nurture Humanitarian Engineers in order to contribute to sustainable and positive human and environmental impact, motivations and professional pathways must be considered. If they are not considered by students, graduates, and educators, they can lead to negative experiences or unmet expectations, which impact studies and career progression. This may also lead to the adoption of inappropriate practices, which in turn will not contribute to positive sustainable outcomes.

3. Methodology

To explore the impact of initial motivations and the development of a professional identity for sustainability, a HumEng program will be examined. HumEng education promotes sustainable impact through the integration of learning, research, and practice in developing and vulnerable countries and communities and contributes to students' job readiness in social innovation and global sustainable development. This links engineers to questions of sustainability through the lens of HumEng, capturing perspectives, discussions, and content that are often lacking within a traditional engineering curriculum.

3.1. Setting

Data were collected from HumEng courses, which prepare engineering students to develop creative solutions for sustainability challenges, in a research-focused university located in the US northeast. The courses focus on sustainability issues and the conceptual framework of HumEng from theoretical and practical perspectives. A project-based learning approach has been adopted as one of the instructional strategies to address sustainability issues in HumEng courses. Over the course of the semester, students explore socio-technical sustainability challenges and solutions with a system-thinking approach with the help of stories and case studies of successful and failed HumEng projects from diverse world regions and fields such as healthcare, energy, food and agriculture, education, income generation, and access to capital. Students then develop appropriate and sustainable solutions and implementation strategies. In this course, there was an emphasis on understanding one's customers and their context and on attending to the economic sustainability of ventures. Students drew heavily from cases to understand the diverse business structures and execution strategies used by Humanitarian Engineers and the varied challenges they face.

3.2. Procedures and Data Collection

A quantitative methodology was used in order to capture participant's rich data and stories, as used in previous research in the area such as Litchfield and Javernick-Will [14]. This combined an open-ended survey open to all students with a smaller number of interviews to further explore key emergent themes. This allowed the triangulation of interpretations of the survey data as a member-checking process via the interviews. Data collection questions built from existing research in the area focused on students' own definitions of HumEng, their motivations to enroll in the course, the major influences for the motivation, and the skills they believed it would take to fulfill their goals. The research followed the university's human subject ethics protocol to ensure informed consent and privacy. There was no reward for participation. Further details of the data collection from the two primary sources are below.

Open-ended survey questions included personal background, motives to be a Humanitarian Engineer, and future possible self questions. In addition, students were asked questions that addressed their perspective of the concept of HumEng. This was delivered online at the end of the HumEng course. Interview questions were designed to encourage participants to elaborate on their HumEng perspective and related experiences. In the beginning, we used more general questions rather than asking specific identity questions. We asked retrospective questions reflecting on their socio-cultural backgrounds to confirm open-ended questions (Appendix A). Interviews were scheduled at the participants' convenience and lasted approximately 30 min. All interviews were audio-recorded and transcribed for data analysis.

A total of 46 engineering students (24 males and 22 females) in the course were recruited to answer basic demographic information and open-ended surveys. After an online survey was conducted, ten participants completed follow-up interviews (five males and five females) based on their availability.

3.3. Data Analysis

Data analysis was guided by exploratory qualitative data analysis suggested by Ivankova and Creswell [22]. Initial open-ended survey data provided individual characteristics to conceptualize and guide questions for semi-structured interview data to identify key relationships among participants' concepts of HumEng and motivations. Following this, data from interviews were analyzed to highlight the underlying mechanisms contributing to participants' HumEng identity development that are associated with other influences. A final phase integrated results from the two data sets to draw findings.

Two major coding processes were followed, open coding and axial coding, suggested by Corbin and Strauss [23]. The process needs to be conducted by returning to the original data a few times to construct conditions and to identify a central phenomenon. Then, selective coding develops and describes propositions or hypotheses that connect different categories around the core phenomenon in order to develop a theoretical model. After the coding process, we integrated two data sets as the final step of analysis to develop insights on the central phenomena and subprocesses. We focused on links or gaps between how participants respond to the online survey and follow-up interviews. More likely, the first open-ended data were to provide demographic information and basic concepts of HumEng and interview data enhance and fill in gaps. For the validity of the analysis, transcribed notes, interpretations, and conclusions were double-checked and it was confirmed whether the results of the analysis were aligned with the existing literature.

4. Results

We present the findings organized into four categories that address four major influences on participants' HumEng identity development: (1) honoring their socio-cultural background; (2) practicing engineering skills; (3) helping others; (4) and traveling and encountering new cultures. These categories worked to facilitate and generate motivation for students to develop their vision and identity as Humanitarian Engineers. Before introducing the themes that are related to Humanitarian Engineer identity development, we begin by providing a synthesis of participants' motivations to be Humanitarian Engineers.

4.1. Motivations to Be Humanitarian Engineers

In order to understand participants' motivations to be Humanitarian Engineers, we asked their perspectives on HumEng. A frequency analysis (via NVivo 12) showed the participants' definitional words revealing the overarching theme of improvement and the connecting of humans and community. Participants defined HumEng related to a communal goal, such as helping people or communities in need and improving/changing lives and demonstrating engineering knowledge and skills for problem-solving or engineering practice. Participants tended to include these five keywords in their definitions besides human and HumEng, which are the most frequent words for the definitions but indicate the word itself: problem, solve, people, community, and create. They used words representing characteristics as an engineer such as problem, solve (solutions), develop, and create and mentioned words linked to humanitarian such as people, community, help, and improve. Interestingly, while male students frequently used the words problem, solutions, communities, develop, and help in their definition of HumEng, female students frequently employed problem, solve, people, community, create, and improve.

It seems that female students were more likely to define HumEng related to a communal goal in a detailed manner, such as "engineering with the goal of improving the lives of the underprivileged and marginalized of underdeveloped communities". Some female students incorporated the words social responsibility or sustainability in their definitions, and it seems that they had a deeper understanding of HumEng, whereas male students were more likely to specify their definitions related to practicing their engineering skills (e.g., "developing solutions in hopes of solving a definite problem"). These differences in definitions may help guide researchers to consider the human dimension of HumEng at the very early stages of HumEng theory and development alongside the technical dimension regarding engineering practice through problem-solving. A focus on problem-solving can also lead to a deficit approach to development, looking for individual problems and issues to be solved rather than focusing on promoting human development and well-being [24]. This is in contrast to a strengths- or assets-based approach, which places greater emphasis on local communities and individuals and building from existing resources, strengths, and skills [25].

The responses indicate that while female and male students did not all operate with the same definition of HumEng, their foundation is generally the same. All seemed to see HumEng as an extension of human activities and as a collaboration between people and community.

In terms of motivations to be Humanitarian Engineers, four common categories of motivations in both male and female students were documented: (1) communal goals to help others or improve the world, (2) demonstration of engineering knowledge and skills in real-world contexts, (3) interest in HumEng and sustainability, and (4) career readiness. Both genders showed predominant motivations toward the communal goal of improving the world and the demonstration of engineering knowledge and skills, the latter of which motivates male students more than female students. Besides these shared motivations, male students answered that self-development, such as changing their way of seeing the world and learning something valuable in life, and prior experience related to HumEng brought them to the course. Male students took HumEng as an opportunity to practice and confirm their engineering skills. Female students reported that experiencing other cultures and traveling abroad encouraged them to join the course. While female students paid attention to new cultures, male students seemed to be interested in adopting new inputs for self-development (See Table 1.)

	Male	Female	
Motivations	 Communal goals to help othe Demonstration of engineering Interest in humanitarian engin Better career readiness 	Communal goals to help others or improve the world Demonstration of engineering skills and knowledge Interest in humanitarian engineering Better career readiness	
	 Self-development through meeting new cultures Prior experience regarding humanitarian engineering 	• Exploring other cultures and travel abroad	
Major influences	• Aspiration to practice engineering skills and knowledge	 Familia/cultural background Altruism Encountering new cultures 	

Table 1. Motivations and major influences to be Humanitarian Engineers by gender.

4.2. Major Influences

In order to understand what influenced students' motivations to be humanitarian engineers, they were asked about their personal experiences and interests encouraging their class decision-making. Four categories of influences emerged to explain students' motivations to become Humanitarian Engineers: (1) honoring their socio-cultural back-ground; (2) practicing their engineering skills; (3) helping others; (4) and traveling and

encountering new cultures. These categories worked to facilitate and generate motivation for students to develop their vision and identity as Humanitarian Engineers.

Data analysis led to the development of a model based on a central phenomenon (see Figure 1), a HumEng identity that coalesced by reciprocal interactions of engineering identity and humanitarian identity. Engineering identity seemed congruent with engineering skills and interests while humanitarian identity was influenced by a communal goal (helping others) and a motivation to explore new cultures. This emergence and development of HumEng identity generated envisioning a possible future self as Humanitarian Engineers.

Engineering identity and humanitarian identity are demonstrated as bubbles in order to show the mutually exclusive and reciprocal relationship between the two, and they are permeable and flexible according to the situations and time. In this study, participants' HumEng identity consolidation has not happened yet because they are still in the developing period. Therefore, certain factors may change in their impact (support or hinder) continuously as the two identities fuse or consolidate in a HumEng identity. In other words, participants' HumEng identity seemed to develop over time as a result of accumulated life experiences as well as a possible future self who will practice engineering in a humanitarian context. The arrows demonstrate the influence and exposure to various sustainability topics that impact participants' humanitarian and/or engineering identity. Interestingly, female students seem to develop a humanitarian identity more than an engineering identity while male participants develop an engineering identity more than a humanitarian identity. The four individual influences identified are described further below.

4.2.1. Influence of Familial/Cultural Background with Sustainability Issues

As a first theme, we identified a significant role played by cultural background or critical incidents in allowing participants to envision a future self as a Humanitarian Engineer. Most frequently shared in interviews were references to the familial community, the closest and most fundamental community. Participants reported on their previous experience and interactions within the context of socio-cultural groups that struggled with a lack of resources. Participation within cultural/familial groups allowed them to enrich their motivation to be Humanitarian Engineers, and this process impacted their identity development. In other words, participants' country of origin and ethnic background seemed to be not only strong influences on participants' envisioning of a humanitarian identity but also indicators of the participants' perceived humanitarian and engineering identity development at that time. Several participants with heritage connections to African or Asian nations testified that they wanted to become Humanitarian Engineers to support their own country; they were motivated to commit themselves fervently to acquiring engineering technical and entrepreneurial skills. For example, a male student from Africa mentioned:

There were a lot of problems to solve in my hometown ... most of all, water sanitation, vegetable production, and language education are the most urgent matters. I want to contribute to my community. I think I can make some difference because I learned a lot. I am a software engineer so I can develop something.

This excerpt demonstrates the significance of participants' background as a motivator to be a Humanitarian Engineer because of their background. During the interview, he mentioned several times his hometown and its sustainability challenges intensively, and he is hoping that he can contribute to the community with his software engineering skills. He said that he already developed software that can help children to learn languages. It seems as though he has developed both humanitarian and engineering identities compared to other participants who are developing one side first (e.g., engineering identity or humanitarian identity). Another student, participant F, mentioned that she grew up in a family who were refugees, and she wanted to return to her home country to help others:

I'm from Kenya and I have seen how much impact a well-thought-out social venture can have in solving the general public's problems such as water sanitation and farming. I intend to have the skills to spot a problem and follow a repeatable process to solve their problem in a sustainable/profitable manner.

Interestingly, this participant did not mention much about her engineering skills throughout the follow-up interview, but she addressed starting a social venture to solve problems for her home country and spent quite a long time expressing her passion to work for her community. It did not seem that she had a strong sense of self-efficacy as an engineer. In her case, her humanitarian identity is more significant than engineering. We noticed that other participants who described past impactful triggering events were also influenced to become Humanitarian Engineers, such as participant G:

My mom was definitely encouraging as she was an entrepreneur with her own start-up law firm. Hearing the experiences of others really encouraged me and then being in Africa was one of the highlights of my college life. I want to be an engineer who can help those who need help.

In her case, her mom was the greatest influencer on the participant's envisioning of being someone who can help others. She also had or was developing more of a humanitarian identity rather than an engineering one. In sum, several students seemed to be influenced by their cultural and family background to pursue becoming a Humanitarian Engineer. We separated this source of motivation from another theme, 'I shall live for others', because students who explicitly mentioned their background seemed to use it to envision a particular future context in which to practice being a Humanitarian Engineer, possibly serving as a stronger resource of motivation.

4.2.2. Ambitious Boys: Desire to Practice Disciplinary Skills and Knowledge

Participants' sense of HumEng identity seemed strongly influenced by a level of engineering knowledge and skills and entrepreneurial knowledge. We inferred that a perception of disciplinary knowledge acquisition significantly impacts participants' HumEng identity and enables them to envision possible professional selves as Humanitarian Engineers. Interestingly, more male students mentioned their engineering competency first, followed by the humanitarian aspect, whereas female students identified helping others (humanitarian aspect) more often as a major factor in wanting to be Humanitarian Engineers before demonstrating their engineering competency. There was a substantial number of male participants expressing their strong engineering competence and self-efficacy as engineers while explaining their motivations to join the HumEng class. Participant D mentioned that he would like to be a Humanitarian Engineer because he can practice what he learned from school. He thought that getting an ordinary engineering job in a firm would be boring and would rather have more freedom to practice his ideas and engineering skills. He also addressed that becoming a Humanitarian Engineer would provide more opportunities to practice this creativity, problem-solving skills, and engineering skills. He did mention supporting and helping others, but practicing engineering skills was a greater motivator than helping others. Similarly, another participant E expressed:

I am pretty good at software programming...America is too packed. I think I can find more opportunities in other countries like Africa...I think I can help people through a technology social venture.

Along the same lines, male participant H seemed to be preoccupied by his engineering competency and mentioned:

I am an engineer at heart, but what I want more than anything is to use my strong suit in math, problem-solving...my engineering skillset to make a real difference in the world, to create revolutionary products that help peoples' lives.

Interestingly, this participant expressed himself as an engineer who will create products for people. It seems his engineering identity is more solidified than his humanitarian identity. He provided what knowledge and attributes support him to be an engineer including math and science knowledge as well as problem-solving skills. This is another example that shows multiple identities develop across engineering and humanitarian values. In this case, engineering identity seems to be a more dominant identity than humanitarian. This could relate to an understanding of engineering as "technology"- rather than "human"focused and that, in fact, this student could see that all engineering makes a difference in peoples' lives.

Participant B stated, "As an engineer, I would much rather be doing hands-on work and be able to see the direct impact of my work on others". Thus, one reason mentioned by students for joining the HumEng course seemed more related to the opportunity for realworld practice of engineering skills rather than for its humanitarian connection. In addition, according to participants' testimonies, it seemed that participants were envisioning or developing multiple identities: engineer, entrepreneur, and humanitarian. However, they did not seem to have a solid concept of HumEng. In addition, no female participants mentioned their engineering competencies that will allow them to be Humanitarian Engineers. Their motivations are discussed in the next section. Finally, there is an interesting phenomenon that seems to confirm the multiple identities negotiation between engineering identity and humanitarian identity. That is, these dual identities are not static but dynamically fluctuating through their thoughts, inspirations, and emotions until they are consolidated.

4.2.3. Women's Altruism: I Shall Live for Others

Most participants mentioned that they had a life goal or desire to help others through their technical engineering skills. Some students already had some degree of vision and understanding of HumEng. However, female participants showed a stronger motivation to contribute to others or communities than male participants. As addressed in the previous section, male participants were more interested in demonstrating their disciplinary competency through humanitarian works while female participants seemed to have more communal goals and desire to help others with their acquired technical skills. In this case, the humanitarian side of identity is more significant than the engineering identity, as Figure 1 presented. As female participant C stated:

I am incredibly interested in helping people across the world, and I have been heavily involved in philanthropic work since the 9th grade. It is incredibly rewarding, and I can't explain how important it is to use our resources to help those who have none.

In this excerpt, participant C expressed her strong desire and determination to help others. Although she had strong convictions and desires to help others, subsequent interviews and writing samples showed that participant C did not have a clear action plan to fulfill those desires. In addition, her engineering-related knowledge and competency were still developing, as was her sense of engineering identity.

Participant A also shared participant C's strong conviction for humanitarian work.

I wanted to get some more real-world experience on how to use my engineering education and supplement it in order to help others. HumEng combines what I am already learning in school, with different aspects in order to create products to help others. There are a lot of people who need help. I am majoring in system engineering so I am not too sure how I will help them but I think I can figure it out.

Whereas participants A and C do not have a clear sense of future HumEng plans or work, participant K discussed how her humanitarian drive was specifically related to her plans. In addition, participant K said she grew up in a rural area in Africa, she never had hot water, and the town is still struggling with water sanitization. She would like to solve this issue for the community, and that is why she chose to be an engineer. She spent considerable time explaining HumEng throughout the interview. She said even if she did not know about the term HumEng, she always wanted to be a person who can fix those issues. She learned the concept of social entrepreneurship, but she does not think she will start a business. Her humanitarian identity seemed much more significant than her engineering identity at this moment.

In their responses, male students' overall data did not show the same level of concern for humanitarian motivations in engineering work. That is, as the previous section explained, male students did share a sense of humanitarian identity, but it was not as significant for male students as it was for female students. For instance, male students would only briefly mention helping others as a single phrase rather than provide long descriptive answers as female students did. However, interestingly, female participants seemed to express that helping others is their final goal and that technical skills are necessary tools to accomplish their goals. They also demonstrated socially oriented emotions such as sympathy and empathy for current sustainability issues. This altruism theme also showed an example of multiple identities development according to female participants' motivation and knowledge. Female participants' humanitarian identity seemed more significant than their engineering identity, but some seemed to struggle with combining those different identities due to their technical competency. As it was demonstrated in the previous section, male students are more confident about their technical skills, and they would like to demonstrate them in a humanitarian and sustainability context. Therefore, male students' engineering identity seemed more significant than their humanitarian identity.

4.2.4. Out of the Box: To Meet New Cultures in the Future

As a last theme, several participants addressed that they would like to be Humanitarian Engineers because they had a passion for traveling and exploring new cultures. They liked the nature of the work of HumEng that requires connections to new cultures and working internationally. Participants who mentioned experiencing a new culture seemed as if they have a particular future envisioned international community that they would like to be associated with. Participants who addressed traveling and exploring new cultures seemed to have a weaker commitment to becoming Humanitarian Engineers compared to individuals whose value for HumEng came from a desire to help others, previous experience, or motivation to practice their technical skills. As an example, Participant H mentioned that she wanted to be a Humanitarian Engineer because she can travel and learn about new cultures. Participant J also mentioned:

Personally, my biggest motivators are that I love learning about new cultures and new places. I wanted to get some global exposure, and this class and this minor allows me to combine all of these aspects.

Participant M addressed that her life goal is traveling and helping other people, but she did not have many opportunities to travel. During the interview, she said that she is hoping to obtain an engineering job so that she can travel. She did not demonstrate a strong desire to help others, but she liked the encountering-a-new-culture aspect of HumEng. She did not express a humanitarian identity nor an engineering identity. Participant K mentioned:

I grew up in a small town in Pennsylvania. I did not have many chances to see the world...I thought it's wonderful to learn about other cultures and how I can contribute to others with my engineering skills...I wish I could get a job in another country.

This category of motivation for the HumEng program encompassed not simply wanting to enjoy opportunities to go abroad and learn about new cultures but also to contribute to others. Students think understanding different cultures will be inevitable for engineers who will work in foreign countries. This aspect is related to the previous section about helping others, but they would like to experience a new culture while helping them. In terms of conviction, their commitment to being Humanitarian Engineers seemed low, and their engineering identity is slightly more significant than humanitarian identity. Therefore,



their identity negotiation process is milder than other participants who have stronger motivations to be Humanitarian Engineers.

Figure 1. The conceptual model of Humanitarian Engineering identity development.

5. Discussion

Findings showed that participants in the HumEng course had various motivations to envision becoming Humanitarian Engineers. Many students mentioned their profound desire to help others, with some locating the source of this motivation in their cultural background. Others seemed to be attracted to HumEng without a solid sense of what was involved in practice, but rather, they saw the course as allowing them to develop their technical and entrepreneur skills in a real-world context. Finally, some participants saw becoming Humanitarian Engineers as providing opportunities to travel to new cultures, something that seemed exciting.

The categories of motives found in this study can inform engineering programs seeking to develop the ethical and social commitment of their students. This can assist in overcoming the concerns of Huff et al. (2016) that the engineering profession often favors a culture that prioritizes an individual's merit or agentic outcomes instead of promoting communal relationships embedded within the social environment. We identified that female students were attracted to this program in proportion to male students to a much greater degree (54% female participation in the class compared to 23% for engineering overall in the same institution). Additionally, female participants were more likely than males to express wanting to use their engineering skills to help others, whereas males were more likely to want to use program opportunities to practice their engineering skills. This echoes the results from Stoakley et al. [15] and Rulifson and Bielefeldt [17], where female students' motivations were skewed toward "social-connectedness" or "altruism" while males had more of a tendency toward "career" or "enhancement". Thus, it is worth considering offering courses such as those in the HumEng program that emphasize a humanitarian ethos in order to attract more female students to Engineering programs. However, programs and opportunities must not be offered simply for recruitment; rather, they must be authentic, appropriate, and supported. Otherwise, challenges and issues are created for female students undertaking them. Both Litchfield and Javernick-Will [14] and Rulifson and Bielefeldt [17] found greater numbers of females motivated by human impact leave engineering studies or the workforce if those motivations are not met compared to those with lower social impact motivations. This suggests educators should highlight the range of roles and impact pathways available for students rather than a more traditional or narrow understanding of careers that can achieve social impact and connectedness.

Students should be encouraged to critically reflect on their motivations to understand them in relation to best practice in development. Motivations primarily based on opportunities to travel abroad or experience new cultures, if translated to practice, can reinforce views of development based on colonialism and privilege, where the Humanitarian Engineer is engaging for their own benefit in terms of travel and experiences, particularly when international [26]. This is in contrast to strengths-based approaches, where the role of a Humanitarian Engineer is to constantly reflect on their role and position within a project [24]. Based on the findings in this study and the literature, reinforcement and reflection of motivation are critical for retention in HumEng programs as well as for the recruitment process. Moreover, students' motivations are generated by their experiences and socio-cultural backgrounds, which are strongly associated with their identity development.

This study suggested multiple identities' development and an identity fusion phenomena based on the results of data analysis. Several participants said that they would like to be Humanitarian Engineers, but it did not seem that they have a clear understanding of the area. However, it appeared that some participants, mostly male students, have been developing an engineering identity with humanitarian interests. Some female students developed more humanitarian identities rather than either engineering or HumEng identities. It seems that their interests and previous socio-cultural experiences played a significant role in their identity development, and only a few of them consolidated this into a Humanitarian Engineer identity. These participants had significant experiences with humanitarian issues, and they chose to solve those problems through their engineering knowledge and skills. In this case, participants' engineering identities and humanitarian identities were fused and consolidated as one emerging Humanitarian Engineer identity. This phenomenon seems aligned with the construct of multiple identities [27]. Although most participants were still going through a self-defining, identity development, and negotiation process, data showed that their Humanitarian Engineer identity development was significantly influenced by the acquisition of a certain level of engineering knowledge and skills, self-knowledge, and vision as their emerging Humanitarian Engineer identity helped them overcome the challenges that they will be facing in the future. For participants who testified that they have sufficient engineering skills, most seemed settled in their engineering identity, but their emerging humanitarian identity seemed shallow.

The data showed the significant impact of future possible selves on motivations and identity development emerging with a melding of participants' various socio-cultural background characteristics, engineering knowledge, and skills. Originally, Markus and Nurius [28] introduced possible selves as the representations that individuals create about who they are, what they might become, who they would like to become, and who they fear becoming. In this study, the envisioned future self as Humanitarian Engineers appeared as a significant impact on current academic motivations to pursue engineering degrees as well as the development of the emerging HumEng identity. Participants could envision themselves as Humanitarian Engineers from the development of their identity that is possibly associated with particular triggering events in the past. This finding is aligned with Park and Schallert [27], who stated that the construction of possible selves has been recognized as an important factor for one's identity development, and the production of possible selves is a mechanism associated with the identity exploration process.

Finally, sustainability is one of the fastest-growing topic areas of undergraduate engineering education [29]. As an implementation, the study contributed to improving instructional strategies to teach approaches to sustainability for undergraduate engineering students by providing students' personal motivations and attitudes toward sustainability topics. Further, there is active engagement across countries with a strong HumEng presence, including the USA, Canada, UK, Australia, and NZ, to identify and embed best practice for education and practice in the area. In Australia, for example, a dedicated Community of Practice for HumEng has been established within the peak professional body, Engineers Australia, to support further consideration of its practice and education. Links between sustainability, the SDGs, and engineering practice and education are being formalized through governing accords and frameworks. As recently as June 2021, a revised Graduate Attributes and Professional Competencies (GAPC) Framework was approved by the International Engineering Alliance Accords and Agreements with the World Federation of Engineering Organisations (WFEO), which included specific mention and links to the SDGs [30]. As highlighted by the Committee on Education in Engineering, "this is the most significant change to the Framework since it was first developed in the early 1990s", and it captures and articulates the role of engineers in global sustainable development [30].

6. Conclusions

This paper presented perceptions of HumEng across different genders and engineering disciplines. The results provided insights as to the benefits of humanitarian experiences that provide motivations to develop an engineering identity. Having discussed the subthemes underlying participants' motivations as they traversed their HumEng course, a final point has been made. The central phenomenon portrayed in Figure 1, that of the emerging HumEng identity, depended on motivations, as we have discussed above. These motivations were not only in mutual interaction between humanitarian identity and engineering identity. Thus, there were ways that the various motivations to be Humanitarian Engineers and envisioning a possible future self as such were connected to the sub-themes of developing engineering discipline-specific expertise. Future studies can explore the development of professional identity as Humanitarian Engineers through ethnographic case studies with Humanitarian Engineers or a follow-up study with current participants after their graduation. The nature of case study research allows for a more detailed and nuanced description of individuals who became Humanitarian Engineers regarding identifying their various influences and challenges. Based on the information from qualitative studies, measures to assess how participants envision their possible selves as Humanitarian Engineers and what factors influence their career decisions can also be developed for quantitative investigations to further enhance the findings here and support career identity development.

Author Contributions: Conceptualization, J.J.P.; methodology, J.J.P.; writing—original draft preparation, J.J.P., M.P. & J.S.; writing. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Sample Interview Questions

Can you tell me about your socio-cultural background?

Are there any particular individuals who influenced you to be a humanitarian engineer? Can you tell me your motivations to be humanitarian engineers? What does it mean

for you to be a humanitarian engineer? Can you tell me about your identity as an engineer? Can you tell me about your identity as a humanitarian engineer? What milestones have you done so far to be a humanitarian engineer? Why are you taking a HumEng course?

What are your short-term and long-term career plans?

How do you envision yourself as a Humanitarian Engineer?

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