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ORIGINAL PAPER

poCDIO: A Methodological Proposal for Promoting Active Participation in Social Engineering Projects

Janneth Arias[1] · María Catalina Ramírez[2] · Diana María Duarte[3] · María Paula Flórez[2] · Juan Pablo Sanabria[4]

Abstract Currently, both public and private organizations, as well as the academic milieu are developing social projects in order to strengthen and improve the quality of life. This is the case of Engineers Without Borders Colombia (ISFCOL for its Spanish acronym), an organization formed by engineering teachers and students from Los Andes University and the Minuto de Dios University Corporation that develops engineering projects within communities in order to solve environmental and social problems. However, based in the group's experience, a problem has been identified regarding the absence of a methodology that promotes the active and effective participation of all the parties involved, which can prevent the accomplishment of otherwise technically viable, socially responsible, and sustainable projects. Looking to address this issue, this paper presents a methodological proposal for promoting the active participation of all the parties involved in engineering projects that have a social impact. The proposal is structured following the stages of the oCDIO context (Observe, Conceive, Design, Implement and Operate), and is successfully applied during the development of an ISFCOL project in which the participation of all the parties involved becomes a key element for the effective accomplishment of the engineering proposal and for the generation of socially responsible impacts. Namely, the project "Fortalecimiento Negocios Verdes Comunitarios Provincia del Guavio" (Community Green Businesses Strengthening in the Guavio Province) whose main goal was to strengthen the innovation and the entrepreneurship in the Guavio region communities, consolidating thus an active participation network of 400 members made up by small entrepreneurs and students from rural communities close to the city of Bogota and from higher education institutions.

✉ Juan Pablo Sanabria
jps150@hotmail.com

[1] Centro de Educación para el Desarrollo, Corporación Universitaria Minuto de Dios, Bogotá, Colombia

[2] Industrial Engineering Department, Universidad de los Andes, Bogotá, Colombia

[3] Distancia Cero, Bogotá, Colombia

[4] Universidad de los Andes, Bogotá, Colombia

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Introduction

Several impoverished regions in Colombia suffer from problems related to lack of public utilities and services, such as water and electricity supply networks. This problem persists, among other reasons, because of an absence of potentially viable projects to solve it. Presently, the Colombian society has enormous social differences; this scenario however allows development opportunities to emerge from diverse sources. This is the context in which was created Engineers Without Borders Colombia (ISFCOL) thanks to an alliance between the University of Los Andes, the Minuto de Dios University Corporation and vulnerable communities (both rural and urban). The group, composed by several professionals, students, and teachers from the engineering and social fields, seeks to generate an impact, through the coalescence of technical, scientific and social knowledge, in order to contribute to the development of projects with communities looking to solve environmental and social problems. The strategy of the group has been to identify regional vulnerability conditions and active participation strategies that provide interdisciplinary work spaces in order to design and implement solutions according with the below criteria:

1. Aim to optimize the economic, human and environmental resources.
2. Justify their viability from a social and a technical point of view.
3. Contemplate the environmental effects they will generate, keeping in mind both the environmental costs and benefits.
4. Evidence the use of engineering tools.
5. Are innovative.
6. Generate a social impact, that is to say that benefit and can be replicated to a large number of people.
7. Are socially inclusive, in other words that the target community participates as an active, reflective and critical actor in all the stages of the project.

Based on this, the group has identified the active participation of all relevant parties as a key factor for the development of knowledge, skills, and resources required for a successful fulfillment of the criteria. Hence, throughout this paper the group establishes a process of self-evaluation and learning based on some of its experiences in order to highlight participation as a crucial element in the development of engineering solutions. This process allows us to configure a methodology that regards participation as a fundamental axis in social engineering projects and that will be evaluated afterwards through a successful application case.

Accordingly, the structure of this paper is as follows: (1) A theoretical framework is presented, explaining the notion of 'engineering project', describing the context oCDIO and examining the concept of participation, focusing in the active participation; (2) Some of the projects carried out by the ISFCOL are presented as study cases; (3) The study cases are evaluated using the theoretical framework proposed and the participative component factor; (4) The methodological proposal poCDIO is presented, which promotes the active participation of all the parties involved in social engineering projects; (5) The Community Green Businesses Strengthening in the Guavio Province project, which uses the poCDIO methodology, is presented; (6) A flow matrix for the parties involved is proposed for the

application case; (7) Finally, the main learnings and conclusions from the application are presented, as well as some suggestions for future works.

Theoretical Framework

Before presenting a methodology that promotes active participation in engineering projects, it's important to detail in depth what we understand by 'active participation' and 'engineering projects' (Aslaksen 2013), as well as the relation between these terms. Below we define these concepts and explain the methodology oCDIO, which is pivotal in the proposal presented in this paper.

Engineering Projects

An engineering project is a "cyclic and unique activity for making decisions (Halin and Shengnan 2012), in which the knowledge of engineering science basis, the mathematical ability and experimentation combine themselves in order to be able to transform the natural resources in mechanisms and systems that meet the human needs" (Corzo 1990). Based on the above, en engineering project seeks to evaluate the viability of undertaking a proposed task, following a series of stages, each of which follows a systematic order and is a part of the different steps that must be carried out in order to achieve the expected results (Munier 2014).

Krick (1988) defines seven stages for any engineering Project. The initial three stages constituting what he calls the primary cycle, and the remaining ones the cycle of consumption-production as it is shown in Fig. 1.

There are two types of engineering projects: by evolution and by innovation. The former prevailed in the beginnings of Engineering, due to the relatively small demand for technology; it consists in the progressive evolution of a system after its establishment through sustained improvements until the desired level was attained. The innovation project has its origins in a previous study of the market needs, but it is not solely based on them, the engineers have a special sensibility that allows them to foresee the future needs of the human being and therefore they project with an idea already in their minds.

Ocdio Framework

This methodological framework defined as Conception-Design-Implement-Operate (CDIO) has been developed by researchers from various engineering schools. In this framework, a group of researchers has added the observation phase (Ramírez et al. 2011).

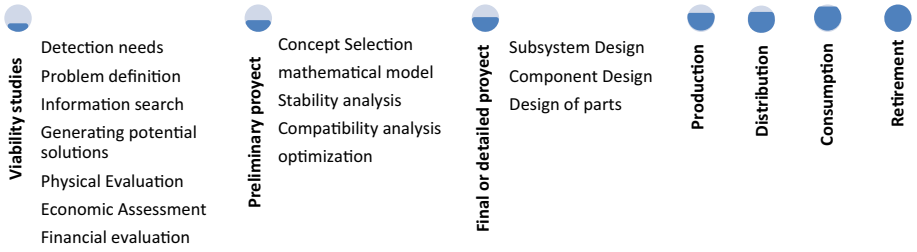

Fig. 1 Stages for an engineering project

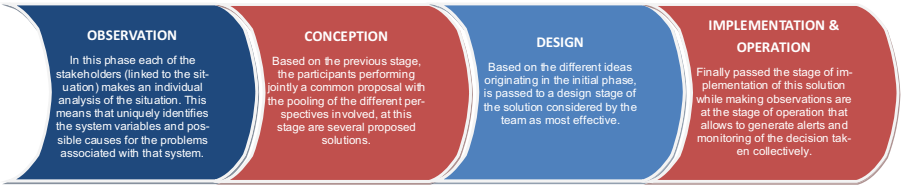

Fig. 2 O + CDIO Model

Based on the conceptual framework of Observation-Conception-Design-Implementation-Operation is to collectively build the analysis of a complex situation and proposed solutions to it. In this context is made the development of the engineering projects with the innovation context that was mentioned before. Figure 2 is a description of each of the phases of this framework:

Participation

According to the World Bank (2010) participation can be understood as a "a process that allows the participants involved to influence and take control over their own initiatives, decisions and the resources that concerns them" (Mohanty and Tandon 2010). The Food and Agriculture Organization of the United Nations defines it as: "a process through which all the members of a community or organization become involved and can influence the decisions related to the activities being developed that concerns them" (Food and Agriculture Organization of the United Nations 2007). Below, we will describe each different type of participation and we explain in detail the active participation.

Types of Participation

Trilla and Novella (2001) propose four types or categories of participation: simple participation, consultative participation; project participation and meta-participation or synergic participation. Before defining each category it is important to state that even though they are qualitatively different, they are not mutually exclusive, since two or more of them can take place alternatively or in succession within a single institution, activity or project. Likewise, these types of participation apply for every population group.

Simple Participation It occurs when someone takes part in a project or activity as a spectator without having previously intervened in its preparation or in the decision making process regarding its content and development (Alhajj and Rokne 2014). The individuals restrict themselves basically to follow indications or to respond to stimuli, its simplest form consisting of *just being there or making an appearance*, which can be measured quantitatively. In this type of participation the project's responsibility is external to the participants.

Consultative Participation It consists in listening to the individuals concerned, that is to say they share their opinions and knowledge regarding the different aspects of the project that concerns them, directly or indirectly. Moreover, channels and spaces of communication are proposed (Mackenzie 1966) such as: surveys, workshops, polls, and questionnaires, among others, in order to evaluate the approval of an activity or a project, as well as to gathering and facilitating information.

In the consultative participation the questions are posed from an external point of view, for example: what do you think of this? what is your opinion regarding that? This type of participation does not delve in collective conflicts regarding the individuals or the conditions of the surroundings.

Project Participation This type of participation is more demanding that the aforementioned ones, it consists in the individuals taking part in the design, planning, preparation, management, execution, and control of the process, as well as in its evaluation. This type of participation requires the commitment and co-responsibility of all the parties involved, and throughout its development the participants make the project their own.

In this type of participation the individual becomes the agent of its own development and—just like in the consultative participation—spaces and channels of communication and participation are created and provided. However, the questions, which were posed from an external point of view in the consultative participation, are now posed from an inner perspective: What are we going to do? How are we going to do it? What are our commitments and responsibilities?

Meta-participation or Synergic Participation The participants consider that the participation and communication are not enough or that they are not effective enough; therefore they demand or generate new participation spaces and mechanisms. This type of participation includes certain "rights" (right to vote, freedom of speech, freedom of association, right to protest, right of collaborative working), and thus there is a need of spaces, means, and institutions that will guarantee these rights, such as media involvement, forums, negotiation tables, networks, participation councils, assemblies, etc.; as well as individual and collective competences in order to exercise those rights.

For this type of participation it is necessary to provide and promote in the population the abilities required for the participation such as: debating, teamwork, tolerance, and effective communication, among others.

What is Active Participation?

Active participation is defined as the consideration and acknowledgement of the opinions and inputs of the actors that are part of the collective involved. For this participation to take place the transparency of all the members is required, as well as a free and open exchange of information (The World Bank Washington, D.C. 1996).

In order to have an effectively active participation three conditions must be met: (1) Recognition of the right of the individuals to participate in the issues that modify their quality of life; (2) The technical and social capacities required to undertake these modifications; (3) The proper means, tools and spaces to make it possible (Trilla and Novella 2001).

In this regard, Cernea (1995) proposes five aspects that enable the active participation:

1. The mode of participation must be known and accepted by all the actors involved in the project. It should not represent only the interests of some parties or sectors.
2. Concrete roles and tasks must be assigned to the different participants of the project.
3. Diverse and flexible participation scenarios should be created for the persons or groups to work in the task they have been assigned.
4. Pedagogic techniques and tools should be implemented in order to promote the participation, so as to encourage the gathering of information and resources

5. The individual and collective skills have to be identified and fostered in order to generate high impact actions.

Study Cases

Engineers Without Borders Colombia (ISFCOL) was created as an alliance between the communities and the engineering schools of two Colombian universities: The Los Andes University and the Minuto de Dios University Corporation. It was established as an interdisciplinary group that seeks to generate social impact through engineering projects in vulnerable communities, that is to say that it looks for the improvement of the conditions of life of the vulnerable communities through solutions arising from the joint work of teachers, students, communities and other key actors.

Engineers Without Borders Colombia, is an organization composed by teachers, student and professionals of engineering and social disciplines, who works in alliance with the communities in order to improve the latter's quality of life through engineering projects that are economically sustainable and culturally viable. Through these projects the group intends to promote the development of engineering students and professionals, as a result of practical experiences that have a social and environmental conscience, as well as promoting the community's autonomy.

Below we will present some of the projects carried out by ISFCOL. We will make a brief description of each case and, using the framework proposed, we will make a self-evaluation of the participative component and the impact it had in the project. Thus we will identify the type of participation used in each case and analyze its pros and its contras regarding the development and the results of the projects.

Case 1: "High Quality Water in your Home" Project Mochuelo-Bajo—2010

Mochuelo Bajo is a peripheral neighborhood of Bogotá, located in the far south rural zone of the Ciudad Bolivar district, next to the Doña Juana sanitary landfill, the main landfill of Bogotá. This sanitary landfill crumbled over 10 years ago with 800 thousand tons, causing one of the worst environmental crises the city has faced. Strong odors and pest infestations became the daily suffering of communities close to the landfill, such as Mochuelo-Bajo.

Presently, the community of the Mochuelos is the most affected by the emission of polluting gases and leachates from the six thousand tons of waste that the landfill receives each day. The residents of the adjacent communities present numerous health problems, mainly gastrointestinal, skin and respiratory diseases. Besides the unpleasant odors resulting from the proximity of the landfill, there is the smell of the raw sewage that runs through ditches on both sides of the streets. The drinkable water comes from a natural mountain spring, but the purification techniques are unsafe and the supply network is precarious.

"High quality wáter in your home" ("Agua de calidad para su hogar" in spanish) was a project developed in Mochuelo-Bajo. This initiative was created as an ISFCOL collective action. This project sought to identify a vulnerable scenario in Bogota that had problems regarding the quality of the drinking water, in order to address these problem through the use of simple and efficient technologies such as the production and installation of home-made sand filters for water consumption, which could improve not only the quality of the water, but also the general welfare and life conditions of the families involved in the project.

Looking for information regarding the living conditions and the unfulfilled basic needs of the Mochuelo families, some observation tours were performed and over 100 families were surveyed. Based on the results of the surveys, 20 families were selected to receive the filters. The criteria for choosing the families were: water turbidity, which was analyzed in university laboratories; precariousness of the living facilities; overcrowding conditions; and level of income. This was the context in which 15 homemade filters were produced and installed.

Finally, looking to increase the number of people that could benefit from the technology, the families that learned about the production and maintenance of the filters were asked to replicate the information to the other families. This, however, was not done successfully and generated tension and conflicts among the participating families, as can be seen in the following testimonies:

Once the project was finished, Mrs. María Gonzáles, a community leader and participant in the project, stated:

> I think that the installation of the filters divided the neighbors, not everybody knows how to build and maintain them, and the people do not share the information. Besides, there are families that were in worst sanitary conditions that the ones that participated, but were not included in the project (Interview with María González, community leader, 2010).

Mrs. Bertha Jiménez, community leader declared:

> I have not heard of the filters project occurring in my neighborhood, which makes me feel excluded. Moreover, even though the project accomplished the installation of the filters, the decision making should have been shared with all the community since any occurrence taking place in the Mochuelo-Bajo sector must be a shared responsibility (Interview with Bertha Jiménez, community leader, 2010).

In the same order of ideas, Hector García, head of a family and filter beneficiary, expressed:

> It would have been better if we had been given work or education opportunities. I consider that the filter was not urgent. Besides, in the community we have always had participation and collective unity problems; the people in charge of the project should have work harder on those aspects so as to choose better the families beneficed with the filters, or perhaps another type of project would had developed. (Interview with Hector García, head of a family, 2010).

The testimonies show that after the project was done it had a low approval rating among the community, due to possible incorrect approaches in the information given to the community, the decision making, the participation strategies implemented, and even the problem identification. Hence, the participant's perception that the project did not had an important impact in their lives.

Case 2: Quality of Water Improvement in Guayabal de Síquima-Cundinamarca, Colombia—2007

This project looked to configure a proposal for the improvement of the water quality in a rural community in the jurisdiction of the Guayabal de Síquima municipality—a rural zone 71 km away from the capital. To that end, an easy to build and maintain filter was designed, developed and implemented by the ISFCOL. Beyond the preconceived establishment of certain standard steps to be followed, the main concern of the initiative was to

Fig. 3 Engineering Students from the Torres rural community

understand the community's perspective of what was happening. The interaction with the community was based on the dialogue and the teamwork, which was complemented with by the analysis carried out in the universities laboratories. The participation was concreted methodologically in field work experiences, interactions between students, community leaders, and residents, and community workshops for reaching agreements regarding the work, the design, and the technical implementation of the technology proposed.

Besides ISFCOL, the project included additional actors: members of the Municipal Unit for Technical Agricultural Assistance—(UMATA), the Guayabal de Síquima town hall, and residents of the rural community. The research focus implemented was the OCDIO methodology [Observe-Conceive-Design-Implement-Operate] (Ramírez et al. 2011), see Fig. 3.

In the first stage of the project groups of students and teachers visited regularly the area and, along with members of the local community, observed and identified the causes for the water pollution. This stage was fundamental not only for the understanding of the problem by all the actors involved, but also for devising together the process of intervention. This happened in work meetings and workshops. Once the problem was acknowledged, the proposal to be evaluated was conceived collectively. In this phase the source of the pollution was identified as an organic nature, and therefore the solution had to tackle that problem. Given the above ISFCOL made several technological proposals.

The proposals were assessed with the community and the financial viability was examined. A crucial part of the participation in this stage of the process was the formal agreement made by the different parties regarding their respective commitments. With the information gathered in the previous stages (2), the technological solution was *designed* in the laboratories of the universities with the community. The implementation of the technology was the stage with the higher participation and integration levels. During several weeks the engineering students realized all their deficiencies and all that they could learn from the community, achieving a powerful integration between the residents of the community that had been involved throughout all the process and the new residents, who understood the value of these work alliances.

The value of the proposed solution was that every individual understood his/her need of knowledge. This allowed the accomplishment of an integrated participation by the community and the engineers. Moreover, this generated a virtuous circle in which new members joined the process in its different stages in order to contribute to the community strengthening through an appropriate technological proposal.

Case 3: Quality of Water in the Santa Isabel de Potosí rural community-Guasca—Cundinamarca, Colombia—2012

The "Quality of Water in the Santa Isabel rural community" was developed in the municipality of Guasca-Cundinamarca, which is located approximately 57 km away from Bogota. It is important to notice Santa Isabel is the rural community located the farthest away from the urban area and that due to its geographic location it has a paramo ecosystem containing the water spring which provides water for the 70 families living in the community. The project started by the end of 2012 due to the low standards of water quality perceived by the residents, who suggested as a possible hypothesis for the cause of the problem, the evident destruction of the ecosystem due to the potato crops. These perceptions were communicated to the members of the ISFCOL team. From that moment on and during a year and a half, the ISFCOL team along with the community developed a process of observation and diagnose with the purpose of designing a filtering technology that improved the quality of water.

For the decision making regarding the type of filter that should be used, a methodology was designed adapting the Syntegration model with the Analytic Hierarchy Process (AHP) which allowed the iterative introduction of socially valued criteria into a decision model that usually is restricted to technical criteria (Ramírez et al. 2014). The result was the conception of the carbon filter, as the alternative presenting the highest score when both the social and technical criteria were taken into account.

Even though the decisions of the observation and conception stages were made in a participative way, the process did not achieve in generating a high level of cohesion with the community, which hindered the global empowerment in the subsequent stages. The main reasons for this problem were the low credibility of the project among the population, due to past experiences related to the same problem, a low level of interaction and sense of belonging in the community, and a high economic and social diversity in the group of residents.

Analysis of the Study Cases

The improvement of the quality of the drinkable water is a very important issue in several regions of Colombia; hence the three engineering social projects described were related to quality and the efficient use of the essential hydrological resource. Taking into account the work developed in the different cases presented, we will carry out below an analysis from the perspective of the oCDIO, see Table 1.

In the search to provide effective solutions to a vital aspect of survival for the human beings, the researchers experience in the different projects evidence the crucial role of the participative component for the success of the projects, because its absence or mismanaging can lead to the failure of the engineering social project. Next, we will present an analysis in detail of the participation for each case.

Table 1 Analysis of the cases from the perspective of the oCDIO context

Case	Observe	Conceive	Design	Implement	Operate	Participate
Mochuelo	All the aspect of the problems were identified	A viable and feasible solution was technically defined	The technicians were mainly the ones in charge of the design	The implementation integrated the community through an initial group of families	The operation linked the community and the engineers through an initial group of families	The participation was restricted to the surveys There was not a clear procedure for integrating the user's participation and the final solution. The work being made with other members of the community was not integrated
Guayabal de Síquima	The technical and financial viability was evaluated with the community	Although there was a joint conception, the most relevant was the recognition of the knowledge contribution of all the parties involved	The design was headed by the technicians	The implementation required the adaptation of the work by all the parties involved	The operation consisted in a disciplined work by the community	There was a conscious effort to integrate different stakeholders which did not had an apparent connection to the problem
Santa Isabel	The problem situation was identified solely by the affected community	Community involvement led by the engineers	Community involvement led by the engineers	Community involvement led by the engineers	It was not effective	The real participation of the community was evidenced only in the beginning of the process. The other stages were led by the engineers and not by the community

Case 1: "High Quality Water in your Home" Project Mochuelo-Bajo—2010

The project implemented in the Mochuelo Bajo community helps to illustrate the importance of effective diagnose tools that facilitate the knowledge of the milieu and the perceived needs of the community for addressing properly the issues.

The Mochuelo case evidences that the information gathered in the survey was insufficient for the proper identification of the social problems in the Mochuelo Bajo sector. Moreover it did not identified the real needs and feelings of the community, because the inquiry was focused in the material living conditions of the families: facilities, income and public services (or lack thereof); neglecting key aspects such as social relations, conflicts and tension among the neighbors, traditional knowledge and know-how, spaces and forms of communication/participation, aspects which were relevant for knowing the context in which the technical and social intervention would be effectuated.

The project carried out in Mochuelo was successful from an operative and instrumental point of view, as the installation and functionality goals were reached within the time limits projected. Nevertheless the participative component was not handled appropriately, as the community did not take part in the making of the decisions, there were not enough spaces provided for the families to express their opinions on the development of the project, the gathering of the information was limited to surveys, and the possible conflicts that could arise from within the community and its surroundings were not taken into consideration.

To sum up, in the Mochuelo community a consultative type of participation took place, which did not allow the active participation of the community, which can be confirmed in the testimonies presented in the last chapter.

Case 2: Quality of Water Improvement in Guayabal de Síquima-Cundinamarca, Colombia—2007

The project implemented in the municipality of Guayabal de Síquima achieved in its design and execution several important aspects regarding the issue of participation. Firstly, it identified relevant social actors for the execution of the project such as: peasant leaders and territorial organizations like the local town hall and the Municipal Unit for Technical Agricultural Assistance—(UMATA). Secondly, there was an exchange between the technical-professional knowledge and the traditional knowledge, know-how and experiences of the community, which was essential for the residents because it allowed them to perceive themselves as important actors in the process, and not only as mere spectators or simple beneficiaries; which resulted in a high sense of belonging regarding the project. Thirdly, several spaces for participation were generated such as: discussion and information tables, focus groups, and meetings; likewise, diverse techniques for encouraging participation were implemented (workshops, interviews, etc.) which were fundamental in the identification of the potentialities and weaknesses of the community. Taking the above into account, the participation developed during the project can be classified as project participation.

Case 3: Quality of Water in the Santa Isabel de Potosí rural community-Guasca—Cundinamarca, Colombia—2012

The project implemented in the Santa Isabel rural community showed that the diagnoses are essential in the work with the communities because they are an indispensable input for

designing and implementing projects with a social impact, however if too much time is employed in their elaboration, there is the risk of demotivation as the persons may consider that their participation in the project is limited to being sources of information.

On the other hand, this project was fundamental for confirming that the identification of the problems in a given community can be achieved in two ways: in the first one external agents detect the problems and decide to intervene, in the second one the community itself identify its own problems and look for the solutions. The project implemented in the Santa Isabel rural community is an example of the latter, as it was the community itself that perceived that the water pollution was due to the destruction of the paramo ecosystem, and tried to look for solutions on their own, but their efforts were not enough and they arrived to the conclusion that they needed to combine their know-how with other types of knowledge, which is why they sought the support of the IFSCOL.

Even though the team of engineers could perform a good diagnosis of the zone, and conceived the carbon filter as the best solution given the social and technical criteria (Ramírez et al. 2014), it could not solve the problem of the quality of the water because the cohesion and empowerment required were not generated in the design and implementation stages.

The experience in the Santa Isabel de Potosí rural community shows that projects of a social nature can employ multiple efforts in the observation and conception stages that, although relevant, do not transcend due to the slow level of progression and lack of evident results of these stages in the eyes of the community, and the subsequent negative effects in their participation. This situation was intensified in the present case due to the small amount of resources which reduced considerably the levels of visibility of the process, and the low density of the population of the rural community, resulting in sustained difficulties for establishing a constant relation between the community and the activities that were taking place.

Even though the process of observation and conception was designed, from the methodological point of view, to establish a project type participation, in view of the results concerning the empowering and transcendence of the firsts stages, the final participation of the project must be regarded merely as of a consultative nature.

Methodological Proposal

Based on what has been presented in the previous chapters, it can be said that it is important that the forms of participation are clear and actively managed throughout the project in order to guarantee the means for all the actors involved in the project to be able to align their action and efforts towards the same goal. Hence the importance of proposing a methodology that promotes active participation.

Below, we propose, from an engineering and social work perspective, a methodology that promotes active participation integrated into each stage of the oCDIO methodology (see Fig. 4). It is an innovative methodology since it is the result of field work experience and interdisciplinary work made by the ISFCOL. The methodology is explained in detail in the Table 2.

Even though the methodology shows the stages in a systematic way, these stages are not linear since the methodology is flexible as the person implementing it can alternate the stages, unify them if pertinent, and fulfill them gradually in different moments.

As a complement to the methodology we propose a working tool that we call participation flow matrix that stimulates the methodology itself and permits evaluating the

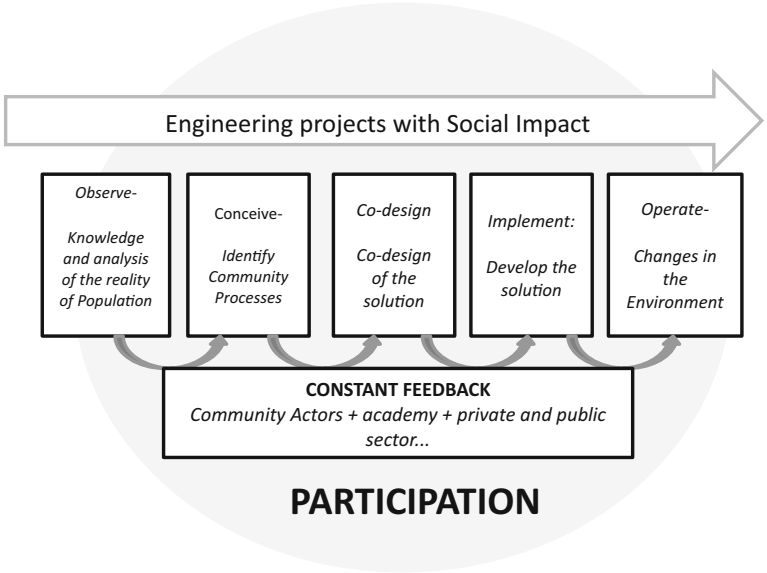

Fig. 4 pOCDIO Methodology

participation level of each stage of the project, as well as assessing globally the participative component. Given its importance it has been implemented for the application case.

Participation Flow Matrix

The participation flow matrix is a dynamic and flexible tool that permits the evaluation of the level of participation for each stage of the project, and the global level of participation once the project is completed.

Utility of the Matrix

1. It is a graphic scenario that promotes the integration of technical, scientific and social knowledge.
2. It facilitates the identification, monitoring, and control of the different actors.
3. It allows a quick identification of the role of the actors and their level of fulfillment.
4. It permits the establishment of the level of participation of each actor for each of the project stages.

Functionality of the Matrix

The matrix is based in the traffic light method. Whereas the traditional traffic light must "control the transit of vehicles and pedestrians ensuring their security", the flow matrix has the function of evidencing the transit of the different actors during the stages of a project to achieve its success.

The matriz is an analogy of traffic light. To each color of the traffic light a set of criteria is assigned, and a score is given according to the participation of the actors in the

Table 2 Relation between participation stages and oCDIO methodology stages

poCDIO stage	oCDIO stage	Participation stage	Description
p + o	Observe	Understanding and analysis of the community reality	From an engineering point of view, the observation consists in the knowledge of the surroundings and the context in which the project will take place. Concrete evidences are required such as: indexes, situations, knowledge of the problem From a social point of view, this entails approaching the history and evolution of the community, its demographic structure, its labor and production system, its sociopolitical context, the dynamics of the human relations, and its social and cultural values The observation process permits identifying and approaching the real problems and needs of the communities, it also allows formulators and participants of the project to recognize themselves as cultural and social beings in relation to the others. It also permits identifying the collective and individual potentialities and skills of the people in the community
p + C	Conceive	Identification of the community processes	From an engineering perspective the conception consists in the process, after obtaining evidences of the variables and their relations, of identifying different solution alternatives. Furthermore, the scope and the objectives of the project are established. It is important to answer the questions what is the project for? who is it for? not only from the viewpoint of the formulators, but also from that of the community From the social perspective, the intention is to promote the collective and individual potentialities of the stakeholders, to identify production profiles, and high performance teams are assembled. The roles and commitments for the development of the project are assigned
p + D	Design	Co-design of the solution	Engineering wise, designing consists in creating a solution alternative that is regarded as adequate From the social point of view, the objective is the creation of spaces for communication and debate, where the project participants perceive an atmosphere open to the exchange of ideas. Spaces of participation are created, that is spaces where the knowledge, the interests and the different resources are transformed in innovative designs and actions that provide creative solutions
p + I	Implement	Launch	Implementing, from an engineering standpoint, involves putting into action the design, evaluating it, and, if needed, redesigning Launching the ideas and designs, from the social perspective, entails the recognition of the responsibility of the project, which leads to questioning how will the design and implementation of the project benefit or affect the welfare of the communities? Properly addressing this question generates a working environment of transparency and social responsibility. Activities that contribute to the solution and that answer to the co-design previously established

Table 2 continued

poCDIO stage	oCDIO stage	Participation stage	Description
p + O	Operate	*Transformation of the surroundings*	From the engineering point of view, operating consists in monitoring the implementation to verify if the problem initially identified is being solved From the social perspective, the accomplishment of the project's objectives is pondered, taking into account if they were settled, accepted and approved by and with the participants. The actions are monitored, and the transformation of the surroundings and of the quality of life is assessed. This stage requires a constant supervision that assures not only that the technical solution is taking effect, but also that the co-participation in every stage has generated added value throughout the process

fulfillment of the criteria. In other words, the score will indicate the level of participation of the stakeholders for each stage of the project, and the final level of participation once the intervention is completed.

The criteria and scores taken into account for the matrix are as follows:

(Green)—The stakeholders participate actively in the making of the decisions and the roles and commitments are satisfactorily fulfilled. (High) Score: 3
(Yellow)—The stakeholders are involved in the project, they assume their roles and commitments but their fulfillment level is sporadic. (Medium) Score: 2
(Red)—The stakeholders participate of the process as spectators, receive and provide information but do not take decisions regarding the project and do not have specific roles assigned. (Low). Score 1
(Negro)—The stakeholders do not participate of the process as spectators, nor do they receive or provide information, they do not take part in the making of the decisions regarding the project and do not have specific roles assigned. (Null). Score 0

Final level of participation according to the cumulative score obtained throughout the project.

If the cumulative score is between 10 and 12 the participation is considered to be high
If the cumulative score is between 6 and 9 the participation is considered to be medium.
If the cumulative score is between 0 and 5 the participation is considered to be low.

Below we present the case of a stakeholder (N°1) to whom certain roles (A) have been assigned, and who properly fulfilled them during every stage of the project. This results in a high final level of participation, since the final cumulative score he/she obtained is located in the upper bracket (between 10 and 12)

On the other hand, stakeholder N°2 had also certain roles (B) assigned, which he properly fulfilled during the first stage of the project, but his level of fulfillment in the subsequent stages was merely sporadic, therefore his final participation by the end of the project, according to his cumulative score (between 6 and 9) was medium. Finally, stakeholder N° 3, took part in the project assuming certain roles (C) and fulfilling them sporadically in the initial stage, and afterwards he/she stopped playing a relevant role as he/she did not continue to assume commitments or task, and therefore his final participation is considered low (between 1 and 5).

Table 3 Example of the participation flow matrix

Civilian/ institutional stakeholders	Roles of the stakeholders	Level of participation INI the project stages				
		Participation +Observe	Participation +Conceive	Participation +Design +Implement	Participation +Operate	Final participation level
Stakeholder N°1	A	3	3	3	3	12
Stakeholder N°2	B	3	2	2	2	9
Stakeholder N°3	C	2	1	1	1	5

The matrix is a simple evaluating tool, easy to understand, that allows every stakeholder to observe the transit of their tasks and responsibilities as well as their level of participation during each stage of the project, see Table 3.

Below, we present the application case for the methodology presented, which permits participation to be evidenced in terms of the social impact achieved when active participation is integrated into all the scenarios of the oCDIO methodology.

Application Case: The Community Green Businesses Strengthening in the Guavio (Cundinamarca) Province Project

The project was constituted as an initiative developed cooperatively by the academic and public sector institutions looking to strengthen the innovation and entrepreneurial capacities of the Guavio region communities in order to consolidate an integrated network with multiple participants to support the development of participative solutions for the needs of the local small businesses. The academic sphere was represented by two institutions, Engineers Without Borders Colombia and the Social Innovation Science Park. The participation from the public sector came from the Science, Technology, and Innovation Secretariat of the Cundinamarca Governor's Office, see Fig. 5. It is important to note that the project managed to align all the diverse interests, resources and capacities of the aforementioned institutions, so as to generate results with community impact, overcoming the limitations that arise when the dynamics of the Colombian academic and public sectors clash.

The project was developed in three municipalities of the Guavio Province (Guasca, Gachetá y Junín) in the Cundinamarca department, bordered to the south by Colombia's capital, Bogota. The participants were 370 students in grades ten and eleven (equivalent to juniors and seniors) from rural schools, 47 small companies from the three municipalities, and over 30 university students. In terms of its development, although the project had some previous stages during the years 2012 and 2013, it was in 2014 when the alliance between the academic and public sectors was formed and the project was fully carried out.

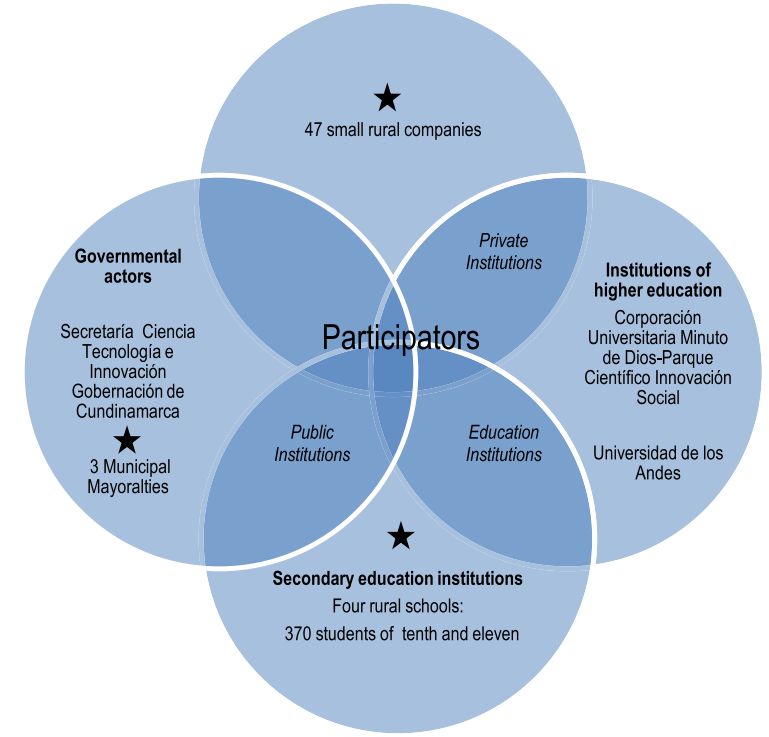

Fig. 5 Project participants

This initiative was Part of the project "Enhancing Social Innovation capacities through the Science Park in Bogotá-Cundinamarca", funded by the General System of Royalties, and developed under the Special Cooperation Agreement SCTeI No. 019 of 2013, between the Local Government of Cundinamarca and the Corporación Universitaria Minuto de Dios, and the PCIS-037-14 agreement signed with the Universidad de los Andes.

Regarding its structure, the project was constituted by three main objectives, each of which had specific products and activities. Taking the above into consideration as well as the diversity of institutions and stakeholders involved, the project stood out to be the ideal scenario for applying the poCDIO methodology, as it could guarantee the participation of all the stakeholders involved as well as the fulfillment of the project's expected goals. The application of the methodology aimed to develop in a participative way the solution ideas proposed for the needs of the small rural companies, to that end it sought to answer the following questions:

1. If all the stakeholders must participate in the design of the solution ideas, what strategies must be applied in order to enable this participation in a way that it delivers the expected objectives?
2. Taking into consideration that the solution ideas will be proposed and fully developed in the context of the project, how must the participation spaces must be designed in order for the solutions to effectively address the needs identified by the small companies?
3. What are the steps that must be taken to make the solutions consistent with the scope and resources of the project?

In this sense, the poCDIO methodology allowed the solution ideas to be structured through the observe, conceive, design and implement stages, having as a continuous and transversal variable the participation of the diverse group of stakeholders. However it must be noticed that in order to properly establish the participation in the project it was necessary to develop tools that allowed the construction of solution in a collective and concatenated way.

Below we present the detailed development of the poCDIO methodology in the context of the project. With the purpose of emphasizing the role of active participation in an engineering creative process, for each stage we will specify the type of stakeholder involved in the participation space, the tools employed, and the results that were concatenated to the next stage:

Participation + observe (P + o)

Before discussing solution ideas or the scope of the work that the project entailed, it was necessary to establish relation with all the stakeholders that were going to participate in the project. These relations were formed around the recognition of the project's scope and objectives, taking always into consideration the need to build communication tools that were relevant to the profiles and expectations of each stakeholder. Therefore several communication spaces were created such as: personalized meetings, focus groups, group encounters, in which the discourse of the project was adjusted accordingly to the perceptions of each stakeholder.

Type of stakeholder Small company (Table 4).

Type of stakeholder Schools-Students (Table 5).

Type of stakeholder University Students (Table 6).

Type of stakeholder University students, school students, small companies (Table 7).

Table 4 Participation + Observation in small company

Spaces designed for active participation	Tools employed
Personalized meetings with small companies	Document of the project presenting the small company, the scope and the objectives of the project.
	Characterization surveys
Group encounters and focus groups with small companies in each municipality	Graphic tools

Table 5 Participation + School students observation

Spaces designed for active participation	Tools employed
Personalized meetings with rural schools	Document of the project presenting the schools, the scope and the objectives of the project Characterization surveys.
Innovation workshop for rural school students to prepare them for participating in the Conceive stage	Workshop learning guides.

Table 6 Participation + University students observation

Spaces designed for active participation	Tools employed
Engineers Without Borders Colombia course "Engineering, Innovation and Green Entrepreneurship" whose objective was to prepare the university students for participating in the Conceive stage	Program and guides of the Engineers Without Borders Colombia course

Table 7 Participation + Small company, school and university students observation

Spaces designed for active participation	Tools employed
Seminar "Sustainable Entrepreneurship: Quinoa Cultivation and other Green Businesses"	Seminar structure Guides for group encounters
Space for group acknowledgement and for the observation of successful entrepreneurship cases displaying good environmental and social practices, which provides participation tools for all the stakeholders for the Conceive stage	

Results

The P + o stage lasted approximately 4 months. In it the participants successfully identified the context and the surroundings in which the project would take place. Moreover, the participants identified collective and individual skills relevant for the project, as well as several variables that allowed understanding globally the system of the developing project and the particular profiles, interest, and needs of each stakeholder.

Furthermore, in this stage were established the foundations over which were developed the commitments and responsibilities to which the institutions and individual engaged, consolidating thus the network of actors that would participate actively in the conception stage and that was composed by 370 school students, 47 small companies and over 30 university students.

Participation + Conceive (P + C)

Once the bases for the relations with the stakeholders were established, and the activities related to the collection of information and the analysis of the context were done, the conception process was carried out in the space called: "Green Solutions Laboratory", which had been designed for understanding the different roles that the different actors involved in the project were to play.

Table 8 Participation + Conceive in small companies, school and university students

Spaces designed for active participation	Tools employed	Applied methodology results
Green Solutions Laboratory	Laboratory guide	Once the collective and individual potentialities of the stakeholders were recognized, production profiles were identified, and high performance teams were assembled. Afterwards, the roles and commitments for the development of the project were assigned, which led to the community to perceive the utility of the project from their own perspective and needs

Type of stakeholder University students, school students, small companies (Table 8).

As a result of the application of the methodology, the stakeholders network conceived 10 solution ideas that emerged from the global needs of the small companies that participated.

As we will see, even though the aforementioned ideas addressed the most important common needs of the 47 small companies and the active participation of the different stakeholders, during the design and implantation stage the ideas had to be re-conceived in order to consolidate those that eventually would be made real.

Participation + Design + implement (P + D+I)

Based on the analysis of the solution ideas generated in the conception stage and on the characteristics of the project, the design and implementation stages were merged into one, in order to generate noticeable and visible results from the ideas, intending to generate with them an operation relation from the community after the project was finished.

Type of stakeholder University and school students, small companies (Table 9).

Table 9 Participation + Design in small companies, school and university students

Spaces designed for active participation	Tools employed	Applied methodology results
Participative design spaces for each solution idea	For each solution idea tools were developed for facilitating the participative work in the design and implementation	The participants successfully transformed their ideas and expectations into innovative designs and actions that generated the final proposals Also, in this stage the participants asked themselves how much would they be beneficed or affected by the development of the project, which led to the consolidation of a working environment of transparency and social responsibility
Project's closure Presentation of the solution ideas to clients and investors	Prototypes of the solution ideas	Presentation of the final solutions proposals

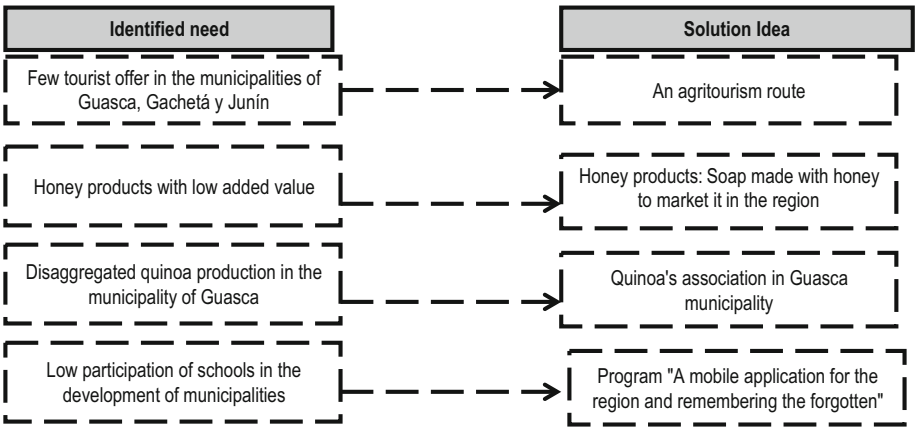

Fig. 6 Solution proposals

The implementation of the methodology, through the promotion of active participation in the different stages of the project, delivered as final results from the project the identification of the main needs of the communities and the development of prototypes of solution ideas that addressed those needs. It is important to remind that although ten solution ideas emerged from the Green Solutions Laboratory, during the design and implementation stage, that lasted for two months, the following four proposals were consolidated in Fig. 6.

Participation + Operate (P + O)

For concluding the implementation of the poCDIO methodology, it was determined that the operation of the solution proposals would take place after the finalization of the project and would serve as an indicator of the incorporation of the proposals by the stakeholders into their own realities.

Application Case Analysis

The "Participation flow matrix" tool was used in order to evaluate and analyze the participation levels throughout the methodology, the results are presented below in Table 10

As can be inferred by the application case description, most of the active participation took place in the 'observation' stage. The reason for this was the fundamental need to establish close ties with the participants from the beginning of the project in order to define roles based on the abilities and resources of each stakeholder. In this sense, one of the primary conditions of active participation was fulfilled by respecting the right of the stakeholders to deeply understand the issues that modify their quality of life.

Additionally, it must be noted that the strategies for promoting participation cannot be systematic or generalized, since it is the analysis of the interest, abilities and resources of each stakeholder that allows designing proper participation tools and spaces. Likewise, it is important to remark that it is the direct dialogue with all the stakeholders in the project that

Table 10 Example of the participation flow matrix

Civilian/ institutional stakeholders	**Stakeholder main role**	**Participation level by project stage**				
		Participation +Observe	Participation +Conceive	Participation +Design +Implement	Participation +Operate	**Final participation level**
University Students	Assistance in the conception and design of the solutions	**1**	**2**	**3**	**Not quantified as this stage will time limits take place outside of the project's time limits.**	**6**
School Students	Learning of tools for guiding the conception and design of solutions	**1**	**3**	**2**		**6**
Small Companies	Building of the solution ideas	**1**	**3**	**3**		**7**
Project's Research Team	Assistance and design of the participation spaces	**3**	**1**	**3**		**7**

facilitates the identification what each stakeholder considers to be the relevant elements and his expectations regarding the issue.

As shown in the flow matrix, during the "observation" stage the schools, small companies, and university students initially participated as information receivers, because they had to understand the scope of the project in order to have the freedom to choose whether or not to participate. Consequently, the research team had a more active role as they had to generate the setting that would incite the other stakeholders to participate actively. In terms of the matrix, the role of the research team was to upgrade the stakeholders level of participation from the "red criterion" where they are little more than information providers, to the "green criterion" where they actively participate in the making of decisions".

As it was mentioned above, the "conceive" stage took place in the "Green Solutions Laboratory", where it was possible to gather all the stakeholders in a "creativity and collaborative construction day", that was very successful in terms of participation. This achievement was a result of the arduous 4 month effort undertaken during the observation stage and the structuring and transversal planning made by the research team. According to the stakeholders flow matrix, different participation levels took place in this stage. In the

case of the school students and the small companies there was an active project-type participation, as they assumed roles and activities which implied a co-responsibility and they were the ones making the decisions regarding the solution ideas that were to be designed and implemented, ensuring thus that they will be the ones with the highest potential for addressing their common needs. The university students present a yellow valuation in the matrix, as they hay a guiding role in the proposal and selection of ideas, which can be understood as a moderate but justified participation. Finally, the research team had a red level participation because during this stage of the project their intervention was minimal, limited to guaranteeing the development of the research laboratory and the reception of the information.

For the design-implement stage, the participation had a high level as both the design and implementation of the solution ideas took place through actions and tasks that integrated the knowledge, abilities and interests of all the stakeholders. It is important to note that the participation level of the school students was restricted because they did not have complete freedom to make decisions in their institutions.

As it was mentioned before, the operation stage was not included in the scope of the project since it was determined from the beginning that it should be carried out by the community independently of the presence of the research group. Nevertheless, from a methodological point of view, the research team has the responsibility of making a final supervision for confirming that the solution ideas were in effect incorporated to the reality of the participating community.

Regarding the results, the implementation of the poCDIO methodology allowed a diverse group of stakeholders to participate actively in a process to develop solutions that began by the recognition and establishment of relations and finished in the design and implementation of four solution ideas: an agro-touristic route; honey derived products; quinoa association of the Guasca municipality; and the "A mobile app for the region and remembering what has been forgotten", which gave a direct answer to the common necessities of the participating community, composed by the rural schools and small companies of the Guasca, Guachetá and Junín municipalities. This means that the participation was defined based on the function that it would serve in the project, consequently in the early stages the participation was not conceived as active, it became active when the stakeholders acquired conscience of the implications of their participation and decided freely to be a part of ideas conception process.

As final analysis, it is important to indicate that since the project did not integrate the "operate" stage, the global evaluation of the stakeholders flow matrix mentioned in this paper's theoretical framework is calculated using only the "Observe, Conceive, Design and Implement" stages. Taking into consideration that the highest score changes from 12 to 9, the global evaluation of the present case will be made using the following scale:

- A final score in the 7 to 9 bracket is considered as a high participation level
- A final score in the 4 to 6 bracket is considered as a medium participation level
- A final score in the 0 to 3 bracket is considered as a low participation level.

Regarding the final participation level, the small companies and the research team obtained a high level, whereas the final participation of the university and school students ranked in a medium level. From a general perspective the results are coherent with poCDIO methodology and the different participation strategies devised for each stage. The high level of participation of the small companies is due to them being the central axis of the project, and the solution ideas being conceived, designed and implanted according to what the small companies declared to be their common necessities. Regarding the research

team, it is coherent that its participation level was high, since it was the stakeholder that designed and guided methodologically the process, which gave them a high influence in the making of decisions. Concerning the school students, their medium level participation is considered to be due their lack of freedom in the making of decisions because all the spaces of participation were mediated by the schools as institutions. It could be argued that their level of participation in future instances could increase if spaces of participation outside of the school institution were created, as this would enable them to participate actively in the role of potential entrepreneurs. As for the university students, their medium level of participation is coherent since their main role was to support and contribute to the methodological process, rather than to make decisions concerning the solution ideas. Finally it is important to point out that there are no low global valuations, which evidences the importance of the approach in the poCDIO methodology that makes of participation a strategic and essential component. Nevertheless, it can be inferred that even if the participation was active, the time allotted for the technical details of the solution ideas was limited. Therefore, it can be concluded that the increase in the level of the participation and the number of stakeholders, demands in turn a corresponding increase in the time assigned for achieving solutions of a higher technical and operational level.

To sum up, it is necessary to remind the main objective of the project which looked to "consolidate an integration network of multiple stakeholders that facilitates the participative development of solutions to the needs of the local small companies". Regarding the term "network" it can be said that this is an abstraction of the interaction among roles and stakeholders that took place as a result of the implementation of the poCDIO methodology which allowed the collective development of the final solution ideas.

Conclusions

The researches experience in each one of the projects evidences how the participative component is a relevant factor in the results of the engineering projects that have a social impact. The poCDIO (Participation-Observation-Conception-Design-Implementation-Operation) proposed in this paper is the result of the integration of the oCDIO model and some stages proposed from the social domain looking to obtain an active participation from all the stakeholders involved in the projects. With the poCDIO methodology, an approach is proposed from an engineering standpoint that ensures the participation of the stakeholders in each stage of the oCDIO methodology looking to achieve successful results. In addition, the Stakeholders Flow Matrix proposed guarantees the measuring of the participation of each stakeholder throughout the intervention. The Stakeholders Flow Matrix is a tool that allows the identification of the key stakeholders in a project, their relation to it, and the assigned roles, and to relate them to their degree of participation on their impact in the different stages of a social engineering project. Hence it was used as a mechanism to evaluate the participation of the stakeholders during the development of the methodology.

Even though it could be argued that the active participation should be a systematic constant in the development of an engineering project, the application case shows that it is important to qualify this participation through roles and the analysis of the different moments of the project. Therefore it is important to establish a balance between the participation and its effectiveness in terms of the projected goals. This balance must be also based in the analysis of the resources, expectation and abilities of the stakeholders.

This methodological proposal intends to reinforce the collective work made by the community, promoting thus the collective and participative creation of innovative spaces for regional entrepreneurship that fosters the sustainable development of a country such as Colombia.

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