Board 119: Pre-engineering Programs and the Instillment of Empowering Abilities for Minorities: the Case of the SaviaLab Program

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I am studying Civil Engineering with major Design, Engineering and Innovation UC, and at the same time I am doing master's program of engineering sciences. I entered university throught Talent and Inclusion Program. In my first year of university I saw the educational differences and since then one of my greatest motivations is the education quality in primary and secondary school in Chile.

Introduction

This article describes one of the few cases of pre-engineering programs in Chile. STEM study programs have become increasingly relevant as they are considered vehicles for economic and social development. Nonetheless, one of the major concerns in STEM education is the lack of adequate representation of minority groups in these programs such as women, low-income, rural, first generation students, ethnic minorities and other social identities typically underrepresented in STEM (Yelamarthi & Mawasha, 2008; Lichtenstein, Chen, Smith, Maldonado, 2013). Introducing diversity into STEM programs is likely to create a scenario where there is an improvement "of creativity, innovation and quality of STEM products and services" (Burke, 2007, p.7). The conventional wisdom explaining underrepresentation of minorities in STEM is typically attributed to a problem of program enrollment and dropout rates, but these are more likely to be the direct effects caused by the lack of parental participation in university education, prior educational disadvantages, among other risk factors (Cabrera, 2001). To overcome these challenges, many initiatives with both private and public funding have been deployed. Among these, engineering schools in the US have developed educational programs to instill engineering abilities while students are still in high school. These programs have been called pre-engineering programs.

Academic studies have showcased the benefits of pre-engineering education. For example, these type of programs in K-12 are linked to higher self-efficacy in engineering (Fantz, Siller & DeMiranda, 2011), increases in pursuing STEM careers due to the early exposure to math and sciences (Raines, 2012), and positive effects in specific engineering skills such as technology use (Strayhorn, 2011), and academic performance both in high school and STEM undergraduate programs (Raines, 2012; Yelamarthi & Mawasha, 2008). Although there is an upward trend in pre-engineering research, there is also growing concern with the lack of standards in the program's instructional design (Chandler, Fontenot & Tate, 2011). Katehi, Pearson & Feder, (2009) group potential educational gains of pre-engineering programs into five areas:

1.Improved learning and achievement in science and mathematics;
2.Increased awareness of engineering and the work of engineers;
3.Understanding of and the ability to engage in engineering design;
4.Interest in pursuing engineering as a career; and
5.Increased technological literacy.

Despite the fact that 'pre-engineering' as a concept is becoming more broadly employed in the US, it hasn't really reached popularity in Latin America as a whole, or in Chile. This may be related to the lack of clear standards and the vast heterogeneity of programs available. Using Katehi et. al, (2009) educational gains as basic criteria to define a pre-engineering program, we are aware of at least one of the few examples in Chile that can be considered a pre-engineering program – SaviaLab.This article will briefly present SaviaLab's history and describe its participants. Finally, we will describe our ongoing research methodology proposed to evaluate the program's impact as a genuine pre-engineering program.

Our Case of Study: The SaviaLab Program

SaviaLab is an educational program that seeks to instill early innovation and technological tools to middle and high school students in Chile. Particularly, the program looks to widen participation of rural and socio-economically vulnerable students by bridging the gap through the exposure to STEM concepts, role models and technological capabilities. SaviaLab started in 2014 with a hands-on methodology designed by the engineering design area, DILAB, at Pontificia Universidad Católica de Chile (UC). With funding from the Foundation for Agricultural Innovation (FIA), DILAB looked to address the limited exposure or access that young people have to STEM educators or poles like universities or technical institutes.

According to the 2017 Census, 12.2 % of Chileans live in rural areas. This group entails a large group of indigenous minorities (e.g. Mapuches, Aymaras). Students in rural areas are also disadvantaged due to the lack of opportunities for development due to the highly centralized organization of Chile in its capital, Santiago. Since 2014, more than 3,300 students and 120 school teachers from 7 regions (Chile is divided into 16 regions from the north to the south) have participated in the program. Students' ages range from 14 through 18, but they all take part in the same educational design. This is founded on the idea that an autonomy supportive pedagogical structure (Jang, Reeve & Deci, 2010) enables successful collaborations between diverse students, in particular, in the context of design learning (Powers, 2017). Due to its impact in diversity and contributions in teaching technology, SaviaLab was awarded the 2018 Airbus GEDC Diversity Award given by the Engineering Deans Council.

Based on an instructional manual (*see Fig.1*), worksheets and specific short lectures, the program trains middle and high school teachers in an active learning project based experience. Then, the school teachers undergo a deeply structured Project-Based Learning (PBL) program where they do context assessment in their own communities, identify innovation opportunities in their communities and prototype solutions. Throughout the year, students attend technological camps that are instructed by undergraduate engineering students who act as role models.

Figure 1. Instructional Manual in its 2017 version

The program's methodology is organized around two phases: "*el curso*" (the course) and "*el concurso*" (the contest). The course itself is based on two topics. The first one is called "innovation opportunities detection". Teachers and students are taught to recognize the cultural characteristics of their environment and detect key social gaps and habits. This process is based on DILAB's methodology of "Anthro-Design" (Author, 2019). It emphasizes the value of empathy, autonomy and cultural appreciation as the bedrock of early innovation and the value of observation and interviewing as its major tools. SaviaLab teaches students that innovation needs to start from human empathy and not only from technological possibilities. The second one is called "solutions and prototyping". Teachers and students learn concrete tools to foster their ideation process and how to give those ideas physical form using technology. They learn how to prototype, ranging from mockups to fully functional prototypes. It is in this stage where individuals, aided by undergraduate engineering students, tend to come full circle and understand what they are capable of.

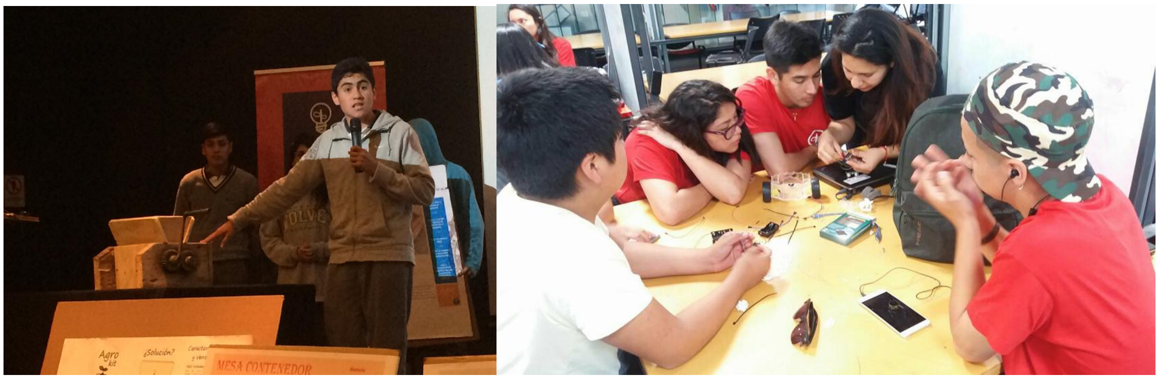


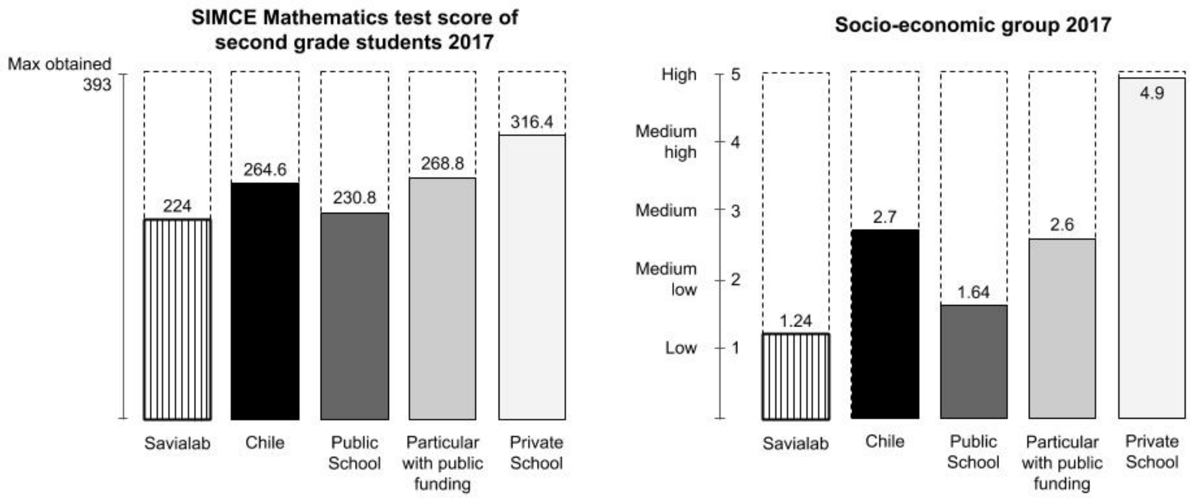
Figure 2. Middle and high school students participating in the program

The second step, the contest, is divided into 3 stages. Teachers who successfully completed the course can participate with their students in the contest. In the first stage, the students apply what they learned in the course by working in peer groups conducting an innovation process. They have to create two reports for an expert jury. The first summarizes the innovation opportunity detected and the second one describes the solutions created. Students groups receive expert feedback to continue to the next stage called the "technological fair" where they present their innovation projects at a university campus which will be usually linked to their engineering school. The participant groups have to make a poster and present a prototype. Then, finalist groups are selected and advanced to the last stage called the "technological congress" in which the expert jury selects three winning groups. These winning groups win a national technology tour that involves the visit to national innovation hubs and technological centers.

SaviaLab's vision is to empower Chilean most disadvantaged students to make them aware of their innovation potential despite their socio-economic disadvantages. For further contextual details on the wealth and education disparity, it is important to understand the different funding structures present in the Chilean educational system. These are: *Municipal* (tax sourced and dependent of the "county"), *Subvencionado* (private with public tax sourced funding) and *Particular* (private). In regards to the type of curriculum undergone, there are three typologies: these are Scientific Humanist (CH), Technical-Professional (TP) and Mixed (HC and TP). Finally, there are two types of schools depending on location; rural and urban.

From 2015 to 2019, SaviaLab has impacted to 95 educational institutions. Of these, 59% are *Municipal* and 41% are *Subvencionados*. Of the sample, 5% are CH, 40% are TP and 55% are Mixed. 35% are Rural and 65% are Urban. All these colleges have a similar school vulnerability index, around of 89,7%, this means that el 89.7% of the students are vulnerable from a socioeconomic and educational point of view. As *Figure 3* displays, the schools that participate in the program are considerably disadvantaged compared to the rest. As an example, the schools that participate in SaviaLab have the lowest academic score in the National Evaluation of Learning System (SIMCE), a standardized test to evaluate the education levels of schools in

Chile.



Note 1: "SIMCE test score" corresponds to the school averages in the mathematic national standardized test taken to Chilean second grade students in 2017.

Note 2: Socio-economic groups were obtained in the Ministry of Education's database. The data corresponds to the year 2017.

Figure 3. Comparison of the academic level and socio-economic level of SaviaLab schools versus different schools groups in Chile.

In addition, the SaviaLab schools belong to the lowest socio-economic group in the country. Because of their disadvantages resulting from the marginalized educational system, students working in SaviaLab are in special need of a structured and narrowly-tailored educational experience that leverages the possibilities to access tertiary education. Therefore, considering the perceived impacts of the SaviaLab pre-engineering program in a marginalized community, there is a high need to evaluate the program's concrete impact in aspects as learning tech skills and self-efficacy.

The research team at DILAB UC is currently designing the research methodology to provide evidence of the program's impact. To assess educational change, we developed a mixed methods concurrent triangulation design (Creswell & Clark, 2007). It is in our interest to address the following research questions:

RQ1: Does SaviaLab provide middle, high school teachers and their students with a viable pre-engineering program making that gives them greater access to engineering concepts?

RQ2: How does SaviaLab instill engineering design abilities to Chilean high school students both from rural and urban schools?

The quantitative phase is structured as a pre-post design with a control group. We will adapt and apply the Technology and Engineering Attitude Scale (TEAS) created by Cook (2010) to evaluate changes in students and teachers attitudes toward engineering. We will also use and adapted version of the Engineering Design Survey created by Moazzen et. al. (2014) to explore differences in educational gains resulting from the participation in this program. Using the latter instrument we will also be able to detect teamwork challenges arising from the group projects. The qualitative phase will be based on a descriptive and analytical approach (Flick, 2009). The main research instrument will be thematic 'semi-structured' interviews (Flick, 2009). Results will be coded using open coding technique (Glaser & Strauss, 1999). Data collection should start on the second semester 2019. We expect to collect around 600 participants in the quantitative phase and around 30 in the qualitative phase.

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