

# Humanitarian Engineering: a proposal to articulate Engineering Education with social problems.

## Study Case: Universidad Sergio Arboleda

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**Abstract:** *Academy has focused on theoretical discussions that move away from problems and social and economic realities of the communities. With the objective of create synergy between engineering education and communities with low income the Engineering Faculty of the Sergio Arboleda University have created the Humanitarian Engineering center. This paper presents the model used in the design of the first academic offer of the center: an elective course where students have to face communities challenges in order to design artefacts, systems or engineering process, under social, environmental, technical and economic constraints. First, is presented a framework around Humanitarian Engineering and second the study case where is analysed the model proposal after it first implementation and the result perceived by the students. As a conclusion, there is presented then the changes proposed to the model for the second version of the course.*

## Introduction – overall layout

In the discussion of the main function of universities a gap is perceived between the theoretical and academic components in relation to the problems and social and economic realities of those communities that should be directly impacted (Arango, 2004). According to the aforementioned, shouldn't the fundamental task of education be considered as the generation of professionals that a capable of assuming an active role in the construction of more equalitarian societies with a better quality of life?

Engineering is by definition, an activity that transforms knowledge into something practical (El periódico, 2013). This practicality must be aligned with community interests because it would not be useful to know how to apply knowledge solely on the resolution of problems in books, and not have the capacity of solving real problems that are contained within economic, social and environmental restrictions (Lucena, 2010). Therefore, the goal of engineering must be oriented towards the design of solutions within real environments that may allow the students to identify restrictions that they may encounter within the context itself. That is why, the true challenge of engineering schools and faculties must aim to create an auspicious environment and an active methodology to improve the abilities of the students in attending the needs of a society. Many engineers graduate from the university without being prepared to design under real, true conditions; which means, under economic, social and environmental restrictions (Lucena, 2010). The academy is educating engineers to design, without really considering the importance that learning has in identifying the diverse

problems and evaluating them from diverse areas of knowledge, this causes a lack of humanity in engineering and hinders the creation of a true society. Due to this reason, education in engineering must rethink changes to ensure that these professionals are able to deal with the true needs of the society.

Emphasizing on the need of inculcating these points of focus within engineering education; Julio Esteban Colmenares & Jorge Celis hold that, "in spite of the considerable amount of studies that have been advanced in relation to changes in engineering in the last decade, there is scarce investigation in relation to strategies about accomplishing successful change. Likewise, there is few evidence to evaluate the impact of curricular changes made to different engineering programs." (2016). With the objective of cultivating change in engineering education, a model for a subject is proposed that favors the inclusion of points of focus on community work in a traditional engineering program. Therefore, with this objective, this article presents a design of a subject on Humanitarian Engineering from the Universidad Sergio Arboleda through the implementation of a pilot subject and the analysis of its results. The subject aims that through interdisciplinary groups symbiosis may be generated between the university and the community. By these means, guaranteeing that the students in engineering graduate with a preparation that allows them to attend the diverse needs of society through the design of artifacts, systems or sustainable processes.

In this way, the intention is of answering the question: How to design a subject of Humanitarian Engineering in the context of a traditional program? To accomplish this objective, the structure of the following article is presented as follows: (1) A theoretical framework is introduced where various propositions for change suggested by theoretists for education in engineering are exposed. As well as, a definition on Humanitarian Engineering is provided; (2) Information is synthesized and analyzed regarding Humanitarian Engineering; (3) The methodology used is explained to create a proposal for the design of a subject in engineering on Humanitarian Engineering; (4) The results obtained on the investigation are demonstrated; (5) The investigation is concluded; (6) Some recommendations and implications in regards to the proposal are mentioned.

## **Theoretical framework**

### **Proposal for changes in Engineering Education**

To achieve the goal that engineering education be oriented in the construction of better societies, there are authors that propose different changes in the curriculum of the engineering programs, within which we find the cultivation of an interdisciplinary, sustainable and practical focus.

The change suggested for the cultivation of an interdisciplinary focus is founded on the ability of designing in a participative manner. For this, Verharen, C., Tharakan, J., Middendorf, G., Castro-sitiriche, M., & Kadoda, G. (2013) suggest courses of engineering in which working with interdisciplinary groups is advised in the moment of designing so that the contributions that individuals from the diverse disciplines are taken into consideration. In this way, it holds that positive change may be accomplished in the technology that is designed. By incorporating this interdisciplinary focus in engineering education, as Shields, D., Verga, F., & Andrea Blengini, G. (2014) suggest, it would favor sustainability to the engineering curriculum, because by working with interdisciplinary groups, learning is done under real restrictions (social, economic and environmental). This is of utmost importance, because by taking into consideration these kinds of restrictions in the design of solutions to the diverse problems, one can assure the efficacy of these and the reduction of the probability of them having counterintuitive consequences in the future. Nazzal, D., & Zabinski, J. (2014) contribute that in the -how to-, one must introduce a principle of sustainability in the different subjects of the engineering curriculum and after; create modules or specific subjects where the extent of the relation between engineering and sustainability is addressed.

On the other hand, Colmenares & Ceils (2016) hold in their document: -Hacia una formación más fundamentada y flexible en ingeniería civil- (Towards a more founded and flexible formation on Civil engineering.): “Something that international experience does show is that the changes suggested for the formation on engineering not only aim for it to be more founded and articulate towards mastership, but also that the applicants to a license have a previous professional experience with views on being truly qualified for obtaining the such license.” and continue saying: “the professional license must not be assumed solely as a matter of theoretical knowledge but more as a certification of professional competences and necessary experience to have the ability of developing with feasibility projects that impact and have social responsibility”. This means that an engineer must take all his theoretical knowledge and put it into practice, in the process of solving real problems.

A tool that allows the search of solutions to social problems, is the poCDIO methodology proposed by Arias, Ramírez, Duarte, Flórez and Sanabria (2016), which promotes the active participation of all the stakeholders in the stages of the construction of the theoretical framework. OCDIO meaning observing, conceiving, designing, implementing and operating.

To accomplish these changes in the curriculum that were previously mentioned it is important; as stated by Besterfield-Sacre M., Cox, M. F., Borrego, M., Beddoes, K., & Zhu, J. (2014), to create a shared vision about such innovation, which supposes the support from the faculties to their professor in their own academic teaching and in the implementation of politics that may allow the reward of teacher innovation.

## **Humanitarian Engineering**

One of the other changes that has been developed at the level of engineering education is the cultivation of projects with social and environmental impact. Humanitarian engineering is a focus that has been gaining strength in various programs at a worldwide level as is recognized as a specialty that cultivates the development of communities through the design of technologies, systems and processes. Kevin Passino (2015) in his book on Humanitarian Engineering defines this concept as: “Humanitarian engineering is the creation of technologies that help people.” On the other hand, Juan Lucena (2010) in his book, Engineering and sustainable community development; mentions that Humanitarian engineering refers to the development of communities.

Humanitarian engineering and similar programs have been welcomed by different universities in the United States, such as: Colorado School of Mines, University of Canterbury, Arizona State University, Villanova University, Rochester Institute of Technology, University of Wisconsin-Madison, Carleton University, University of Michigan and Purdue University, The Ohio State University; in Mexico: Tecnológico de Monterrey, Universidad del Valle in México; in Latin America: Universidad Nacional de la Matanza and Universidad Católica in Argentina, Universidad de Chile, Pontificia Universidad Católica, and Universidad del Desarrollo in Chile; Universidad del Valle, Universidad de La Salle, Universidad de los Andes and Universidad Minuto de Dios in Colombia.

## **References on Humanitarian engineering**

The abilities that a student acquires depend on the design and the methodology of the subject. With the purpose of understanding a few of the basic characteristics of a class on Humanitarian engineering, the following Table 1 analyses three references, considering aspects such as: the audience to whom the subject is addressed, the type of subject, the weekly hours that the subject has assigned, the theory component, the practice component and how it is evaluated.

**Table 1: Examples of references on Humanitarian engineering.**

Subject Aspect	<b>Ingenieros sin Fronteras Colombia (Engineers without borders Colombia) (ISF-CO)</b>  <i>Universidad de los Andes (Universidad de los Andes, 2017)</i>	<b>Community Based Research</b>  <i>Colorado School of Mines (Colorado School of Mines, 2017)</i>	<b><i>Humanitarian Engineering</i></b>  <b><i>The Ohio State University</i></b>  <b><i>(The Ohio State University, 2017)</i></b>
Audience to whom it is addressed	Is a subject for engineers	Is a subject for engineers	Is not an exclusive subject for engineers
Type of subject	Elective	Elective	<i>Mandatory for a Minor degree in Humanitarian Engineering, and is elective for other degrees.</i>
Weekly hours that the subject has assigned	4 weekly hours	3 weekly hours	3 weekly hours
Theory component	<p>The topics are focused on the development of the concepts related to the criteria of the projects of ISF-CO: socially inclusive, feasible, environmentally responsible, related to engineering, innovative, technically possible, and of high impact.</p> <p>Lecturers are invited to the class sessions so that they can give talks oriented to the criteria of the ISF-CO projects.</p>	<p>The class sessions are oriented to the development of topics such as qualitative investigation, ethnography, participative observation, collaborative design, community-based mapping, interviewing, and the importance of listening.</p> <p>Lecturers are invited to some of the class sessions to enrich some of the topics.</p>	<p>The class sessions are oriented towards the following topics: poverty, underdevelopment, sustainability, culture, social justice, and development strategies. As well as engineering for community development. Analytical methods and participative humanitarian technology development.</p> <p>During the class sessions discussions in relation to the different topics are held.</p>
Practice component	<p>Through the duration of the course the students must find solutions for a challenge that the community raises in a participative manner. This community may be vulnerable of have development potential.</p> <p>The challenge that the students must solve is chosen but the teachers of the subject.</p> <p>The OCDIO content is used to approach the challenge.</p>	<p>Through the duration of the course the students must answer an investigation question related to a group that is a part of the university community.</p> <p>The group and the question that will be investigated is suggested by the students themselves.</p> <p>Students are taught different tools that are useful in working with communities,</p>	<p>The students work on a final project where they must select and develop an appropriate technology to solve a problem around the world; as well as evaluating its environmental and economic impact.</p> <p>Students are taught different tools for the participative design of technologies.</p> <p>Students are taught some ways to model and simulate</p>

	<p>Field laboratories are performed with the students so that they can get to know the area and interact with the actors involved in the diverse problems.</p> <p>The practice component is developed in groups.</p>	<p>specially tools for participative observation.</p> <p>Students must perform activities outside of the classroom; participative investigation activities with the actors involved in the investigation question.</p> <p>The practice component is developed in groups.</p>	<p>the impact of the given solutions.</p> <p>The practice component is developed in groups.</p>
<p>How is it evaluated?</p>	<p>Quizzes are performed to evaluate the comprehension of the readings assigned for the class sessions.</p> <p>Workshops are graded in which the students can apply some of the tools learned in class.</p> <p>Students present through a portfolio their advances in relation to the challenge. Each portfolio synthesizes and documents the information gathered by at least one of the OCDIO stages. At the end of the term the students have a presentation where they sustain their proposal to experts.</p>	<p>Assistance and participation in class is graded.</p> <p>The application of the tools learned in class is graded; such as: the guide of the interview, the interview, participative observation, and the activity of participative investigation.</p> <p>The students present an analysis of the assigned readings.</p> <p>The students present a final project where they provide a conclusion with regards to their findings during the investigation.</p>	<p>Quizzes are performed about the lectures assigned for the class session and comments on the class are given by the teacher through videos.</p> <p>The students should turn in homework that consists on resolving problems from the main textbook of the subject. (<i>Humanitarian Engineering: Advancing Technology for Sustainable Development, 3rd Edition</i>) Some homework must be done on the Matlab programming software.</p> <p>At the end of the duration of the course the students turn in a report on a final project and they sustain it.</p>

Based on what is presented in the Table 1 of references, it is possible to view that there are many shared aspects in the three Humanitarian Engineering subjects that were analyzed. At first, all the courses have a theory and practice component. The theory component provides the student with tools that can be developed in the practice component that will consist in the execution of a project or of the solution of a challenge. It is common in all cases that this component be performed in groups.

It must be clarified that not in all cases the practice component is focused on finding solutions to local problems. The social system that wishes to be analyzed depends on the context and possibilities of each place.

On the other hand, it is made evident that a humanitarian engineering subject does not necessarily need to be conformed by engineers, and thus; is important that all students learn techniques and are able to apply participative methodologies in working with multidisciplinary teams.

Also, one may see that the three reference courses are elective. This may be explained by considering that, even though these subjects deal with pertinent topics for the formation of any professional, and particularly, for the formation of any engineer; that not necessarily all the topics that are dealt with are of interest to all people. It is hopeful that, behind the diverse problems addressed in class the human being is considered as a central actor and the commitment of the students be total.

As far as the manner on how the students are evaluated, each subject has its own different pedagogical strategies. Nonetheless, it is common that in the three courses the final project

is evaluated. Additionally, in the three references, apart from the grade obtained from the project, other activities are performed to evaluate theoretical knowledge. In none of the cases midterm evaluations are done as a method of evaluation.

## Study Case: Methodology

Following is presented the methodology used to define a course model on Humanitarian Engineering. The proposal was tested in the Industrial Engineering program of Sergio Arboleda University as a strategy to include new perspectives to its traditional approach:

1. Initial proposal of a course model on Humanitarian Engineering in Sergio Arboleda University
2. Model Implementation
3. Students evaluation by an anonymous survey and professors perceptions of the model
4. Model re-design based on the results

## Initial proposal of a course model on Humanitarian Engineering in Sergio Arboleda University

The Humanitarian Engineering course was designed in order to achieve the following objectives:

- To create synergy between engineering and other programs of the university and set up multidisciplinary groups to design artifacts, systems or engineering processes, under social, environmental, technical and economic restrictions.
- To create synergy between low income communities (living in and around Bogota) and the university through the co-creation of engineering solutions.
- To train the students in skills and competencies based on the humanist-scientific approach.

With that scope, the course was defined as obligatory so all the students from industrial engineering program (in its pilot phase) could get an approach to the role of the engineer in the context of communities projects. These types of experiences help the development of design skills with economic, environmental and ecological constrains which are needed to have a complete professional profile in any economic sector in the times of the 2030 agenda.

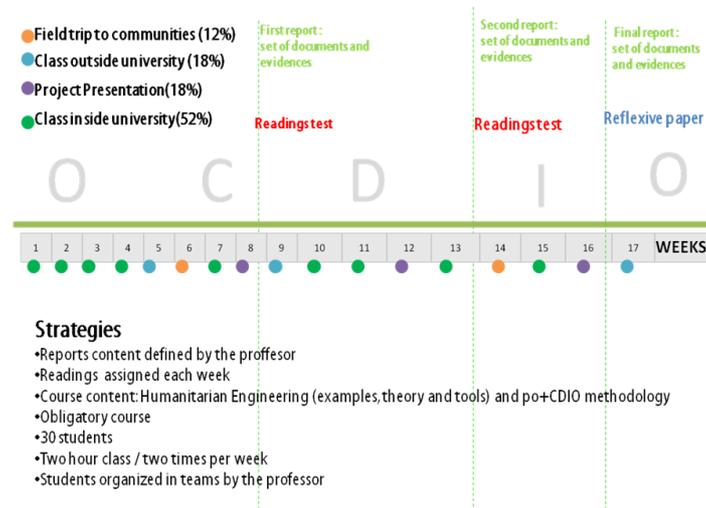
About the methodology, according to the objectives established, the course required having a practical approach. With that intention, the course model was aligned with an innovative proposal made by Distancia Cero, an social entrepreneurship with the mission of decrease the distance between the reality and the academia by promoting an education strategy named Challenge Based Learning. Distancia Cero provided to the course a challenges portfolio posted by two social organizations:

- **Casa Taller Armando Sueños:** A woman collective initiative which looks for the empowerment of the community of Guasca, a town located at 50 km from Bogota. It challenge was: ¿How to define a communication strategy in order to make financial sustainable Casa Taller?
- **Fundación Poca Lana:** An ONG with more than 10 years of presence in Ciudad Bolivar, one of the poorest areas from Bogota. It challenge was ¿How to generate a business model with paper or plastic recycled with a group of mother in condition of vulnerability?

The course was design around the development of these challenges where the students had to propose solutions in teams using the methodological frame po+CDIO, proposed by the

organization Ingenieros Sin Fronteras Colombia as an adaptation of the frame CDIO created by MIT.

Following is presented the model course that was implemented for it first time in the second semester of 2016. These aspects are related to the general characteristics that engineering courses with a communitarian emphasis usually focus on (as was shown in the section “References on Humanitarian engineering”)



**Figure 1: Initial proposal of a course model on Humanitarian Engineering in Sergio Arboleda University**

## Results

In order to evaluate the model, at the end of the semester the students completed a survey (33 answers) where they were asked about their perception of the course. The main priority was to understand from the point of view of the students, if there was a perception that the course was effectively adding value to their educational experience. Here are the principal results:

### General perception

20% of the students indicated that the course was very relevant to their training in engineering; 60% indicated that it was relevant; 20% indicated it was indifferent or little relevant.

### About the assessments

- 30% of the students said they dedicated more than the minimum time needed in the assessments; the 50% just the time needed
- The students indicated that the course should be more flexible about the design process they have to face. Not being too methodic
- Although the readings were related to the course, they perceived it didn't have much to do with the challenges that are the main objective of the class.
- There was a quantity of assessments that didn't have a real connection with the challenged and it was perceived as a waste of time.

### About the methodology

- 55% of the students indicated they perceived the methodology as very innovative (they hadn't had a class similar); 33% indicated is innovative.

- 88% of the students indicated that the experience of working with real challenges was very valuable for their learning.
- Almost the 95% of the students said that it was clear how to apply the po+OCDIO methodology
- 55% of the students indicated they were interested on continuing the challenge because working with the communities was a truly important experience for them

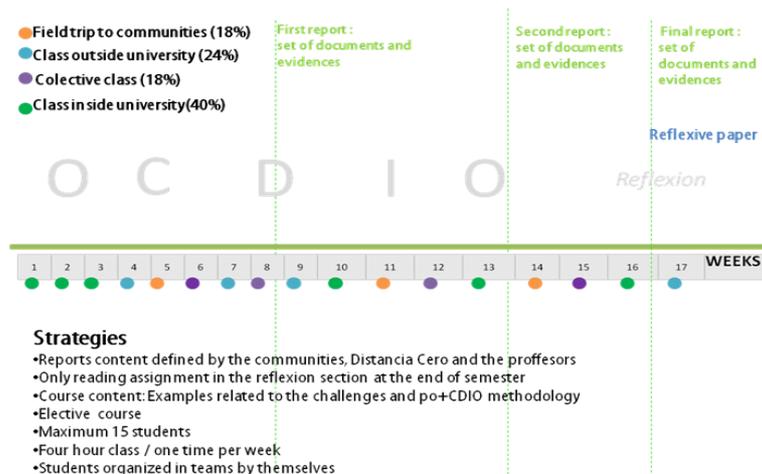
## Findings

After the assessment process and according to the results it was defined that the most valuable aspects of the model was the implementation of the challenge based learning methodology. In the context of the Engineering Faculty of Universidad Sergio Arboleda this approach showed innovation in the student educational experience. Nevertheless it is important to emphasize that there were some aspects that did not function correctly and that should be corrected in order to respond effectively to educational offer. First, the development of the challenge requires an important amount of time so it is necessary to minimize the assessments that are not directly related to it. Minimizing the content of the class is related to have classes more focused on having experiences outside the classroom.

Also, Humanitarian Engineering is an open and complex field so it is necessary to bring experiences and examples that are related to the challenge so the students can connect this information in a easy way to their practice experience along the course. Respect to the assessments, the reading and its tests along the semester did not contribute to the learning process but the reflexive paper (and the methodology given) did help to understand the principal conclusions from a personal perspective. In this way, Humanitarian Engineering should connect both theoretical and practical component.

## Conclusions and recommendations

After an analysis of the results, there was included some changes to the course model on Humanitarian Engineering that are now being implemented in the first academic semester of 2017, considering that both theoretical and practical component are important.



**Figure 2: Proposal of a course model on Humanitarian Engineering in Sergio Arboleda University**

This focus will ensure that the students will have to make some decisions about a design process in social, economic and environmental constrains. That also means that all the

class assessments should be focused on the challenges because the amount of time the students are going to dedicate on facing them is enough to the learning objectives. It is valuable to have a reflexive exercise at the end of the semester where they can analyze their experience using readings related to humanitarian engineering so they can generate their own conclusions. About the impact of the results, the assessments should be defined before the semester begins in a negotiation between the communities and the professors (not only by the professors). In these process is really valuable the role of organizations as Distancia Cero. With that strategy, the students will have goals but they will have the liberty in deciding how to do it. In this process the professors have a roll of facilitator. These also will ensure the immediately impact on communities because it will be measurable in terms of the accomplishment of the assessments.

The course should be elective and no obligatory. Although the professors think the sense that Humanitarian Engineering should be a clue for the development of design skills of the students, there are a common perceptions or paradigm that working with communities is not transversal and is not for everyone. Said that and Thinking on the compromise of the students it should be elective. The po+CDIO frame should be used as a frame and no as a methodology. The students can defined how they embraced it taking into a count that those are the basics steps in a design process

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