Ingenuity and Society

A humanitarian engineering education experience in Colombia.

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Abstract: Engineering education can address the analysis of disputes related to the effects generated by the techno-scientific activities over social relationships and nature. Education processes conceived from this approach allow debates and train professionals who may be involved in processes of design, implementation and monitoring scientific and technological practices and policies towards a more contextualized education in Humanitarian Engineering.

In this direction, the course Ingenuity, Science, Technology and Society was created. Offered since 2014 by the School of Engineering as an elective course for all undergraduate programs in Bogotá Campus at the Universidad Nacional de Colombia. This course is intended as a space for reflection and action, complementary to the formal curriculum. It allows the interaction of students from different disciplines with the aim of formulate proposals for solutions to socio-technical problems with marginalized communities through co-design. As for the characterization of students, in nine semesters 600 have signed the course, of which 403 have filled out an initial survey, and 557 have filled a second one. Some of the findings are: 40 academic programs from 10 schools have participated, involving 77% of men and 22% of women and 1% that define themselves as other. About the evaluation of the course, the students said that the 90% of them consider the course relevant for their professional life and the 95% consider that the course have to continue in the University.

Keywords—component; Humanitarian Engineering, Engineering Education, Interdisciplinary, Marginalized communities, Colombia.

I. INTRODUCTION

This article discusses the main elements of the course Ingenuity, Science, Technology and Society (ISTS)[1] in the framework of Humanitarian Engineering Education (HEE). This academic activity intended to encourage reflection and the work of co-creation between the University students and vulnerable communities[2], with the vision of transforming the role of the engineering in the society and develop socio-technical solutions, together with the users and the communities.

In the first part, pedagogical approaches that guide the course and based on humanitarian engineering education are addressed. The second part is dedicated to the presentation of the ISTS course, specifying their background, objectives and thematic lines. Finally, the characterization and an evaluation of the first nine versions of the course is made. For this assessment, is taking into account aspects such as the distribution of students according to the semester, gender, program, and students perception of the relevance and promoting interdisciplinary of the course.

1 The name of the course in spanish is “Cátedra Ingenio, Ciencia, Tecnología & Sociedad”.

2 The identification of socially vulnerable groups obeys different criteria: some contextual factor that makes them more likely to face adverse circumstances for their social integration and personal development, [...] the group of behaviors that involve greater exposure to harmful events, or the presence of a shared basic attribute (age, sex, ethnic status) that confers common risks or problems” [1].

II. HUMANITARIAN ENGINEERING EDUCATION

Humanitarian Engineering (HE) is a field of engineering that has been developing for a couple of decades working on the role of engineering in solving the problems of vulnerable and marginalized communities [2] and transform their relationship with those communities. The scope of this approach considers all engineering disciplines, and it focuses on those technologies considered culturally inclusive, appropriate, economic and sustainable [3, 4]. In this sense talking about education of the engineers of the future, Amadei and Wallace state:

"A new form of engineering education is needed, one that covers a wide range of technical and non-technical issues, including water provisioning and purification, sanitation, public health, power production, shelter, site planning, infrastructure, food production and distribution, and communication (…) The challenge of creating a sustainable world demands a new and holistic look at the role of engineering in society. [5, pp.7 -10]"

Engineering as a whole has resolved the needs and problems of society through the history. However, some sectors of the population have been marginalized economically, socially, politically and technologically, creating consequences and issues in specific communities [2]. This unequal situation represent a challenge for the academia and especially for engineering schools that can be addressed through new educational, pedagogical and practical processes using the co-creation [6, 7]. The first aim is generate solutions with these communities through a process reflection and action of in terms of sovereignty and social justice [8, 9] .

The field of HE is growing, its places for action are discussed in the literature without a consensus. According to Cuny [10] suggest three environments of humanitarian engineering operation, the first is emergency response, the second is transitional response and the third is development. Conkol [3] establishes three scenarios of action, a) Disaster recovery, b) Development and c) Re-development. Finally, Kinsner [11] proposes four levels of action, a) Natural disasters (fires, storms, tornadoes, tsunamis, earthquakes, floods), b) Humanitarian crises (genocides, wars, undemocratic elections, injustice), c) Developing countries (water, food, shelter, energy, sanitation, health), and d) Developed countries (poor communities, aged, persons with mental-physical, communities not represented). The previous scenarios demonstrate a big scope of the practice of HE, however is critical to find contextualized methodologies.

This framework as an object of inquiry in academia and professional practice for engineers, is recent. It has been discussed and built from institutions and individuals in the United States, Australia and European countries. Therefore, here it is one of its main limitations, that is not yet a reference framework in Latin America, Africa and Asia universities, in other words in the Global South [12, 13]. In the global north the HE framework has been applied in some higher education institutions. Even with the introduction of this approach and specific subjects in the Engineering curriculum, there have been found are conceptual challenges in its implementation [14, 15]. From the point of view, engineering education must introduce new frameworks, methodologies and concepts according to the cultural, political and geographical and environmental context. This could be possible through make relevant their actions in favor of strengthening the relationship with society as a whole and particularly in local territories [16]. Also, the relevance of the concept of co-creation and co-design in engineering education is critical [17,18]. Other element that is problematic is a lack of reflection around evaluation of HEE activities.

As an innovative academic proposal, the ISTS course attempts to create new methodological approaches to achieve the expectations of students and communities not only for it content, but by the process of co-design. The main framework used are Problem-Based Learning and Service Learning. In this sense within the Universidad Nacional de Colombia it has been explored the adoption of those approaches in this learning experience [19, 20, 21,22].

III. INGENUITY, SCIENCE, TECHNOLOGY AND SOCIETY.

The course is one of the initiatives of the Engineering School to strengthen the relationship between university and society in the current Colombian context. This initiative came in 2014 at Universidad Nacional de Colombia in Bogotá, in the absence of academic spaces for reflection, discussion and action around the link between academia and marginalized communities inside the Engineering School. The course each semester receives about 50 student of all schools in the University. It has its origins in the work of the student group "Ingenio Sin Fronteras", which since 2010 has been working on the relationship between engineering field and marginalized communities in Colombia.

The student group "Ingenio Sin Fronteras" (Ingenuity Without Borders) born as an initiative to actively participate in solving problems with the people, using technical, scientific and social knowledge. Its work is focused on global problems such as poverty, lack of opportunities, food security, health and environmental care [23]. Regarding the historical particularities of the creation of the group and the nature of the name, below the most relevant information is presented:

"The initiative "Ingenio Sin Fronteras" arises from the participation of students from the Universidad Nacional de Colombia (in Bogotá) in the International Seminars "Ingenieros Sin Fronteras Colombia" - (Engineers Without Borders Colombia - EWBC). However, the process of "Ingenio Sin Fronteras" begins independently as an outreach activity led by students, mainly for two reasons; ethical differences compared with particular issues on ISFC and the need to find the identity of the group from these differences ...

…The techno-scientific work with communities does not involve only the participation of engineers from academia, since the skills acquired by technical training superficially involves the interaction with society and to that extent it is considered that there must be a transdisciplinary work with the participation of students from other disciplines, such as in the

particular case has meant the presence of students of sociology, anthropology and social work. Therefore, in addition to issues of gender, the name of "Ingenio" is adopted unlike "Engineers" as a symbolic act of inclusion." [24, p. 5].

Coming back to the course, the main objective is to build capacities and foster critical thinking in students for the co-creation of science and technology projects with vulnerable and marginalized communities. This can be achieved through:

- Discuss the role of science and technology in the current development model and its importance in society alternative proposals.

- Re-frame the role of basic science and engineering areas as needed for collective wellbeing.

- Introduce theoretically approaches and methodologies of working with marginalized/vulnerable communities from a science and technology perspective.

- Promote the creation of innovative proposals to facilitate the emergence of transdisciplinary research process and action, focused on the communities.

The methodology of the course focuses on theoretical lectures with national and international experts about successful and unsuccessful community experiences around the role of science and technology in the collective wellbeing. The lectures and experiences are conducted by experts from higher education institutions, community-based organizations, civil society and NGOs working in depth issues of local innovation that involves co-creation. Each lecture is addressed from the perspective of engineering or disciplines such as sociology, anthropology, economic studies, political sciences, health sciences, agricultural sciences and arts related with the techno-scientific sphere. Those lectures reveal a high number of fields and links with other disciplines that Humanitarian Engineering have. Particularly in Colombia, where the conflict has made a deep footprint in the Universities and communities. Also, the course create a space to identify key actors on the ground to weave a net of social transformation in the country. The lectures are supported in previous readings, allowing discussion and group work.

On the other hand, a practical component is carried out. Led by interdisciplinary teams of five students, the formulation of a joint techno-scientific project with a vulnerable/marginalized community is developed throughout the semester towards the community engagement [25]. The problem is defined and at least one possible socio-technical solution is contemplated. The main components should be clearly referred are 1) background and problem framing 2) the methodology of work with the community, 3) strategies of social appropriation of knowledge and social innovation, 4) technical feasibility, 5) risk assessment and project sustainability.

The results of the project formulation are socialized, discussed and evaluated by community members and guests who have experience in working on those areas. As parallel work, students individually write an essay that evolves throughout the semester based on the content addressed in the course. The objective is promoting writing, critical thinking, communications skills and reasoning ability of students about issues and opportunities in the humanitarian engineering. The course has been performed nine times, from first semester of 2014 to the second semester of 2018. With the time the group that led the course have been refined pedagogical tools used, introducing activities that promote teamwork and critical creativity. This subject can be characterized as an interactive integration initiative [26], to integrate the three missionary functions of universities in Latin America: teaching, research and outreach, while is interacting with marginalized social sectors in Colombia.

In the start of the course in 2014 the content was set on three interconnected modules, where relevant issues are discussed on the relationship between science, technology and society. The first module was related to the critical view of science and technology and the role of the university. The second module focuses on science, technology and innovation in a post conflict scenario in Colombia. The last module was called alternatives to conventional development paradigms and offer different visions to create futures linked with transitions of the actual economic model.

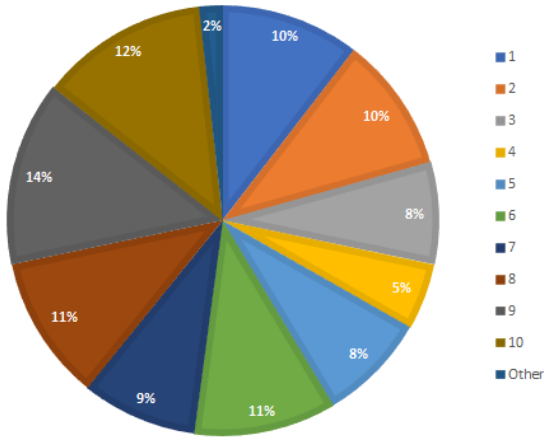
IV. Research methodology and analysis

During the period that has been given this course the self-assessment is an important way to identify educational needs. The improvement and enrichment of contents, methodologies and pedagogic tools are a driver to assess the performance of the course. This allows the consolidation of a relevant alternative within engineering education particularly in Colombia, now in a peace-building process.

The mechanisms used for this evaluation were the use of a questionnaire for the characterization of different components of the course (characteristics of students, lecturers, topics addressed in projects and tests) as well as the students evaluation of the course at the end of each semester. Feedback provides qualitative information that bring insights to assess the relevance of issues, the development of content, the performance of the speakers and organizers of the course, as well as methodologies and evaluation. Similarly, it allows to know the perception of the students regarding the contribution of the course in vocational training (acquisition of tools, knowledge and skills) and relevance in their curriculum.

Thus, according to the Academic Information System (AIS) at Universidad Nacional de Colombia, the course has been taken by 600 students from different undergraduate programs. However, one initial survey is conducted at the beginning of the semester and only has been filled out by 403 students. Below, is presented the information about the characterization of the students.

FIGURE 1. Distribution of students on semester completed.

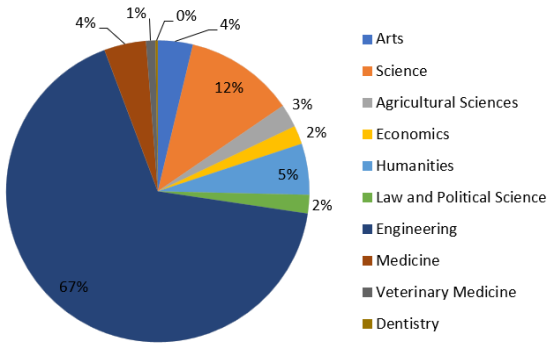


Source: Authors

Regarding the distribution of the students related with the advance in their program, in general terms, it is homogeneous. The highest percentages are in the ninth and tenth (last semester), 14% and 13% respectively (Figure 1). In this sense, the different experiences of the students create an opportunity to collective learning between them, the experienced and new members of the academic community.

In terms of academic programs, they have been students present from 40 of the 49 existing undergraduate programs in the Bogotá Campus (Figure 2). As for Schools representation, the course has had 10 from 11 Schools, whose participation is distributed as follows: Engineering 67%, Science 12%, Humanities 5%, Medicine 4%, Arts 4%, Economics 2%, Law and Political Science 2%, Agricultural Sciences 2%, Veterinary Medicine 1% and Dentistry 0.2%. The only school that didn't participated in the course yet is Nursing.

FIGURE **2**. Distribution of students according to school.

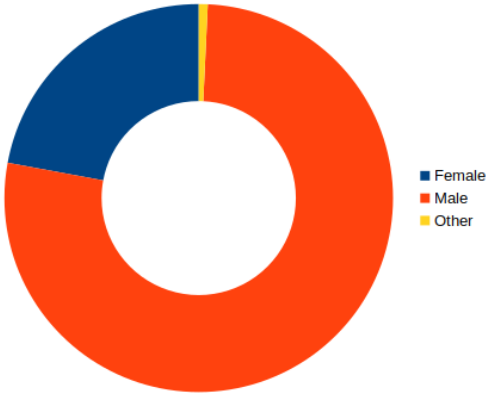


Source: Authors

The diversity of knowledge in the course represent an incredible asset in terms of the perspectives, skills and mindsets that they can put on the table. Also, the experience to start working and learning with people from other disciplines is an important soft skill for the professionals that the world need.

In terms of gender, participants of the course were 77% male, 22% female and 1% that defines as other (Figure 3). This being evidence of the need to increase the participation of women in issues related with science, technology and innovation. The above is related with STEM education to girls, that is directly related with the relevance about the role of women in the advance of techno-scientific alternatives in order to actively participate in the construction of a peace engineering framework.

FIGURE 3. Gender distribution in the course.

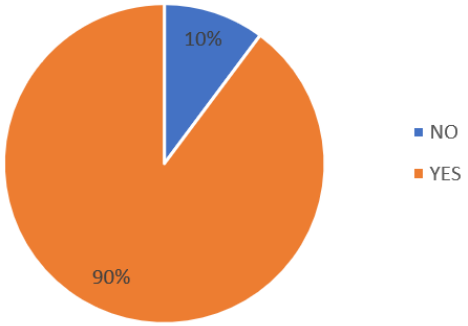


Source**:** Authors

Regarding the perception of the students at the end of the semester, a second survey was conducted as an evaluation element. This final instrument was filled by 557 students. In this survey we ask questions around the continuity of this academic space, relevance of the content to the professional life, interdisciplinary, possibility to start a communitarian project, tools provided to complement the discipline, link with the program curriculum, takeaways, comments on evaluation methodology and final thoughts.

In this case, the evaluation led by the students allows us to improve the course each semester. The first question is related with the continuity of the course. In order to determinate the reasons to keep offering this space and receive feedback about its content, we ask "Do you consider that the course should continue to be issued in the following semesters?" The positive answers ranging between 90% and the negative were 10% (Figure 4).

FIGURE 4. Perception of students on continuity of the course.



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Some of the comments from student around continuity were:

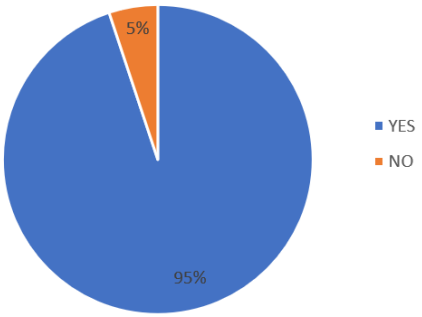
"Because in engineering we have no component that questions us effectively about what to do and is important in the training of critical engineers who contribute to the construction of a country."

"Because it is an opportunity for students to give their knowledge to the community, and make more real and more beneficial their projects. In this way the projects do not stay in the academy but have an impact, at least local."

"The course must have continuity so that new perspectives are generated to re-imagine it, to allow the diffusion of the projects so that these expand and have continuity as well as to serve as a space of multidisciplinary reflection on the problems that there are in the academy, industry and the role of the professional in a post-conflict context. In addition, so that the projects that have been generated do not remain on paper, the continuity of the course is imperative."

About the relevance of the course for their professional and personal life. The student express that the pertinence of this learning experience is positive in 95% of the cases, meanwhile the 5% affirm that isn't (Figure 5).

FIGURE 5. Relevance for their professional and personal life.



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In addition, the relevance of the course for the professional and vocational life is argue as important. Some of the students reasons were:

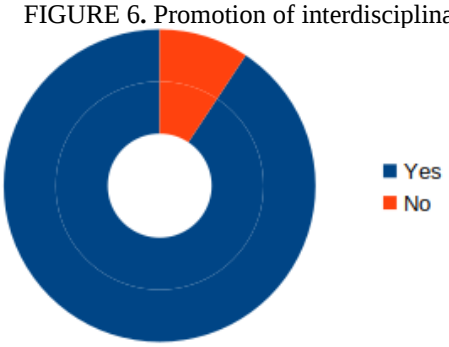
"Because it broadened my perspectives on my role as an engineering student, as a citizen and as a future chemical engineer. We touched on many issues of social importance in which as an engineer I can play a key role."

"From my professional interests, helped me to understand the challenges that the areas of knowledge related to science and technology face the current problems in the world and in the country. To think a critical academy is a task not only of engineers and scientists, but also of humanists interested in the construction of a more inclusive society."

"In the first place because I understood the importance of interdisciplinary. Usually the problems of the communities have multiple causes therefore it is indispensable to work in an articulated way with professionals of all the areas in order to integrate the knowledge and to arrive at a solution to the problem. Secondly, because I understood the responsibility that the university and its professionals have in the construction of society and in development. And thirdly because I learned about theoretical aspects related to the environment, sustainability, politics, war, etc.".

Finally, elements around interdisciplinary were found as a critical point of the course in special, topics related with science, technology and innovation. The Figure 6 shows the perception of interdisciplinary promotion in the course, 90% of the students consider that the course fosters the interdisciplinary due to the team project involving a diverse pool of disciplines, meanwhile 10% argues that isn't.

FIGURE 6. Promotion of interdisciplinary work.



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In the case of interdisciplinary, some of the reasons of the students around the promotion of it, were:

"It shows how an engineering solution can cause more problems than it solves, to avoid these problems a series of works with the community and other disciplines is indispensable."

"Not only for the integration of different disciplines to a preliminary project, but also for the fact of knowing opinions and points of view of different people who have had a completely different formation to mine. The topics of the course in general enriched me as a person and as a professional."

"It is hard to work with colleagues from other schools, but it is equally necessary for the world that awaits us outside the University. Teamwork is the key to success.

"-Lonely, you'll go faster, but together we'll go farther-."

"Because together with the community we work in groups that were formed with students from different careers which contributes to collective learning and the solution of a problem through unconventional methods in our own careers."

On the other hand, some students argue that the course was not interdisciplinary. Below are some comments on that:

"Being engineering students the majority of the attendees, it is logical and evident that in the groups there will be more engineers, whose mentality is surprisingly homogenized (from what little I could share with them). I would have liked there to be at least 1 student from each area of knowledge per group (exact, humanities, arts, etc.) but this is impossible because of the focus of the course."

V. Conclusions

This academic space contributes from a science and technology perspectives to generate alternatives to the creation of knowledge and solutions for a new relationship with the society. The interdisciplinary projects with communities for a post-conflict scenario in Colombia are described as appropriate. Technological sovereignty of communities victims of social and armed conflict is a goal in the lens of Humanitarian Engineering. It also aims to create space for the construction and consolidation of peace and social justice inside Universidad Nacional de Colombia, particularly in the engineer School from an academic perspective involving teaching, research and outreach.

From the viewpoint of the project-based learning and service learning framework this experience offers elements to understand the role of interdisciplinary and the focus at community level as a critical foundation to change the relationships between university and particularly engineering school with social sectors in Colombia. Specially, this Humanitarian Engineering initiative is creating a base for a peace engineering framework in the Colombian post-agreement context.

The diversity of the student in terms of time in the university and advance in the program is distinctive of this course. Nevertheless, it is necessary to improve the project-based methodology towards a virtuous dialogue between the explicit knowledge of the students and the tacit knowledge of the community members. This can be done through a wider learning scenario beyond the engineering discipline, and also the traditional university institutions. Despite the high number of participants in the nine semesters since the course is offered, it is necessary to increase the number of students from different programs besides engineering and science schools to encourage the interdisciplinary desired. On the other hand, the women's participation is a signal of the segregation in the field of science, technology and innovation. This must be face not only at engineering schools, but as an integral public policy and University response to this challenge.

Some of the feedback received by students is expected to implement methodological innovations in the development of the course, including the ability to do field trips and try to promote the realization of the co-design prototype. However, the limits of the time and resources make these elements as a point to consider in the future. Analyzing the answers given by some of the students, is observed the lack of training spaces in the Faculty of Engineering where the phenomena to be studied are tackled with a socio-technical perspective. This is how the engineer's training, focused on the purely technical elements, leaves no room to understand engineering beyond these elements. In this sense, there is evidence of the need to expand this holistic approach within other courses within the Faculty.

In terms of next actions and strategies for the course in Bogotá, it is expected to strengthen the content and methodology. The above through the evaluation by the students, engage of more academic peers, creating a network of educational experiences in Universities. Then, is expected an open scenario to discuss Humanitarian Engineering education in the country according with the new political reality after the peace agreement. The short-term goal is the escalation of the course at Campus level, expanding the number of places, creating a space for dissemination and wider impact, creating long-term projects with communities and social organization across the country. Finally, share these reflections to the university, academic community and civil society at global scenario.

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