



## A Learning Model Proposal Focused on Challenge-Based Learning

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### ABSTRACT

This paper proposes a model that comprises a learning exercise based on challenges, which tends to promote non-technical skills such as oral expression, communication, resource management, leadership and problem solving among engineering students. Since engineers have been recognized throughout the world for their ability to creatively solve problems, using the technical knowledge developed in their professional career, it has been considered that these skills make it easier for them to reach results that involve the solution of mathematical problems, or those related to science, through the use of technical skills, research or analysis and synthesis. In this sense, the academia seems to have placed the emphasis on hard and technical skills, while, non-technical ones, have been left in a secondary stage in the case of engineers, ignoring their role on their professional development. This project proposes a model that will bring together more than 180 engineering students and 4 university professors, by involving them in a real challenge that they might solve by means of their technical and non-technical skills. The model is being applied at a university and their first results show the need to modify the engineering training processes, to include the development of appropriate competences in engineers, in response to the demands of a globalized world.

**Key words:** Challenge based learning, Industrial engineering, Soft skills.

### INTRODUCTION

The dynamic world in which engineers operate presents them with new demands and offers new challenges in the diverse, profound and incessant changes that humanity faces while walking in the 21st century (Nguyen 1998).



This set of changes that are occurring in the business, social and economic environment, requires attention from academics and also entrepreneurs, since real problems are generated continuously and demand attention of many professionals, including engineers. These scenarios not only demand the technical approach in engineering training, but, as several studies have shown, it is also needed the development of non-technical skills among students, which includes attitudes, soft capabilities and values, integrated altogether with technical knowledge and skills. This will allow an engineer to function effectively in different contexts (Zah and Dh 2015). Within this frame of reference, competences as: the ability to communicate with colleagues and bosses, the ability to express their opinion with respect and forcefulness, to argue their positions, to manage resources, to lead teams, or the ability to solve environmental problems reinforce and complete an engineer professional exercise. There is also another issue to add to this context: nowadays there is a lack of effective pedagogical practices that prepare students as future engineers, according to the soft skills required by markets (World Economic Forum 2016).

Within this framework, the problem statement of this project is focused on how to contribute to existing curriculum and pedagogy to strengthen the skills needed by engineers. These skills may respond, as stated before, to global trends in terms of abilities that will help future engineers to tackle industry and organizations' problems. Our contribution is therefore envisaged to pedagogical practices in accordance with the global drivers of change. While much has been said about the need for reform in basic and university education, the dynamics of workforces continue pushing changes due to the rapidly grow of some jobs, and the adjustment of most occupations (World Economic Forum 2016). This work set as a focal point, a subset of changes that make emphasis on the integration of technical and non-technical capabilities. This integration will likely encompass future variations of syllabus and on the supporting teaching material and techniques, which includes methodologies used in class, which are determinant in the learning process, since they directly affect the active participation of the students in the individualized learning experiences, and this also make a difference on the skills and knowledge acquired, and orientate students' interests and learning processes (Salinas 2008; Stratulat 2013).

This article will deal with a teaching-learning method as a basis of a model intended to provide a learning experience that combines technical and non-technical skills for industrial engineering students. The work is presented in a frame of reference that, using challenge-based learning, places engineering students in the position of facing real problems, and encourage them to use their engineering knowledge and some soft skills such as: as a team work capability, leadership and communication. Many academics now a days agree on the fact that exposing engineers to non-technical areas of study will expand their skills and knowledge, and increase their job prospects by better meeting the requirements of the industry (Nguyen 1998; Jou, Hung, and Lai 2010).



Thus, this project presents a model that is being tested with 186 university students of the industrial engineering program of Universidad Industrial de Santander, in Colombia. 30 groups of students were built-on. There was at least 1 student from each one of the 4 different courses integrated in this project. These courses were: Managerial Issues I and II, Entrepreneurship and Human Resources. They were all exposed to our proposed model: a learning exercise based on challenges, by means of which they had to propose a solution to a real problem involving technical competences of the career, as well as non-technical ones.

The research has been conducted by 4 teachers of the engineering program, and the project lasted 12 months. The GALEA laboratory was the origin of this proposal, as GALEA promotes teaching and learning experiences based on alternative methods such as project based learning and challenge based learning among others (Torres-Barreto, Alvarez-Melgarejo, and Prada 2017). Information and communication technologies were considered within the model, allowing a technical support during the whole project which included the communication and integration of the groups. A virtual character named “Antonio”, was designed in order to accompany the students in their journey through the activities that constitute the challenges themselves. The theory that supports this model, the methodology used, as well as the partial results, are exposed in this paper.

### ENGINEERS IN SOCIETY

Historically, the profile of an engineer has been associated with a broad background in calculation methods, and therefore, with technical skills such as the application of methods and numbers for problem solving. Expanding his mathematical maturity and his ability to work with abstraction, the engineer has developed skills to communicate properties and characteristics of magnitudes in a graphic, numerical, symbolic and verbal form. In addition, the engineer has historically contributed to the use of computerization in the resolution of problems, the processing of technical literature, as well as the proper handling of interdisciplinary language (Curbeira Hernandez, Bravo Estevez, and Bravo López 2013; Vargas and Irigoin 2002).

Moreover, during the seventies, the term “competences” was developed. It included complementary skills that are now considered of high importance in the training of professionals. The competence of a professional was then defined as the “set of capabilities, skills, and abilities with which to perform the activities defined and specifically linked to an occupation” (Rodriguez Moreno 2002). Thus, in the seventies, an engineer was competent if he had the ability to perform the technical functions of his occupation. However, the concept of competition was changing and its attributions now include flexibility and autonomy, thus becoming a multidimensional concept (Vargas and Irigoin 2002).



So much has migrated this term, that today is understood as: “what makes the person able to perform in a job or to successfully complete an activity” (Rojas-Zapata and Hernández-Arteaga 2018). To achieve this, an engineer, for example, will need the combination of knowledge, skills, dispositions and specific behaviors. Therefore, competencies differ from the requirements of a job in such a way, that some authors claim that, the skills required nowadays of an engineer can be grouped into four categories: 1) Social and communication skills; 2) Methodological competences; 3) Participatory competences taking into account the specific knowledge on the subject, and finally, 4) Specialized competencies (Marzo, Pedraja, and Rivera 2006).

Thus, the role of engineers in today’s society is given not only by the ability to solve problems using their mathematical heritage, and their creative ingenuity, but also, by the sum of their specialized, social, communication and participatory skills.

#### **THE MASTER CLASS AND ITS IMPACT ON LEARNING PROCESSES**

Over the last decades, research lines evaluating academic results of students have emerged. The research has been focused on students’ responses to traditional methods of education (Vásquez and Torres-Barreto 2014). Numerous works agree on the importance of designing an appropriate set of techniques and strategies to support the learning processes. Most of these strategies focus on achieving significant and lasting learning over time (Agelot 2001; Estévez 2002; A. Ontoria, Gómez, and Molina 2006; A. O. Ontoria 2006). Those teaching strategies become important to understand how the procedures that an agent uses consciously and adaptively, may accompany the learning process (Díaz Barriga and Hernández Rojas 2002), and how they combine the interests, efforts, and accomplishments of the actors to achieve the comprehensive education of students (ACODESI 2002). In any case, these researches seem to coincide in the fact that argumentation, critical reflection, concepts construction, dialogue between peers, didactic interrogation and collaborative learning must be incorporated in every teaching-learning strategy (Corredor, Pérez, and Arbeláez 2009).

In contrast to these findings, there is the master class as a teaching methodology that has historically been imposed. This implies a low engagement of the students in the learning process, a fact that has contributed to low the students’ motivation. In this type of classroom, the teacher verbally communicates certain information to the students, who play the role of receivers of information. The teacher represents the ultimate truth, and both, teacher and content, are the center of activity (Isaza Restrepo 2005). Teaching models based on this methodology do not encourage the student to learn or inquire beyond the information provided by the teacher (Domínguez et al. 2015). However, this methodology has some advantages, among them: 1) it offers an organic, integrated



knowledge and 2) shows an appropriate way to approach and develop a topic (Montenegro 2015). On the other hand, it has great disadvantages, the most important is that students are considered passive, isolated and distant receivers and teachers focus more on their career development than on student learning. The notion of learning in this practice is based on repetition and therefore on memorization (Isaza Restrepo 2005).

Based on the previous considerations, one might contemplate that university professors have been mostly trained with traditional education models, where the master classes are predominant, being the concentration on the theory the most significant teaching model (Schank 2000). Therefore, this would be one of the reasons why the lecture is still present in the universities classrooms today, even though, this methodology does not fully respond to society's demand nor does it conform to the principles of knowledge construction (León and Crisol 2011).

In addition to previous observations, is relevant to highlight the influence of teaching methods on learning outcomes (Lopez 2008), such methods have a crucial influence on the education of children, youth, and adults, with long-term personal and social implications. The teacher as a mediator between knowledge and students should promote linking knowledge with practices, the connection between general and specifics and, problem solutions skills (Davini 2008). Given the above, it is necessary to explore alternative methodologies and built up methods that reinforce the soft skills related to engineering, in order to achieve a high-quality education (Fernandez March 2005). These skills could improve the students' involvement on learning, as well as their social and ethical commitment, enabling them to assess not only what is learned, but also the ability and learning skills (Ruiz 2011).

### **LEARNING BY CHALLENGES FROM ITS ORIGINS**

In contrast to more traditional methodologies, the challenge-based learning has emerged. It was originated in Apple and the VaNTH ERC Engineering Research Center. In 2008 apple carried out a project called "Apple Classrooms of Tomorrow-Today", in which the students worked on teams, not only among the classmates but also interacting with teachers and external specialists in the specific field of knowledge (Apple 2011). Apple named this method: Challenge-Based Learning (CBL).

At the same time, the VaNTH ERC Institute, integrated by the Universities of Vanderbilt, Northwestern, Texas, Harvard and MIT, implemented a method called Challenge-Based Instruction (CBI). This method was centered on the issue of: "How People Learn". In this case, the focus was placed on students, knowledge, evaluation, and society (Bransford 2000). They also proposed the Action-Reflection Legacy Cycle. This cycle is based on the collaborative work of students in order to solve



a problem through the following phases: 1) challenge, 2) generation of ideas, 3) contribution of various participants, 4) research, 5) skill test and 6) publication of the solution” (Cordray 2009; Fidalgo-Blanco, García-Peñalvo, and Sein-Echaluce 2017). Together, these two exercises have been combined to form what we now know as Challenge-Based Learning (CBL).

Nowadays, the CBL is entering the classroom as a pedagogical approach. It is being incorporated into the human sciences, management and also, engineering. The CBL demands a real-world perspective because it suggests that learning involves the student’s doing, thinking and acting with respect to a subject of study (Sein-Echaluce 2016). This approach provides a learning framework focused on the student, which emulates the experiences of a modern workplace (Fidalgo-Blanco, Sein-Echaluce, et al. 2015). This is how the CBL takes advantage of students’ interest in giving practical meaning to education while developing key competencies such as collaborative and multidisciplinary work, decision-making, advanced communication, ethics, and leadership. Table 1 shows a summary of most cited studies regarding CBL exercises performed on academic environments.

The CBL shares some features with Project Based Learning. Both approaches involve students in real-world problems as well as in the development of specific solutions. However, instead of presenting students with a problem to solve, the Challenge Based Learning offers them open and general problems and they will have to find out the challenge to be addressed (Fidalgo, 2015). It also shares similarities with the gamification, in terms of the application of conceptual elements of video game design in environments such as business, commercial marketing, and education, allowing the latter to involve the student in solving cases and activities using mechanisms of reinforcement from rewards for effort (Prieto 2014).

The CBL integrates elements of research, interdisciplinary and student-oriented learning. It builds up an active learning environment (Whitney Brooke Gaskins 2015), where students should deal with problems with various solutions, and choose the optimal solution path (Johnson 2009). In CBL students get involved in real life problems (Johnson 2009), and those of global interest (Jan 2012). The student is also expected to identify the essential questions within a given problem and also to use the acquired knowledge to solve it (Rillero 2012). Thus, this methodology provides information about a certain challenge, and while allowing students to develop their skills, keeps the teachers as a support throughout the entire approach to the challenge and the proposed solution. Given these characteristics, the CBL was chosen as the base methodology for building up our model. CBL had the protagonist role in this model by promoting students’ autonomy through teamwork. Students have to propose a valid solution using their technical knowledge, but also they have to create synergies, and collaborate altogether within each group, using non-technical skills as well as technical ones.

**Table 1. Main studies regarding CBL.**

Authors	Subject of study	Country of application	Main findings
(Baloian et al. 2004)	The authors use CBL for describing several classroom scenarios. Challenges included ways to develop, design and implement solutions for problems related to scientific phenomena.	Sweden, Germany, Chile and Colombia.	Students have become more interested and involved in science learning when these tasks can be supported by authentic scientific inquiry activities, done in collaboration with other peers and supported by multimodal interaction. The teacher adapts, proposed and elaborated and applies the tools to their needs flexibly and creatively.
(Ikonen et al. 2009)	Describe the implementation of CBL in Embedded Engineering as a part of a Syllabus in Helsinki Metropolia University of Applied Sciences (UAS).	Helsinki, Finlandia	CBL is an effective method for engineering education, since it the engineering students to conceive, develop, implement and operate. CBL is an effective and highly activating method of teaching, that requires active involvement, extra time and additional effort from teachers.
(Jou, Hung, and Lai 2010)	Apply CBL approaches to enhance motivation and learning effectiveness in students' of the robotics subject.	Taiwan	CBL approaches are able to enhance students' course achievements and motivation. Also, students can explore the essence of design, manufacturing, mechanisms, control, and the integration of robotics. There is no difference in the satisfaction of students of two groups, this because challenge based learning approaches require students to learn under a strict standard
(Cheung et al. 2011)	CBL applied to cybersecurity education, to improve student learning via a multidisciplinary approach which encourages students to collaborate with their peers, ask questions, develop a deeper understanding of the subject and take actions in solving real-world challenges.	Boston, United States	Improve of more than 50% of students', in computer and security skills, interest in learning security and ability to teach other students.
(O'Mahony et al. 2012)	Compare two teaching approaches in a work environment: conference-based and challenge-based learning	Washington	Greater interaction among participants in the challenge-based group. This group performed significantly better on posttest items requiring integration and synthesis of concepts.
(Gaskins et al. 2015)	CBL in an undergraduate Basic Electric Circuits (BEC) course to reduce negative experiences and increase motivation.	United States	An improved classroom experience with the use of CBL. The CBL helped students feel comfortable asking questions and dialogue with the professors.
(Cheng 2016)	CBL as an innovative strategy that can develop nurses' 21st-century skills.	Hong Kong	The experience provided the nurse students: knowledge on a subject relevant to their careers, gave a method for rationally tackling a real world problem and initiating a creative solution.
(Fidalgo-Blanco, García-Peñalvo, and Sein-Echaluce 2017)	A methodology that allows applying the CBL within the context of the subject "Computing and Programming" of the Degree in Energy Engineering.	Madrid, España	The effectiveness of the CBL method to encourage cooperative work was observed. Students share information, interact and collaborate with each other, through the discussion forums associated with each stage.
(Yang et al. 2018)	Evaluate the effectiveness of CBL on students' creativity and innovativeness, of nursing.	China	That is, students improved their ability to think more imaginatively, to innovate, learn in a flexible way and be more open to risk-taking through challenge-based learning. Also there were changes in the attitudes and behaviors of students.



## METHODOLOGY

This project started as an initiative of the GALEA-Lab (a laboratory devoted to explore learning interactive environments on the campus at Universidad Industrial de Santander). It represented a group of university professors, who understand the problem of the non-technical competencies of the industrial engineering students and treated it as a phenomenon that need a lot of attention from the academia. They also noticed that the CBL methodology could support the development of some of these competencies, by exposing a group of people to scenarios where critical social problems were presented to them, and interaction among students and social actors in order to propose solutions were needed (Santiago 2017).

The following courses were considered for this research: Entrepreneurship, Business Management I and II, and Human Resources. All of them, belonging to the line of “Business Management”, within the Industrial Engineering Program. Once the methodology was selected (CBL), the next step in building-up the model was to define the areas for which challenges could be designed. Those were identified through expert consultation and documental analysis. For this purpose, and given that the challenges must address a real social problem, as a source of information, the following documents were considered: The global sustainable development goals Plan (UN, 2018), The Santander (Colombia) Development Action Plan (Plan de Desarrollo Departamental 2016) and the Future of Jobs (World Economic Forum 2016). Also, various interviews with: government advisors, regional entrepreneurs, and the Executive Director of the Cluster of Information Technology Industries of Santander - Colombia, were considered as a reference in order to identify the challenge’s subject. Main findings related to work with experts is shown in Table 2. Interviews were held on a semi-structured basis, and they lasted 1 hour on average. The questions included: (a) In the current context, what is your opinion regarding the competences of young engineers? Do they match the market needs? (b) As things are now, do you think business collaboration within industries and universities to create larger pools of skilled talent is important? (c) Considering that there is a need for more talent in certain job categories, and, that this is accompanied by high skills instability across all job categories, how do you think business, government and individuals may react to these challenges? (d) Within an academic semester, what would a challenge be for a group of students trying to face up this threats?

By applying a systematic analysis of the aforementioned information, five challenges were identified. They were prioritized taking into account the following criteria: 1). Significance: related to the number of courses whose knowledge could be linked to the challenge; 2). Cross-cutting issues, that is, if a challenge was proposed by more than one source of information; 3). Impact: that is the number of people who would benefit from a hypothetical solution; 4). Social effect: if the challenge





**Table 2. Semi-structured interviews with experts.**

Type of stakeholder	Name	Sector	Main findings
Government advisor	Sergio Cajías	Mayor’s Office advisory team	Engineers must assume a proactive approach to their own learning. Governments are called to create the enabling environment to assist these efforts. The challenge should be related to items included in our Regional development Plan. Communications issues
Regional entrepreneurs	Jose Gabriel	Metal and mechanics	Business collaboration within industries to create larger pools of skilled talent is crucial.
	Jaimés Román		Multi-sector skilling partnerships are needed.
	Juanita Rueda	Health	Collaborative models that underpin many of the technology-driven business changes are also needed.
	Henry Torres	Services	The challenge would necessarily contain diverse elements of knowledge that an Industrial Engineer must know: Ex.: optimization processes, human relationships, management, etc.
	Odilia Sanabria	Social Services	A social challenge must be face up. Homeless people should be targeted. Managerial aspects of SMEs could also be considered as a challenge. A challenge related to environmental regulations for car washing was also proposed.
IT Cluster Executive Director	Néstor Santos Nova	Information Technologies - IT	Better data and metrics are important in helping to anticipate the current transition in labour markets. The challenge would be focused on a mixture of technical competences and non-technical ones. The challenge could be related to “empresas madre” enterprise. A social challenge must be face up. Homeless people should be targeted.
University representatives	Juan Camilo Lezmes Peralta	University professors	A systemic view of the firm is needed. Engineers need to integrate knowledge from various subjects to helping in support decisions. Technical skills are nevertheless important.
	Luis Eduardo Bautista		A social challenge must be face up. Homeless people should be targeted. World Economic Forum guidelines must be followed. The challenge could be related to “empresas madre” enterprise.

itself deals with a vulnerable population or victims of the conflict; and 5). Context: evaluated the degree to which the problem was related to the students’ life.

The matrix of ideas’ prioritization is presented in Table 3. A Likert scale from 1 to 5 was used. A grade of 5 is the highest prioritization value. In the case of Scope, for example, a value of 5, means that the challenge involves knowledge of the four courses related to the project, and therefore, greater interest for its execution. This prioritization was performed by a focus group of professors, industry experts and undergraduate students of Industrial Engineering. The technical summary of focus group is shown in Table 4.

As it is seen in Table 3, the challenges with the highest priority were associated with the homeless people. Based on this prioritization, a new focus group was created. This time, the group of experts added a problem related to the Industrial University of Santander. This University is 70 years old, has around 16,000 students, 31 undergraduate programs, 33 master’s degrees, 29 specializations

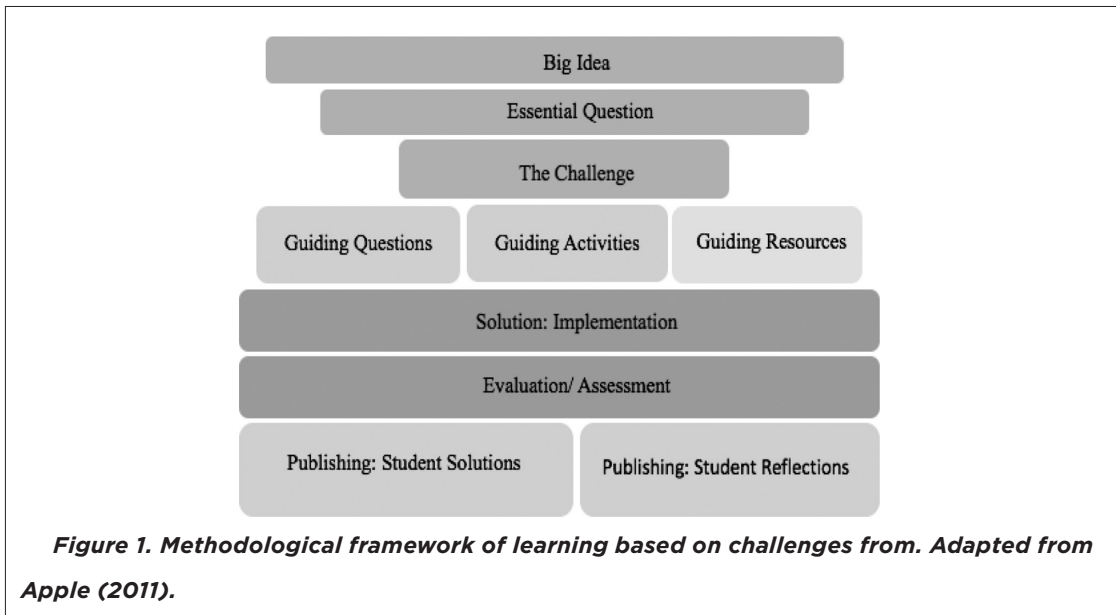
**Table 3. Proposed challenges for the project.**

Criteria/Challenge	Significance	Cross-cutting issues	Impact	Social effect	Context	Total
Regional Government – Communication issues	3	1	4	1	5	2,8
Mayor's office - Empresas Madre	5	2	2	3	4	3,2
Sustainable development goals – Homeless people	5	4	4	5	5	4,6
Regional Development Plan - Homeless people	5	4	4	5	5	4,6
SMEs (small and medium enterprizes) – Strategic Management issues	4	1	3	1	3	2,4
Environmental regulations for car washing	5	1	1	1	2	2

and 6 doctorates. It also has a main campus and 4 regional headquarters geographically distributed throughout the region of Santander. This gives an idea of its academic, social and economic impact in the region and this was the reason this new challenge was added.

Based on these results, the project team decided to work on the challenge related to homeless people. The next step in building-up the model was the design of the challenges. This was made using the CBL methodology of Apple, documented by the Technological Institute of Monterrey (Garza Sada, 2016). According to this methodology, a series of steps must be followed to design each new challenge, as shown in Table 3. According to the methodology, the first step is to choose a broad problem (big idea), that can be explored in multiple ways. This problem has to be attractive to students and relevant for society. From this big idea, the students are called to generate an essential question that better describe the idea. From this essential question, a challenge must be created by means of guiding questions, activities, and resources. Then, the students themselves create a concrete and meaningful solution based on previously acquired knowledge. This is how an innovative and realistic solution is developed. Each challenge will be broad enough to allow a variety of solutions. Afterwards, students have to prepare an action plan to effectively implement the solution.

Once this phase is finished, both the process and the solution itself must be evaluated by professors and students together during a validation phase. This must be performed using qualitative and quantitative methods which include surveys, interviews, and videos related to the work performed with homeless people using the CBL methodology. From the conception of our model, the resources generated (videos, documents, etc.) are expected to become a learning portfolio for different universities interested in replicating this project on their courses. It is important to highlight at this point, that great part of the deep learning indeed, takes place when one reflects on the own



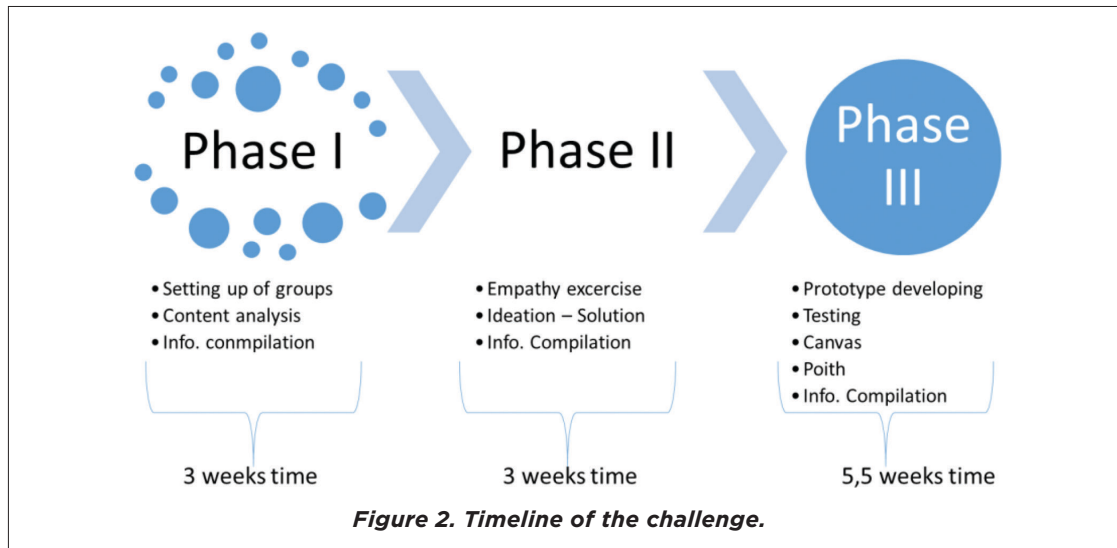
learning, on the relationships between the content, the concepts and the experience by means of the interaction with different agents of the society (Sada, 2016).

The model we proposed is focused on the initial phases of the methodology as shown in Figure 1:

1. Big idea, which resulted from the documentary analysis, and the interaction with actors linked to the university;
2. The essential question for the challenge of “homeless people” was defined taking into account that (a) the solutions to the challenge must involve the concepts and / or objective competences

**Table 4. Technical summary for focus group.**

<b>Number of participants</b>	7	
Name / area of interest of each	Isabella Villamizar Ariza	Graduated Engineer
	Ana Milena Paez Quintero	Graduated Engineer
	Andrés Aparicio	Engineering student
	Mileidy Alvarez	Business Administration professional
	Eduardo Osorio	Engineer – entrepreneur
	Martha de Torres	Entrepreneur
	Yovany Mateus	Economist – entrepreneur
Number of focus groups sessions performed	3	
Duration of each session	1,5 hours on average	
Tools used:	Matrix of prioritization Their preferences were consolidated using an excel file Consensus were reached among participants	



of each subject; (b) the solution proposed by the students must be feasible, and (c) the scope of the challenge included a proposal of a solution. In this exercise the essential question set was: What specific business model proposal you suggest for the homeless people?

3. The proposed challenge was: to set up a business model for a company that will provide either health services, education or food security for the homeless people living in the metropolitan area of Bucaramanga.
4. Nine guiding questions were defined, one for each canvas building block (Osterwalder and Pygneur, 2011).
5. The guiding activities were based on the need to bring students closer to their context, to their city and its needs. At this point, a 3-stages timeline was proposed (Figure 2). The first stage, of documentary analysis, had the purpose to better understand the situation of homeless people, and identify a target group to work with. The second stage included the proposal of a business model for this target group, using the canvas model. This proposal should be based on empathy exercises with people from the target group. Finally, the students have to validate the proposed business model with their target groups. Each of these three phases were going to be monitored by the group of teachers in charge of the project, and the students had specific responsibilities and deliverables to provide at each stage. The last deliverable includes the reviewed canvas, once it has been discussed with the target group and modified, if necessary. Another important deliverable is a video, the students had to produce, in which they explained how the learning process was, the good practices and the lessons learned. The summary of the proposed activities and their associated deliverables is shown in Table 5, and the taxonomy of participants is shown in Table 6.



**Table 5. Activities to be performed during the project.**

Phase	Activity (A) Deliverables (D)	Requisites / deliverables	Duration (weeks)	Tools
1	<b>A1.</b> Setting up of groups	The group must have a member of each subject, making a total of 4 students.	1	LMS: Virtual Room in Moodle to help students in building up the groups
	<b>A2.</b> Context Analysis of the challenge	<ul style="list-style-type: none"> <li>– Define the target population</li> <li>– Evaluate the problem</li> <li>– Evidence of participation in the virtual forum</li> </ul>	1	Technical and strategic documents uploaded in Moodle (LMS) Access to the university’s digital library Priorization matriz
	<b>D1.</b> Compilation of A1 & A2	Document with names of the members of the group, the target population, the problems to be addressed and evidence of participation in the forum.	1	
2	<b>A3.</b> Exercise of empathy with homeless people	Approach to the population (Taking into account the permission of the person to carry out any action).	1	Local NGOs to help the students contact the homeless Business Canvas Model Video recording tools
	<b>A4.</b> Ideation-solution process	Represent the possible solution on a canvas.	1	
	<b>D2.</b> Compilation of A3 & A4	Document with the description and evidences of the approaching process to the targeted population.	1	Stationary to draw the prototype and present it to homeless
3	<b>A5.</b> Prototype development and testing	Prototype of the solution of the challenge, using a creative format chosen by the student Prototype testing.	2	Test-Bank built up during the Project. Local NGOs advised students in their activities
	<b>A6.</b> Setting of canvas	If changes in the business model arise, while prototyping and testing process, the respective adjustments to the initial canvas are made.	1	
	<b>A7.</b> Pitch Preparation	Production of a video in which the students introduce their final business idea.	0,5	Video edition software
	<b>D3.</b> Compilation of A5, A6 & A7	Document with prototyping test material and the test of the final solution, the adjusted canvas and the Pitch video as an annex.	2	

**Table 6. Taxonomy of students taking part of the study.**

Subject	Semester within the Program of study	Number of Students	Male	Female
Human Resources	8 <sup>th</sup> (4 <sup>th</sup> year)	57	17	40
Entrepreneurship	8 <sup>th</sup> (4 <sup>th</sup> year)	32	15	17
Business Management I	7 <sup>th</sup> (3 <sup>rd</sup> year)	42	19	23
Business Management II	8 <sup>th</sup> (4 <sup>th</sup> year)	55	20	35
<b>Total</b>		186	71	115



6. The guiding resources refers to documentation such as the worlds' Sustainable Development Goals document, Official Regional Development Plans and some papers related to assessment of the homeless people in Colombia. Likewise, the guiding resources included bibliographic material related to the canvas model. All these documents were uploaded to the LMS (Learning Management System) platform (Moodle), where teachers also have the opportunity to enhance information during the semester, by means of the developing of the project itself. This model implies linking students of different courses and different subjects. Each group has to be formed by at least one student from each course. Considering this complexity level, the use of IT (Information Technology), and more precisely, the LMS platform, will allow a continuous communication among the students and the teachers. Every single document or teaching material related to the challenges is being uploaded to the LMS, for the students to know it and use it in the solution of the challenge.

At this stage and industrial designer joined the project. He worked on the man - machine interface for the virtual classroom. As a result of this joint work, the interface includes now a virtual character called: "Antonio". Antonio was design as an element that helps students to understand the context and brings them closer to reality by easily resembling the idea being addressed. This character would represent the central place in the challenge. Antonio will be characterizing a homeless person, dressed and customized as such, and he will be virtually presenting the challenge to the students. The industrial designer was decisive in all this process since he laid the foundations for a good student experience with the platform through a creative graphic interface that would facilitate the interaction of the users with the virtual classroom. (1&1 Digital Guide 2017).

Regarding the actual conditions of homeless people in the city, it is important to highlight that the National Court indicated that this population "requires urgent and comprehensive actions, given the special situation of vulnerability and marginality in which they find themselves, as well as the massive violation of rights to which they are subject. The mere fact of not having a home result in the serious and continuing impact of various fundamental rights". In 2017 the mayor's office of this city estimated that there are around 3212 homeless persons in the city. An alarming figure that socially and economically affects this capital city (Pineda 2017), -some data reveals that 21.5% of homeless people have been in this situation for 11 to 20 years, 8% have been between 21 and 30 years old, while 4% have lived in extreme poverty for more than 30 years. Regarding the age range, people between 30 and 41 years old are the most numerous group with 970 identified individuals. In addition, there are more than 116 people in homeless situation with more than 80 years of age (Blu Radio 2017). Given this context, the challenge could eventually contribute to the solution of this already identified problem.

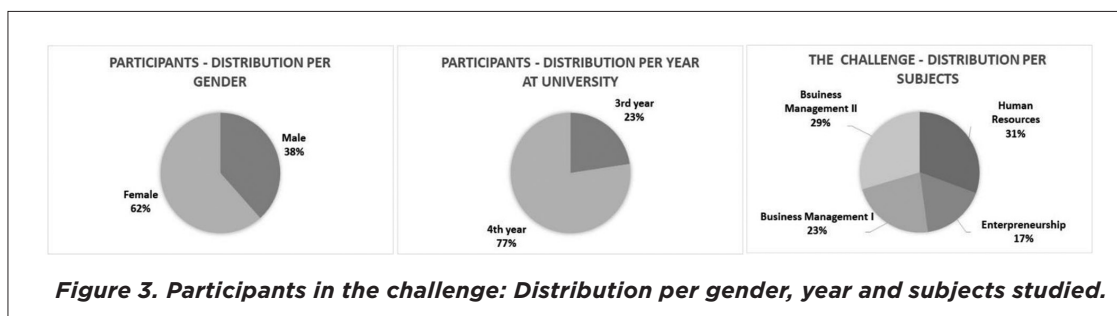


This concrete challenge is being carried out in 3 phases (see Table 3). The students were required with solutions that imply not only the use and appropriation of technical knowledge acquired during the technical training received in the 4 subjects involved in the project, but also solutions generated from their non-technical skills, such as empathy, communication skills, argumentation, negotiation, and teamwork.

As of that moment, the teachers started the process with their students. The objective was to form groups with students from the 4 different subjects, with the purpose of integrating knowledge in the solution of the challenge, and, developing technical competencies, while promoting some non-technical ones. This would allow to cooperate with peers, reinforce communication skills (since there are students with whom they have probably never talked before), and to strengthen leadership and decision-making functions, among others. An additional incentive was set by the group of teachers, who agreed to work together to assign a percentage of their grade in each semester subject, to the execution of the project. Another remarkable aspect of this project was to succeed in joining together four university teachers from the same line of knowledge, not only around the academic exercise itself, but also around a way to contribute to a real problem of this city. This was the first milestone achieved as a project.

Once the model was set, the kick-off meeting of the project took place, and every student participating in the project was summoned. The group of professors explained the purpose of the challenge and the project officially started. The participants were mainly females (61%), and were mostly within their 4<sup>th</sup> year of university (see Figure 3).

In the first phase, each group of students had to establish their target population to work with for the rest of the project. They had to analyze the factors affecting the targeted homeless people, and, they had to participate in the forum through the LMS, at the virtual classroom. The aim of the forum exercise was to express the students' concerns related to the project and receive some feedback by the side of teachers. Once the forum was closed, the students had to formally deliver a document containing: their final target population, the situation or problem to be addressed with them, and some evidence regarding their participation in the aforementioned forum.





At this point of the project, the students have to make an approach to the target group, in order to know in a more detailed way, the current situation and to provide the Project with documentary evidence about their work. The target group have to be interviewed through non formal questionnaires. Recordings and images will also be saved in order to document the process.

An important issue to highlight is that the business model that that had to be created by the groups of students must be self-sustainable and provide a well-being status to the target group, by complaining basic needs such as health, food and housing. In the final phase, each group have to elaborate a video in which they present this experience and the learning reached through this challenge. Finally, they will deliver a document containing graphic material of the tests carried out, the adjusted Canvas solution, the learning experience video and some extra annexes. Along the time-line of the challenge, the students may use different tools to support the activities. The model includes a list of available tools that support students in performing the challenge. The tools are shown in last column of Table 5.

Concerning the length of the challenge, it is designed to last at least 12 weeks. A time line of the challenge y shown in Figure 2. Most universities in Colombia split the academic year into two semesters each, being each semester 16 weeks long. With a model like the one proposed in this project, teachers will have the opportunity of working in this exercise of Challenge Based Learning during the whole semester. As professors and experienced industry practitioners, we truly believe that the relevance of non-technical competences or soft skills on future engineers is so high as to consider devoting the necessary time to grow them up in our students.

## **RESULTS**

Once the challenge began, the groups of students used the Virtual Room in Moodle, and started the work through its three phases. They had the assistance and support of “Antonio”, the virtual character created for this challenge. We have to say that at the very beginning, the students did not wanted to work with someone that was not their “usual” partner. They felt uncomfortable with the idea of working together with peers that were not familiar to each other. They were also interested on the academic reward linked to this challenge (something that each teacher solved in their class). These feelings although, were quickly replaced by new ones in which the challenge itself was the central issue. Students got the assistance of various NGOs to approach the homeless people. When this started to happen, the groups were more and more engaged with the challenge, since the inclusion of the homeless people is an issue very close to the community. There are many individuals in a poverty situation all around the city, but also, surrounding the university, making this topic more





***Image 1. A group of students working together in the solution of a challenge.***

relevant and evident for the students. On images 1 to 3 the reader could find shots related to the worked performed.

Prototypes created by students were totally unexpected, and useful, but, this paper is not about the prototypes and the solutions proposed themselves, this paper is about a model that allows the integration of knowledge from various areas. This paper is about using capabilities as oral expression, communication, resource management, leadership and problem solving, altogether in the resolution of a social challenge. Engineering students learnt, by means of this exercise, not



***Image 2. Some students talking to a homeless inhabitant.***



**Image 3. Some homeless that participate in the challenges with students.**

only to integrate knowledge from various areas, but also to help real people using their knowledge as engineers. Proposed solutions were shared with homeless through the NGOs, and, some of them have the potential to be implemented among this communities. At the end of the challenge the students had to include their main findings in a video they did themselves. The teachers also asked the students to include their perceptions within the video, using a free format, it means: they could explain whatever they wanted in the video, keeping respect and good manners. Results are shown in Table 7.

**Table 7. Students assessment about the project.**

Number of students involved in the challenge	186
Number of working groups	30
Groups that felt uncomfortable with the initial idea of working with unknown peers, but changed their mind as the challenge started.	12
Groups that did not like the idea of working with homeless people.	3
Groups that felt they helped someone and thought engineering is really useful.	22
Groups that, after finishing the challenge, clearly express in the video that social competences are useful and part of lifelong learning	30
Students that stayed working with an NGO linked to the project, no matter the challenge has ended.	5



## CONCLUSIONS AND FUTURE WORK

This paper presents a proposal to apply the challenge-based learning on a real environment, having the homeless people of Bucaramanga as a target group. The idea of implementing this challenge at the Industrial University of Santander was born from the need for an urgent and comprehensive action regarding the soft skills demanded for the 21<sup>st</sup> century among young engineers.

A group of teachers of this university joined together to propose a model in which the engineering students may get involved through a challenge-based environment, in the solution of a real problem. The homeless people of the city was chosen by a pool of experts, as the challenge. The situation of vulnerability and marginality in which homeless find themselves, as well as the massive violation of the rights of which they are subjected make the challenge more relevant, and the project team, including the students, understood the homeless people deserve to be treated based on the principles of human dignity, personal autonomy, social participation and solidarity.

The first part of the challenge deals with the identification, by the side of the students, of the situations that generated the particular conditions of the targeted group, such as interfamily violence, extreme poverty, armed conflict, unemployment, drug consumption, among others. The second part of the challenge involved the proposal of a sustainable business model that tackles their specific needs. All the exercise was widely supported by information technologies, in accordance with the global trends, and supervised by the research team which includes 4 university teachers of the industrial engineering program and the support of GALEA-Lab.

The proposal of this challenge-based learning model arises from a technical school of a university that has historically been recognized as a very technical one, graduating outstanding engineers with exceptional mathematical and logical skills, well prepared to make appropriate use of the IT tools necessary for accurate performance in each area of knowledge at the workplace. The proposal although, is intended to mostly reinforce the non-technical skills by means of an exercise that will challenge their ability to communicate ideas, to feel empathy for less fortunate people that surrounds the university itself and, that will be benefited by the support these students will be able to give them.

The proposed model is being applied at the university since 2018 and their first results were documented in this paper. Considering the scale and significance of the work, the results shown here involve only the model and an initial validation of it. In a future detailed report, the researchers will provide evidence of the content of prototypes created. Future work also include to record new exercises based on this challenge, as well as new challenges created by means of the model proposed here. As a research team, and according to the validation of the model made through this first exercise, we truly believe that despite of the technical skills a university engineering student is being trained for, they lack of transversal competencies that could allow them to carry out the



engineering work in different environments is of a high relevance. We also believe that the soft skills are beyond the technical knowledge. The emotional intelligence, the understanding of the person's needs, the ability to stand up for an idea, the communication skills, among others, can be reinforced through learning based on challenges, as we proposed in this model.

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