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Research Article

Humanizing Engineering Education: A Comprehensive Model for Fostering Humanitarian Engineering Education[1]

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Abstract:

The goal of the paper is to provide guidelines for building a comprehensive model that fosters humanitarian engineering education. The paper brings the voice of field practitioners and students, in addition to academic research, to determine the most critical attitudes, skills, and capacity building practice for empowering humanitarian engineers. A large pool of data related to the research topic was collected through an online questionnaire answered by 187 members of Engineers Without Borders. Inductive analysis methodology was used to analyze the survey results. Moreover, scholarly literature review was done to review the history of engineering and learn about the shortcomings in conventional engineering education and how it could be reformed to meet humanitarian engineering challenges.

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INTRODUCTION

Engineers have made huge efforts to make unimaginable dreams reality, yet their efforts at meeting basic human needs in developing countries are missing. Today most engineering talents are busy with creating luxurious technology for rich customers. According to Paul Polak (2008), "the majority of the world's designers focus all their efforts on developing products and service exclusively for the richest 10% of the world's customer. Nothing less than a revolution in design is needed to reach the other 90%."

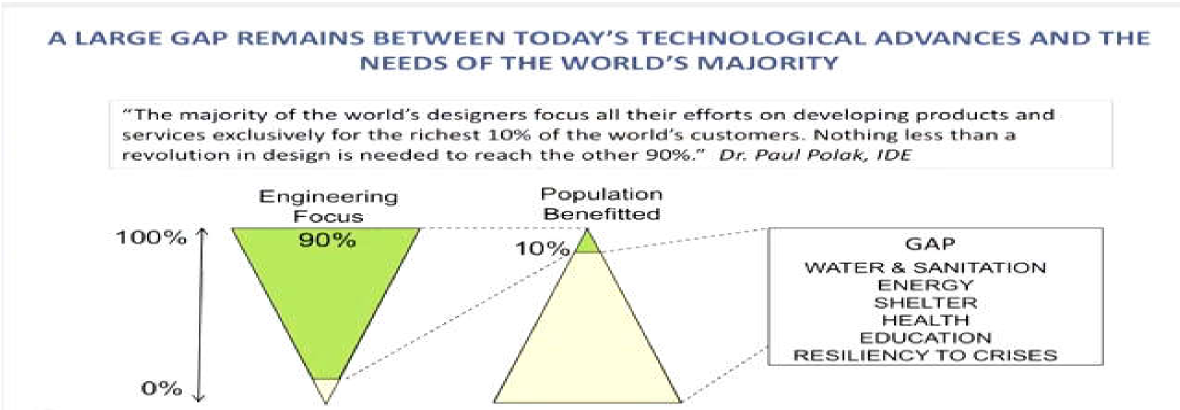

Figure 1. Technological Advances And The needs of The world's Majority. (Amadei, 2011)

Among the other 90%, there are 0.8 billion people who lack clean water, 2.4 billion people who lack adequate sanitation, 1.6 billion people who have no access to electricity. Moreover, malnutrition kills 11 million children under the age of five every year. These facts should put a moral obligation on the engineering profession to direct some effort to meet basic needs of those people. Many of the challenges that face developing countries and underserved communities are related to engineering in some way. Water filtration, building sanitation and housing, designing nutrition supply chain and energy generation is at the heart of the engineering profession. There is an urgent need to involve engineers in solving underserved communities' problems. Recently, a new movement within engineering education emerged to induce engineers to practice more humanitarian role. This movement was called humanitarian engineering. Humanitarian Engineering emphasizes the importance of preparing engineers with adequate knowledge and practice to meet underserved communities' needs. It is a movement to escape the "social captivity of engineering" by capitalism or nationalism or some other form of wealth and power. Encyclopedia Britannica defines humanitarian engineering as "the application of engineering to improve the well-being of marginalized people and disadvantaged communities, usually in the developing world" (Brown, n.d.).

Preparing engineers to meet global challenges and be facilitators for sustainable development requires a comprehensive reform in educational content and practices. Current conventional engineering education programs do not equip students with knowledge of, or skills in, humanitarian engineering practices. One of the main reasons for this shortcoming is the fact that Humanitarian Engineering is a relatively new emerging concept in engineering academia, although it is an old practice used by individual engineers and organizations outside the academic field. Therefore, determining what truly merits being considered humanitarian engineering work is still a controversial issue, since all engineers could argue that their work contains a humanitarian side.

In order to deal with this issue, some HE educators tried to theorize criteria for considering a work as HE. Vandersteen, for example, set four criteria to distinguish what counts as HE work compared to conventional engineering work or pure humanitarian work. First, there must be a need among the people benefiting from this work. Second, that need should be related to basic human necessity. Some humanitarian engineering professionals refer to Maslow's hierarchy of needs to determine the definition of basic needs. Third, the beneficiaries should be involved in the project design and execution. Finally, the work should require actual engineering skills and knowledge (Vandersteen, 2008). Furthermore, Passiono proposed a concept called "degree of humanitarian engineering" (see figure 1.). This concept states that humanitarian engineering work varies in the "degree of humanitarian engineering" (Passiono, 2015). A work that meets crucial needs for a human, involving marginalized people and utilizing many engineering skills and knowledge will have a higher "degree of humanitarian engineering." This work will be at the upper right corner in the figure titled "Humanitarian Engineering." Another, which has the same features as the previous work but with less engineering content, is titled "Humanitarian engineering." It will be located in the middle of the upper line. This concept helps humanitarian engineers set priorities in their work. However, humanitarian engineers should not compromise the humanitarian aspect to use more engineering skills. Serving the community should be their first propriety. In this paper, the term HE refers to any work that utilizes engineering skills and knowledge to meet a basic and crucial human need.

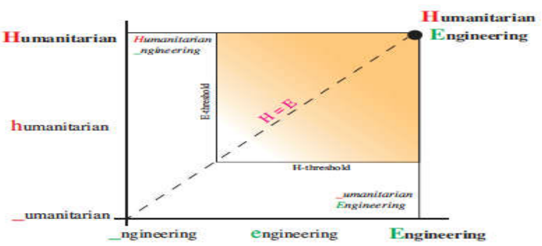

Figure 2. Degree of Humanitarian Engineering (Passiono, 2015)

Figure 3. Maslow's pyramid (Maslow's Hierarchy.., n.d.)

HE work usually requires different tools and approaches than what is taught in traditional engineering curriculum. Traditional engineering curriculum was mainly designed to prepare students to work in the context of industrial and private sectors, while HE work is usually done in a different context. Empowering engineers to work in the humanitarian and community development sectors requires teaching them about wide range of technical and non-technical issues. Today there is still a disturbing lack of interdisciplinary courses in engineering education, and the response from academic institutions in this aspect has been extremely slow compared to the urgent need (Amadei, Wallacewallace, 2010)

Engineering educators recently published research proposing strategies for teaching a humanitarian engineering skill-set. Most of the HE research has been done by academic professors, while humanitarian engineering initially started as a practice outside academia and the nature of the discipline is highly centered on practice outside classrooms, so it is extremely important to include the voice of field practitioners, both professional and student, in determining what type of education, skills and attitude humanitarian engineers need in order to function well in their field. The goal of this paper is to propose a comprehensive educational model that meets the challenge in the humanitarian engineering field based on collective knowledge and the experience of HE practitioners in Engineering Without Borders, as well as scholarly educational academic research.

METHOD

In gathering information for this research, two methods were used: literature review and online survey. The primary goal of the survey is to get information from the practitioners for three issues: 1) The surveyed perception about HE 2) The critical attitudes and skills in humanitarian work 3) What are the best practices for teaching these attitudes and skills. In order to answer these questions the survey was designed to include two types of questions: eight multiple-choice questions and three open-answer questions related to HE. The definition of humanitarian engineering was written at the top of the survey to avoid misconceptions. The first and second multiple-choice questions were adjusted to show the respondent's role at EWB and academic major. The next four questions were about controversial issues in HE. Then, three open-answer questions were intended to directly collect information about the research question The survey was sent via electronic correspondence to more than 240 EWB chapters around the US. Also, it has been sent to a few EWB chapters outside the US (e.g. EWB at the University of Queensland in Australia, EWB in London). The message was forwarded to many members within the chapters by the chapters' presidents. The survey received 187 responses, which represents an adequate random sample size. According to Cohen and Manion (2000), in order for a sample size to be effective in statistical analysis, a minimum of thirty respondents is required. Moreover, Literature review was done to review the history of engineering education and learn about the shortcomings in conventional engineering curriculum and how it could be improved to meet the challenges and requirements in the HE field. Recently, many engineering educators have written research papers proposing strategies for teaching students a humanitarian engineering skillset. The research showed that the proposed strategies could fall under four categories: curriculum changes, informal learning practices to complement classroom education, adapting new methods of teaching that are more suitable to the HE field, and creating philosophical and ethical framework for HE practices. All these strategies were considered in developing the comprehensive model.

History of Humanitarain Engineering Cocept and Practice

Humanitarian Engineering is a new concept, but it is an old practice. Engineers have always been involved in humanitarian work. Engineering as a practice is very old. Imhotep, the architect of the Step Pyramid in Egypt in about 2250 BC, is considered the first engineer known by name (Bentarica, nd). However, engineering as a profession arose in the late medieval or early modern period (Vandersteen, 2008). During the same period, the social philosophy of humanitarianism developed as a movement to enhance ethics, kindness and sympathy to all human beings (Simoes, et al., 2007).

Initially, the humanitarian movement strongly influenced the medical field. It did not have a direct influence on the engineering profession, since engineering emerged in a military context that was controlled mainly by governments (Simoes, et al., 2007, Vandersteen, 2008). The first engineering institutions were created by national governments mainly for military purposes. Only lately, during the industrial revolution in Great Britain, have engineers started to find their way out of the military context. During that period, the term “civil engineering” emerged as a counter term to the military usage of engineering. John Smeaton (1724-1792) was the first one who called himself a “civil engineer” as he began using scientific methods to analyze construction projects. He founded the Society of Civil Engineers, which is considered the first official professional engineering society (Vandersteen, 2008). After that, numerous types of engineering majors emerged to fulfill developed countries’ challenges and modern life needs. During that period, there was no organized humanitarian engineering work to serve impoverished communities. There were few individuals who initiated work that could be considered humanitarian engineering. Fred Cuny, who was a civil engineer, could be considered among the first humanitarian engineers in the modern era. He used his engineering skills to respond to earthquake disasters in various parts of the world (Simoes, et al., 2007). Yet Fred’s and the other individuals’ humanitarian engineering efforts were not sufficient to introduce humanitarian aspects within academic engineering education programs.

The formation of “Médecins sans Frontieres” (MSF or Doctors without Borders) in 1971 was a turning point for humanitarian work within many scientific fields, including engineering. MSF emerged as a result of dissatisfaction with Red Cross, which was controlled by the national government and could not venture beyond safe boundaries. After the organization was established, hundreds of physicians joined the organization to help people in crises and speak for human rights (Simoes, et al., 2007). Influenced by this idea, pioneer engineers established independent organizations that conduct humanitarian engineering all around the world, including: “Ingenieurs sans Frontieres (France, 1982), Ingenieurs Assistance Internationale (Belgium, c.1987), Ingeniera sin Fronteras (Spain, 1990), Ingeniererunden Graenser (Denmark, c.1992), Ingenjorer och Naturvetare utan Granser Sverige (Sweden, c.1995), Engineers without Borders (UK, 2001), Engineering without Borders (USA, 2002), Engineers without Borders (Australia, 2003), Ingenieureohne Grenzen (Germany, 2003), Ingenera senza Frontiere (Italy, c.2005), and others" (Vandersteen, 2008). In 2003, a number of these groups organized "Engineers without Borders — International" as a network to promote "humanitarian engineering…for a better world," now constituted by more than 41 national member organizations (Vandersteen, 2008). Influenced by this movement, many other humanitarian engineering organizations have been established under different names. NGO's recently called for involving engineers in community development, after noticing the contribution of humanitarian engineers and their high potential in solving global challenges. UNESCO published a report titled "Engineering: Issues, Challenges and Opportunities for Development" to emphasize the role of engineering in community development (UNESCO, 2010). At the same time, many organizations related to engineering education started to review engineering education systems from social justice perspectives. In a recent National Academy of Engineering survey, engineers are given very little credit for improving the general quality of life, saving lives, protecting the environment, or caring about their community (Vandersteen, 2008). The same organization released a report in 2005 titled "Educating the Engineer of 2020: Adapting engineering to the new century" that presents the challenges that engineering professions will face in the future. The report has predicted a dramatic increase in the world population, especially in the developing world. The organization called for "Reengineering engineering education" to prepare engineers who can meet global challenges (The National Academy PRESS, 2005). Responding to those calls and the challenges that the engineering profession faces, academic accreditation organizations like ABET included among the list of accreditation criteria items related to humanitarian engineering principles and values. Few pioneer engineering professors have taken the initiative to open humanitarian engineering programs at their universities (e.g. Arizona State University, Penn State University, Ohio State University) Universities nurtured those initiatives because they realized the high potential in humanitarian engineering concepts and practice to enhance student learning, meet engineering education challenges and serve developing communities.

RESULTS

In order to engage a wide number of HE practitioners from various disciplines in answering this question, this research used an online survey. It was decided to send the survey to practitioners participating in a leading HE organization that has conducted many local and international projects, to ensure the quality and validity of respondents' answers. After studying various HE organization profiles, Engineering Without Borders (EWB-USA) was chosen. EWB has initiated more than 684 community development projects in 39 countries and has impacted more than 2.5 million lives around the world since it was established in 2002. It was chosen because it meets the criteria of the research and it offers easy access to many branches of the organization. Choosing EWB in the research does not necessarily imply that it is the most successful organization in the HE field. The multiple-choice questions were analyzed based on the number of respondents for each option. For the open-answer questions, inductive analysis procedures were used to construct patterns that emerged from the participants' responses [5]. In order to analyze data from each question, all similar responses were categorized together and major themes that participants emphasized were identified. Then all the emergent common themes were organized and categorized into a table, and information was extracted from the participants' viewpoints or statements. The strength of the survey results does not rely on the individual experience of each respondent, but rather on the collective experience and knowledge of all the respondents, among them 46 professional mentors and two faculty advisors. This experience was not only limited to successful projects but also the comments from participants about previous experience with project failures were very valuable. Moreover, criticisms raised by some respondents to existing shortcomings in their EWB branch's performance were as valuable as the comments about positive aspects in the organization.

Q1: What is your role at EWB?

Table 1
Answers for Q1

Position at EWB	Number
Faculty advisor	2
Professional mentor	46
Student volunteer	139
Total	187

Q2: What is your academic major?

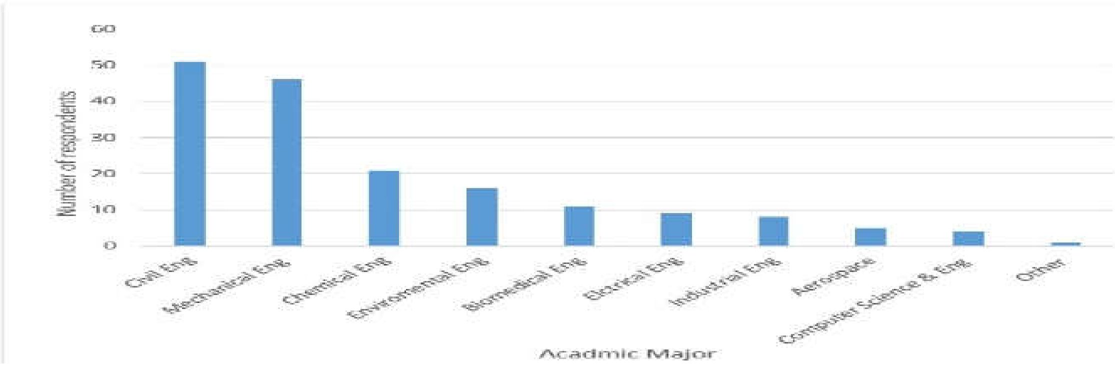

Figure 4. Respondent's Academic Majors

Analysis: The responses show that there is a lack of diversity within the organization. There were mainly two engineering specializations (civil and mechanical) that comprise more than half of the survey responses. This domination could be due to the work of the organization, which is mainly related to construction and civil engineering. In another part of the survey, many respondents asked for an increase in the level of diversity by recruiting members from various engineering and non-engineering disciplines.

Q3: What is the most important reason that motivates you to join EWB?

Table 2
Answer for Q3

Answer	Number	Percentage
Networking and friendship	10	5.3%
Helping people in need	154	82.4%
Learning some skills	14	7.5%
Other	9	4.8%

Analysis: In the survey, almost 83% of respondents joined EWB primarily for helping people in need. This result challenges the stereotype that engineers do not care about community service. Therefore, HE organizations should focus on showing the humanitarian aspects of their work for the participants and the community. Alternately, this result could also have a negative implication for HE work. Once a humanitarian agent has in mind that he or she works mainly to help people in need, it is difficult to build a partnership between the agent and the local people. HE curricula and training programs should prepare students to be facilitators for development and change, not service providers or helpers.

Q4: Do you believe that engineers should use their engineering expertise to help people in need?

Table 3
Answer for Q4

Answer	Number	Percentage
Yes, it is a moral and professional obligation	147	79%
Not necessary	36	19.6%
No, they do not have suitable expertise	1	0.5%

Analysis: The majority of the respondents agreed that it is a moral and professional obligation for engineers to help people in need, using their engineering expertise. Only one person claimed that engineers do not have adequate expertise. 19.6% (36 people) said that it is “not necessary,” possibly intending that not every engineer should necessarily use his or her engineering expertise to help others. The answers referred to the sense of social responsibility among the organization participants, which highlights the cultural reform that could take place within the engineering field due to HE work.

Q5: Do you think your work with EWB has enhanced your academic engineering study at school?

Table 4
Answer for Answer for Q5

Answer	Number	Percentage
Yes strongly	78	42.9%
Slightly	76	41.0%
Academic study does not relate to EWB work	12	6.6%
Other	16	8.8%

Analysis: Around 84% stated that EWB work has enhanced their academic study to some degree. Almost half of this group stated that EWB work has enhanced their academic study strongly, while the rest stated that it enhanced their study slightly. Around 7% of the respondents mentioned that they do not see any relation between their academic study and their work with EWB. This question shows that the majority of the students benefited academically by being involved in HE organizations. This benefit could be directly related to their major, or they may have learned some life skills that helped them in their academic life.

Q6: What is the best way to include humanitarian engineering concepts in engineering education?

Table 5
Answer for Answer for Q6

Answer	Number	Percentage
A separate engineering major	1	0.5%
A minor	27	14.6%
Elective course or design project	72	38.9%
Included in teaching all engineering courses	38	20.5%
No need to teach HE at school	3	1.6%
All options should be offered	43	23.2%

Analysis: The majority of the respondents prefer humanitarian engineering concepts offered as an elective course or as design projects. The option of offering humanitarian engineering concepts in all possible forms is the second highest option chosen by respondents, showing that there is also an interest in studying it as a separate major or as a minor.

Q7: What is the most difficult challenge of HE work ?

Table 6
Answer for Answer for Q7

Answer	Number	Percentage
Cultural challenge	60	32.4%
Technical challenge	25	13.5%
Communication	68	36.8%
Other	32	17.3%

Analysis: The survey responses show that critical challenges in humanitarian engineering relate more to soft skills rather than technical ones. This could be because engineers are usually well prepared in technical knowledge as opposed to soft skills, or it could be due to the nature of the humanitarian work itself. It is critical to balance the technical and non-technical contents in HE educational programs. People who referred to other challenges indicated financial, organizational, political, bureaucratic and logistical considerations

Q8: Should humanitarian engineers focus on doing international projects, domestic projects, or both?

Analysis: Whether humanitarian engineers should be involved in local or international projects is a controversial issue among humanitarian engineering leaders. In the survey, 93.6% (175 people) of those surveyed chose to do local and international projects. 3.7% (7 people) chose international and 2.7% (5 people) chose local. Offering local and global opportunities could be the best solution to this question.

Q 9: What are the most important attitudes in humanitarian engineering?

Table 7

Answer for Answer for Q9

Attitude	#	Remark from respondent answers
Ethics/Morality	35	Morality and ethics were emphasized, especially compassion (18) and empathy (11).
Spirit of service	26	Willingness to help, selflessness and humbleness
Flexibility and adaptability	22	This includes flexibility (13) in changing plans or solution methods and in adapting (10) to new environments and project outcomes.
Patience and persistence	32	HE engineers should have the will to work longer than usual and in complex situations. This requires patience (16) and strong persistence (12).
Positive attitude and optimism	10	Ability to keep up morale through prolonged struggles
Openness	31	Openness (21) to different ideas, and respect of different cultures.
Passion to work and learn	17	Passionate (10) about making a lasting impact with engineering skills and willing to learn through practice.

* **Note:** In tables 7, 8, and 9, the second column shows the number of times the attitude, skills or practices were mentioned by the respondents. The third column presents details related to the attitude mentioned by the respondents.

Q10: What are the most critical skills for Humanitarian Engineers?

Table 8
Answer for Answer for Q10

Skill	#	Skills emphasized
Communication	46	Communications (38), listening and language skills. A clear and consistent point of contact with the community is important.
Project management	12	Planning, risk management, project-oriented work, "Lean" project initiatives, resource management and implementation.
Cultural awareness	43	Cultural awareness and sensitivity (26) is the most difficult challenge.
Global awareness	11	International development, legal issues, politics and governmental systems in the served community.
Participatory development	10	HE projects should be based on collaboration, not only providing service.
Leadership and teamwork skills	22	Organization, leadership (13) mentality, focusing on the target, employing members' strengths, facing challenges, teamwork skills (8), work within a multidisciplinary team
Systematic thinking	13	Seeing the big picture / creating holistic solutions and deep appreciation for sustainability
Innovation and creativity	19	Designing innovative and practical solutions, both technical and non-technical.
Resourcefulness	12	Making the most out of scarce resources.
Problem solving	17	Defining and dissecting the problem, coming up with multiple solutions, then implementing the optimal one and sustaining the gain
Technical competency	29	Sound technical knowledge, especially in appropriate technology, engineering knowledge

Q11: What are the best capacity-building practices for humanitarian engineers?

Table 9
Answer for Answer for Q11

Program/Practice	#	Objectives
International & local HE projects	12	Enhancing all critical attitudes and skills.
Professional & faculty mentorship	7	Enhancing leadership, technical competency, system thinking.
Build multidisciplinary team	15	Fostering innovation, enhancing technical competency, system thinking, respect and openness.
Establish network between HE Org/University	17	Fostering innovation, sharing expertise, enhancing HE academically and practically, improving performance.
Collaborative learning & team work	9	Participatory development skills; teamwork, leadership, communication; humbleness, respect, openness.
Excellent leadership	6	Exploring talents; skills; teamwork, organization.
Courses / workshops / seminars related to HE concept and practice	19	Cultural awareness, global awareness, technical knowledge, leadership, communication, teamwork, ethics.
Dialogue and reflection	6	Attitude: empathy and compassion; Skills: communication, technical knowledge, collaboration.
Involve volunteers in tasks	14	Attitude: spirit of service, humbleness; Skills: project management

A COMPREHENSIVE MODEL FOR FOSTERING HUMANITARIAN ENGINEERING EDUCATION AND PRACTICE

Around Analysis of the respondents' answers and the scholarly literature assures that traditional academic engineering programs are not enough for preparing humanitarian engineers to conduct their mission. This part of the paper suggests a comprehensive model for fostering humanitarian engineering education and practice. The research findings suggest that a comprehensive humanitarian engineering program should include four phases: 1) Creating a philosophical framework for humanitarian engineering education and practice; 2) Reforming contents and methods of teaching engineering in universities; 3) Enhancing humanitarian engineering education and practice outside traditional classrooms and 4) Humanizing the culture of engineering education and practice.

Creating a Theoretical Framework To Guide Humanitarian Engineering Education and Practice

Formulating a theoretical framework for HE education and practice is a very important step in creating a basis for the educational reform and cultural change within engineering. Since there is already a code of ethics for the engineering profession, it will be helpful to start evaluating this code from a humanitarian point of view and then build on it. Much research shows that most traditional and current engineering codes of ethics were mainly formulated for private sector interest (Simoes, et al., 2007, Riley, 2008). As a result, ethics related to business, leadership, and management have been emphasized, while ethics related to community development and humanitarian work were ignored (Simoes, et al, 2007, (Downey, et al., n.d.). According to Catalano, who reviewed many of the current codes of ethics in the US, the current engineering codes lack "areas relevant to social justice, such as impact on poverty reduction or enhancement" (Kabo, 2010). In addition, Herkert, who analyzed the content of engineering ethics instruction, found that the research and teaching on this topic focus mainly on "micro ethics" (Kabo, 2010). These studies and others indicate a need to extend and modify the current engineering code of ethics to make it suitable for humanitarian engineering programs.

Humanitarian philosophy and professional ethics could be used as two pillars to formulate a philosophical and ethical framework for humanitarian engineering. Conventional humanitarian philosophy has been established to promote human welfare, particularly for marginalized peoples (Simoes, et al, 2007). The ethical framework for HE should address topics related to: humanitarian engineers' interventions in foreign countries, the discipline and ethics that humanitarian engineers should maintain during their work, rules of HE work humanitarian engineers' rights and responsibilities, plus critical ethical dilemmas. There should be a system to ensure that engineers, corporations and governments involved in HE projects understand and follow this framework.

Developing a theoretical framework that addresses the issues mentioned in this section will guide humanitarian engineering practice, and enriching the engineering code of ethics will require the collective effort of a multidisciplinary professional team.

Reforming Academic Engineering Program Content and Teaching Method

The following four points are critical to the humanization of academic engineering programs based on the research findings:

- ***Teaching ethics and professionalism:***

Teaching the modified engineering codes of ethics and professionalism concepts in engineering education would be an effective way to introduce HE concepts to engineering students, since professionalism and service are intimately coupled (Passino, 2009, Bixler, et al., 2014). Highlighting service and community development concepts in the codes could encourage students to do humanitarian work and improve their perception of the engineering profession. Engaging students in discussing engineering codes of ethics and comparing it with the codes of ethics from other professions is a great way to introduce humanitarian engineering concepts. It is also an excellent way to enhance critical thinking and broaden the students' perspective on their major.

- ***Required or elective courses related to humanitarian engineering:***

Many engineering programs require their students to take courses in humanities and social sciences. However, this is not very effective, because it is difficult for engineers to learn about areas of social sciences and then integrate them with their engineering background (Bixler, et al., 2014). Integrating social science and engineering concepts in courses such as appropriate technology, sustainable development, technology and society, engineering and social justice, would be more effective. In addition, enabling engineering students to take business courses related to humanitarian engineering, such as social entrepreneurship, leadership, and humanitarian work management, would be very helpful to empower engineers to find solutions to global challenges. Moreover, teaching humanitarian engineers topics related to humanitarian philosophy, development theories, and the history and culture of the engineering profession is beneficial in providing a theoretical and ideological basis for their practice. Design courses, including designing engineering projects related to humanitarian needs, give students practical involvement with the humanitarian engineering concept. Some universities have succeeded in designing a minor or complete degree in humanitarian engineering. However, it is critical to make the courses related to HE accessible to students from various engineering and non-engineering majors without requiring the completion of a complete certificate or degree.

• ***Modifying teaching methods:***

In addition to modifying engineering curriculum, changing teaching methods is also a critical step to prepare humanitarian engineers. Traditional engineering education questions are presented as well-structured problems with given parameters that are stated, and students are asked for the correct solution (Kabo, 2010,Vanderstee 2008). This method is no longer adequate to prepare young people for facing complex, real world problems. In HE, problems are not presented as well-structured but as ill-structured; they are not given with stated constraints or parameters, and they usually have multiple solutions and numerous ways to be solved (Amadei,Sandekian, 2009). With traditional problem-solving methods, students usually learn how to manipulate data to reach the correct numerical solution, but they rarely understand the underlying concepts (Kabo, 2010). Mainstream engineering education is characterized by what Freire called "banking education." In banking education, the relationship between teacher and student is clearly hierarchical, where knowledge is transmitted through a top-down approach. As a result, "the scope of action allowed to the students extends only as far as receiving, filing and storing the deposits." (Freire, 1970). This type of education creates a culture of silence that is obvious in engineering classrooms.

Instead of banking education, problem-posing education should be used to break the hierarchical relationship between students and teacher and develop critical consciousness. Freire described the situation in the problem-posing classroom as follows: "The teacher is no longer merely the-one-who-teaches, but one who is himself taught in dialog with the students, who in turn while being taught also teach. They become jointly responsible for a process in which all grow. In this process, arguments based on 'authority' are no longer valid." (Freire, 1970) Dialogue, which is a missing teaching method in engineering classrooms, is a critical part in the problem-posing classroom. HE educators need to integrate also new methods that enhance teamwork and emphasize different ways of thinking, such as Problem-Based Learning (PBL). In this method, problems are presented in real life scenarios, and the students are asked to work in a group to formulate solutions. In this format, students learn to define the problem, analyze their own learning process and those of the other students in their group. Moreover, they learn organization, teamwork skills, communication and dialogue, and the hierarchical relationship in the learning process between the teacher and students is challenged. Another method suitable for humanitarian engineering is called Project Based Learning. There are three variations of this method: design project, case study, and service learning. Alternating between the three types is useful since each method has defining features, and they may overlap.

• ***Special accreditation criteria for Humanitarian Engineering programs:***

Recently, ABET added to the general accreditation criteria terms of HE. For example, Criterion 3: "An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability" (Amadei,Sandekian, 2009). ABET has established detailed criteria for each engineering discipline; but HE does not yet have special ABET accreditation criteria, since it is an emerging field. In the case of HE, more criteria are needed in cultural understanding, critical thinking through a social justice lens, and an ability to engage with people from different cultures. Creating ABET criteria for HE could ensure the quality of humanitarian engineering programs. This will encourage more universities around the world to recognize this emerging field and establish HE programs.

Enhancing Humanitarian Engineering Education and Practice Outside Traditional Classrooms

In humanitarian engineering, there is no substitute for practical experience. Students cannot learn skills such as risk management, project management, communication, teamwork, etc. by only reading books and solving problems in exams. Therefore, hands-on experience through organizations and settings outside the classroom should be an essential part of HE programs. The survey respondents mentioned some capacity-building programs. This section briefly explains these programs and states some critical points related to informal learning in the HE organization.

- ***Leadership and teamwork:***

Having excellent leadership in an HE organization plays a major role in the success of an informal learning experience. Leadership is not limited to assigning tasks to volunteers; it also includes exploring the talents of the volunteers, engaging every member of the organization, and offering inspiration. It is also beneficial to rotate role positions to give most members a chance to lead the group.

- ***Professional and faculty mentorship***

Guidance from mentors elevates student performance and enhances the learning of various skills. This has often been highlighted in the survey results. It is useful to involve the mentors when evaluating students' performance and the organization's achievements. One respondent emphasized the importance of having rules and policies to ensure mentors' independence and impartiality. In some organizations, the students fund their mentors' field trips, which could influence their evaluation of the students' and organization's performance.

- **Comprehensive problem solving methodology:**

Many humanitarian engineering projects fail because they lack comprehensiveness in the project design (Parsons, n.d.). An example of a comprehensive problem-solving tool is the DMAIC methodology, which consists of four phases. In the first phase, "Define," the problem is defined, as well as the potential resources, the project goal, the customers and their needs. In the second phase, "Measure," data about the current state of the situation is collected. Then the collected data is interpreted during the "Analyze" phase, to know the cause-and-effect relationships. Next, solutions are developed during the "Improve" phase to target the root causes. Finally, during the "Control" phase, metrics are developed to monitor and assess project performance and to ensure that improvements and gains are sustained. This last step is usually missing in humanitarian engineering projects. (George, M. 2002).

- ***Community development through collaboration:***

The goal of community development is to "create self-reliant and self-sustaining communities" (Passino, 2009). There are three main dimensions for community development: economic (e.g. jobs), physical (e.g. roads, parks, buildings), and social infrastructure (e.g. network of relationships, better inter-member interactions, and cooperative problem solving). Humanitarian engineers have to consider these three dimensions in their work to create a lasting system of development rather than a temporary service. Participation of the local people is a critical factor for success in any community development project. It is also important to teach them how to sustain the gains from the HE project in the future.

- **Project management skills:**

Project management is a very important skill in humanitarian engineering. Organizing various on-campus activities could be a useful way to give students a chance to learn how to develop a project plan, schedule and timeline, risk analysis, follow-up meetings, etc. However, HE projects require more than ordinary projects in terms of management skills due to various challenges in developing countries. Therefore, it is important to train humanitarian engineers how to manage humanitarian projects in unusual situations.

- ***Communication:***

Communication is critical for the success of humanitarian engineering projects. Engineers should have direct communication with a local partner from the targeted community throughout the project and after completion to follow up on the results. Difficulties in communication with people in a developing country, due to potential time differences or lack of communication on-site, force engineers to find creative ways to communicate. Humanitarian engineers should be trained to use appropriate words when relating with people in need. For example, it is not appropriate to call them "poor," rather it is preferable to use words such as customer/client/stakeholder/partner.

- ***Multidisciplinary***

Engaging students and faculty from various majors enhances the creativity in the team and produces comprehensive solutions. There could be a need for a specialized humanitarian engineering organization in certain engineering fields. However, it is very important to have multidisciplinary organizations that pool talents from various engineering and non-engineering disciplines and not limit the work of humanitarian engineering to infrastructure projects related only to civil and environmental engineering.

- ***Considering cultural differences:***

Based on the survey, cultural differences are considered the most difficult challenge that humanitarian engineers face in their practices. There is usually a cultural and socio-economic gap between the engineers and the target community (Passiono, 2015). The priorities of the served community are usually different from those of the engineers. Therefore, engineers should first listen to local people and make sure that they understand their needs. Local people are experts when it comes to their community and the problems they face. Learning indigenous knowledge could be helpful in proposing suitable solutions.

- ***Humanitarian dialogue and reflection:***

Continuous dialogue and reflection about the humanitarian side of engineering projects is a pedagogical method that is useful in fostering a spirit of volunteerism and empathy. Organization meetings should not only be about discussing technical problems and assigning tasks. Organizing social events is important for team building, encouraging humanitarian engineers to think about their motivations, and sharing humanitarian thoughts.

- ***Integrating informal learning work with research and academic institutions:***

Many engineering research topics and creative solutions could emerge from HE practice. Establishing a link between academic engineering study and HE organizations would benefit schools, organizations and communities. This could happen through establishing a center for this mission at each university offering an HE program. The goal of such a center would be to establish HE educational courses, to coordinate between HE organizations on campus and off campus, to organize seminars and conferences on humanitarian engineering, etc. The office should work as a bridge between the engineering school and the HE organization work. It could organize international HE projects as study abroad or capstone courses. It should not only serve the students but also coordinate engineering faculty and alumni involvement in HE work and research (Passino, 2009). Alumni and professionals should be encouraged to participate in humanitarian engineering organizations.

Humanizing Culture Within The Engineering Education Setting and Profession

Reforming engineering education would help to humanize the culture within engineering, but it is not enough. The Institution of Engineers in Australia states, “The Review of Engineering Education is recommending no less than a culture change in engineering education." (Kabo, 2010). The following points give concepts and practices for reforming the culture within the engineering education and profession.

• ***Teach critical theories and critical thinking skills:***

According to Vesilind, "The engineer is sophisticated in creating technology but unsophisticated in understanding its application. As a result engineers have historically been employed as hired guns, doing the bidding of both political rulers and wealthy corporations" (Downey, et al., n.d.). Many engineers have accepted neoliberalism and globalization without critical understanding or utilizing critical thinking skills. As a result, they work within neoliberal constraints to respond to market forces without considering taking action to make structural change (Kabo, 2010).

Teaching critical theories will encourage students to ask "why" questions, instead of asking only "how" questions while ignoring the context and consequence of their actions. Also, teaching critical theories and critical thinking skills will enable the student to question dominant engineering culture and practice. Critical thinking is not merely thinking rationally or clearly but having the ability to see beyond what is considered "common sense" (Riley, 2008). According to Donna, "Critical theory poses questions that can help us reframe the problems that face engineering now and help us define new ones. Critical theory employed in an engineering classroom can deconstruct authoritative engineering texts, enable students to encounter problems that go beyond 'given: find,' and lead students to examine their education, including learning objectives, the course syllabus, and the textbook itself." (Riley, 2008).

• ***Transform objectivism to subjectivity in engineering and science:***

Many engineers tend to see their work in positive terms. They take for granted that their work is objective (Kabo, 2010). They focus only on the technical side of problems. This mindset typically results from two other common perspectives in engineering: reductionism and technological determinism Reductionism suggests that a problem could be solved by breaking it down into smaller components. Then, analyzing the components can explain the whole system. This method is used in the problem-solving teaching methods of engineering. (Riley, 2008). Technological determinism emphasizes that technology on its own can further development and solve problems without considering the social, political or other contexts.

Teaching engineering as an objective field of knowledge is not a valid option. Technology and engineering are socially-constructed fields. "Our attitudes toward technology hinge, in a large part, on what we believe about the nature of the knowledge underlying it. Unlike scientists, engineers are working with a world of their own creation, and the act of creation cannot be understood in positivist terms." (Mcisaac, Morey, 1998). An emphasis on subjectivity will encourage engineers to question their belief in technological optimism and to think about cultural aspects and context when developing technological solutions.

• ***Transformative Learning Theory ("TLT"):***

Engineers tend to do work without questioning their motives and perceptions, which are two significant aspects of HE work. This notion could be challenged through transformative learning. According to Mazirow, Transformative Learning Theory focuses on "how we learn to negotiate and act on our own purposes, values, feelings, and meanings rather than those we have uncritically assimilated from others—to gain greater control over our lives as socially responsible, clear-thinking decision makers." (Kabo, 2010). Transformative Learning Theory will enable humanitarian engineers to question their motivation, whether it is for helping people in need, getting connections, learning, or any other reason. In addition, it will enable volunteers to examine their point of view toward undeveloped communities. Do they view them as "less than us?" Ignorant? Lazy? Do they really need our help?

• ***Holistic education to challenge market ideology and military mindsets within engineering:***

Neoliberal ideology and military mindsets are dominant in engineering education and professions. Pawley studied questions such as "who defines engineering problems, who benefits from the engineering problems, and who benefits from the engineering solutions." She also asked who is left out of engineering solutions. She found "engineers work overwhelmingly in private, profit-oriented organizations and on industrial, commercial, and military problems." Most engineering problems tend to be large-scale problems with small-scale problems exiled outside of the engineering profession. This military and market-based education influences how conventional engineers define problems and evaluate engineering solutions. (Riley, 2008)

The implications of these mindsets could in some ways contradict the objective of HE work. Thus, there is a need to provide a more holistic ideology that enhances spirit of service and humanitarian ethics in engineering education. Integrating holistic education theory in engineering courses could serve this need very well. The goal of holistic education theory is to challenge the dominant reductionist culture within the educational system. It relies on five main principles that relate directly to HE. First, holistic education theory puts human development as the primary purpose of education. It emphasizes deepening the relationship between self, family, local community, global community, the planet and the cosmos. Second, holistic education honors each learner (or person in need) as unique and inherently creative, with individual needs and abilities. Third, experimental learning is a core part of the educational process. Fourth, multidisciplinary curriculum is key in holistic education theory. Fifth¸ holistic education theory emphasizes that each individual is a global citizen. (Mahmoudi, et al.,2012)

• ***Encourage diversity to challenge conservative views and white male dominance:***

For a variety of historical reasons, the engineering profession in the US is largely under white male dominance (Mcisaac, Morey, 1998).Sally Hacker, who observed engineering classrooms at various universities, states, "At the most and least prestigious institutions, the institute, and the community college agribusiness program, educators presented a conservative ideology." (Riley, 2008) A study done to identify the political identities of United States faculty members in various disciplines found that engineers have the highest percentage of conservative people. Only 20% of engineers in the study considered themselves left of center, and more than half considered themselves right of center(Riley, 2008). The lack of ethnic, gender and ideological diversity within the engineering profession does not give engineers the opportunity to develop cultural understanding skills, which are critical issues in HE. Engineering schools should design programs to increase diversity especially within humanitarian engineering programs. This could happen, for example, by giving scholarships and integrating global non-western thought in engineering subjects.

• ***Service learning theory:***

Service learning theory could be used to enhance a spirit of service in engineering. Service learning is defined as "a course-based, credit-bearing, educational experience in which students (a) participate in an organized service activity that meets identified community needs and (b) reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility" (Parsons, n.d.). There are four criteria for successful service learning in engineering education: reciprocity, relevance, respect, and reflection. Reciprocity means both student and community should benefit from the service. Relevance indicates that the service provided to the community should be related to engineering skills and knowledge. During the service, there should be mutual respect between the engineers and the community. Finally, reflection is an important step since the objectives of social service activities are usually unclear. (Oakes, 2012).

CONCLUSION

This paper concludes that creating a comprehensive HE program requires a model with four phases. First, creating a philosophical framework for humanitarian engineering education and practice. Second, reforming contents and methods for engineering education in universities. Third, involving students in extracurricular humanitarian engineering work, and creating a loop to integrate the extracurricular work with research and education in the universities. Fourth, humanizing the culture of engineering education and practice.

The most important attitudes that the program should enable students to acquire include, but are not limited to: ethical behavior, especially empathy and compassion, plus spirit of service; flexibility and adaptability; patience and persistence; positive attitude and optimism; openness, and passion to work and learn. The most critical skills that the program should enhance, in addition to the engineering technical background, include: communication, cultural awareness, teamwork, leadership, resourcefulness, collaboration, system thinking, problem solving and understanding the local and global context. The best pedagogical practices to enable humanitarian engineers in acquiring the above skills and attitudes include (but are not limited to): international and local placement, organizing events, guidance from faculty advisors and mentors, taking courses related to HE, working on multidisciplinary teams, sharing lessons among humanitarian engineering organizations, and dialogue and reflection.

Traditional engineering curriculum and teaching methods are not adequate to equip students with these attitudes and skills. Therefore, new courses that integrate technical and non-technical subjects should be offered, using methods that enhance different ways of thinking. Moreover, the dominant mindset within engineering professions that oppose the humanitarian engineering objective should be challenged using social pedagogical theories and practices such as critical theories, holistic education theory, transformational learning, service learning and emphasizing subjectivity. The outcomes of this research could help in designing a comprehensive humanitarian engineering program. Further studies for existing HE educational programs and organization can highlight important points and enhance the research result.

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