Building Engaged Engineering in Curriculum - A Review of Brazilian and Australian Cases

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I currently develop a post-doctorate research at the Aeronautics Technological Institute (ITA) with a scholarship from FAPESP (#2018/20563-3). I hold a PhD degree in Philosophy (University of São Paulo, 2017), a bachelor degree in Philosophy (Jesuit Faculty of Philosophy and Theology, 2008), a master degree in Electrical Engineering (University of Campinas, 2002), and a bachelor degree in Electrical Engineering (University of Campinas, 1999). My research area encompasses philosophy of technology and of engineering and engineering education. I am now studying grassroots engineering (GE) and social/solidarity technology (ST), as well as engineering education, focusing, on one hand, on the ethical-political, aesthetics, and epistemic aspects that both characterize and make GE and ST possible, and, on the other hand, on the challenges the engineering education must face in order to train/develop the capabilities or skills engineers must possess so to be able of doing GE and producing ST. The work I currently develop at ITA is related to the conception and institutionalization of a minor in engaged engineering.

Building Community Engaged Programs in Curriculum - A Short Review of Brazilian Approaches

Introduction

Engineering schools have established a variety of ways of how community engagement programs (CEP) are built into curriculum [1]. But what are the conditions for establishing CEP in engineering schools? And how can we explain the different ways in which CEP programs thrive? From the perspective of the social systems theory, there is an interplay in the dimensions of constraints (structural coercion), free choices, and contingencies, allowing actors a set of options to shape CEP programs [2]. Accordingly, the diversity of CEP programs is not only explained by adapting to cultural contexts but also by choices and unforeseen circumstances. Further, introducing CEP in engineering schools depends on engaged professionals willing to do so, along with a set of favorable conditions including: leadership, openness to educational design, implementation strategy, institutional and financial support, professional networking, and partnerships, among others [3]. So, to understand how CEP programs are shaped today, events of the historical background may be decisive.

In order to better comprehend the patterns of CEP institutionalization, in this paper, we analyze one Australian and two Brazilian selected cases. The Brazilian cases are among the most well-developed CEP programs in the country and very rich in presenting new concepts and practices. They are also made available here for the first time for the international community in the English language. The programs are: the Technical Solidarity Center (Soltec), at the Federal University of Rio de Janeiro, and the Citizenship and Social Technologies Lab (LabCTS), at the Aeronautics Technological Institute (ITA), in the São Paulo State.

Due to a few compelling reasons, we contrast the Latin American cases with the minor in humanitarian engineering at the Australian National University (ANU) in Canberra: ANU's program is a result of a thorough process of reviews and debate about learning outcomes and service learning integration in curriculum [4]; it is a highly flexible and adaptable model; it has been subject of recent research scrutiny [5]; and it is embedded in the Anglo-Saxon culture, emphasizing cultural divergences to the Latin American context.

The paper is structured in four main sections. The first three sections describe each of the selected cases. These sections are organized in subsections with the historical background, the program description (how CEP is built in curriculum), the role of partnerships and funding, and a short account of strengths and limitations. In the fourth section, we summarize the main findings highlighting a) the differences and common features of the CEP programs and b) the variations in the institutionalization process of the CEPs. With that, the lessons we learned are summarized in the final comments, aiming to contribute to the efforts of engaged engineering programs in exploring options and achieving goals.

We have opted to use the self-definition concepts provided by each program: popular (grassroots) engineering (see below) at Soltec, humanitarian engineering at ANU's pathway, and engaged engineering (see below) at ITA.

Technical Solidarity Center (Soltec)

Background

The Technical Solidarity Center, or Soltec, was created in 2003, linked to the Department of Industrial Engineering at the Federal University of Rio de Janeiro (UFRJ), the largest public university in the State of Rio de Janeiro (about 45,000 undergrads and 12,000 graduate students). Its creation was strongly influenced by the presidential government of Lula da Silva starting in 2003, which motivated engineering students and teachers to engage in establishing a place for practice and learning following the ideal of constructing "another possible world" [6], [7].

Currently, Soltec is also part of the UFRJ's Interdisciplinary Center for Social Development (NIDES), "an interdisciplinary service learning, research, and educative program that develops projects in networks, with a territorial and participatory approach, in the areas of social technology and solidarity economy, aiming to construct public policies for social equity and environmental balance" [6]. Social technology and solidarity economy are core concepts in the Brazilian context. Roughly stated, such concepts are associated with the sociotechnical co-construction, along with grassroots people and collectives, of working places and communities more just, empowering, and participatory.

In the area of engineering education, Soltec is known as the oldest and more comprehensive Brazilian initiative of integration between teaching and a specific type of community engagement known as *grassroots engineering*. What is commonly named as service learning in Anglo-Saxon countries, in Brazil is called "university extension," or simply "extension" in the education context.

Although the Brazilian Constitution establishes the inseparability of teaching, research, and extension at the higher education and new laws reinforce this obligation [8], [9], most Brazilian engineering schools do not include yet in its extension programs a strong CE program such as Soltec. Instead, such schools see the extension as initiatives that range "from community engagement to junior enterprise, from cultural production to juridical assistance to the poor, from university hospitals to extension courses destined to present academic knowledge and research to a non-specialized audience" [10].

Following Paulo Freire [11], the service learning practice does not impose an already existent academic knowledge on the community. Soltec follows such an understanding by co-constructing with the supported social group a knowledge that tries to incorporate the participants' knowledge, aiming at both addressing the problems and needs identified by the group itself and empowering the group to change its reality [12].

More specifically, Soltec does what has been called *grassroots engineering* (GE). That is, an engineering practice that seeks to produce solidarity technology [13], usually related to solidarity economy initiatives, drawing on Paulo Freire's popular pedagogy [14] and participatory methodologies (such as action research). In this sense, GE challenges how mainstream engineering is conventionally taught at engineering schools [15]. So, Soltec's primary goal in

students' training is forming *grassroots engineers* or, inspired in a Freirian terminology, *educator engineers*, that is, engineers capable of collaborating with the oppressed in the construction of a less oppressive, socially fairer, and environmentally more sustainable sociotechnical reality [10], [15]. The permanent staff of Soltec encompasses two teachers (with a background in engineering), four technical-administrative officers (two of them with a Ph.D. degree and authorized by UFRJ to do teaching and research), and one graduate student. This team has a transdisciplinary background in Engineering (4), Law (1), Psychology and Journalism (1). The team also includes four to five graduate students from the Master in Technology and Social Development program (explained below), collaborating in the management of Soltec's projects and office duties as part of their scholarship's research commitments. Further, the team counts with six volunteers, with background in Engineering (5) and Architecture (1), from which five are faculty teachers at the UFRJ or other public universities.

The program

Soltec's educative activities take place at three levels: a) service learning practice teams; b) elective undergraduate disciplines; c) master program in Technology for Social Development. Such levels are in a non-hierarchical order. They are summarized as follows:

Service learning practice teams. Currently, six projects are running at Soltec [15]:

- PAPESCA works with artisanal fishing dwellers with issues related to management, solidarity economy, empowerment, environmental sustainability, among others;
- TIFS provides technical support on software engineering to social movements, co-constructing application software, programs, websites, among others;
- OTA supports companies recovered by workers and other solidarity economy initiatives with challenges linked to self-management, and production;
- CACI builds and teaches, along with leaders of the Landless Workers' Movement (MST), courses on agroecological management and cooperation, designed to farmers of the movement and other social initiatives;
- RIPER supports cooperatives of waste pickers, strengthening the cooperatives' networking and fighting for the implementation of the selective collection system, along with the diffusion of the solidarity economy' ideals;
- ETNO provides support on solidarity economy to traditional groups (i.e., native Amerindian communities and *quilombolas* (that is, communities of descendants of runaway slaves)), building up cultural and economic empowerment.

All projects count with undergraduate and graduate students and a project coordinator, who may be of Soltec's permanent staff or a volunteer collaborator.

Project training is usually provided in four ways: i) on the teams' study sessions, which are run every two weeks or monthly, and are meant to offer space, time, and opportunities to acquiring theoretical tools for the support of the assisted groups and to reflect and evaluate about the provided support achievements; ii) on general educative activities offered to all of the Soltec's teams on issues such as solidarity economy, popular education, racism, sexism, LGBTQ-phobia, etc.; iii) on the practice of service learning in the communities, with all the challenges that

grassroots engineering brings with itself, providing the students with the opportunity to learn from more experimented grassroots engineers' practice; iv) on the feedback given by the team's staff on the individual and/or group performance.

Most undergraduate students used to be granted an extension scholarship (from UFRJ) during at least a part of the time they spent at Soltec's activities. This financial support, in addition to the compelling ideals of grassroots engineering, motivate undergrads in engaging at Soltec's projects. For the graduate students, participation at Soltec's interventions is usually part of their main research project, building a strong commitment to Soltec's ideals and practices. Following the economic crises around the deposition of Dilma Rousseff of the Presidency in 2016, the offer of extension scholarships decreased drastically. However, new legislation demanding a 10% minimum of the course's curriculum to be dedicated to extension activities in all higher education shall be implemented by 2021 [9]. This new legislation will be fundamental to help Soltec attract and commit new undergrads to its educational program.

Elective undergraduate disciplines. Currently, Soltec offers two elective disciplines: "Participatory Management" and "Solidarity Technology." Both are four-weekly-hour and fifteen-week-long. The disciplines integrate theory and practice, reserving a fifteen-hour load to a service learning activity [16]. The in-classroom activities and methodological approaches aim to encourage students' active participation and the construction of critical thinking. Such an approach encompasses student groups organized seminars, written reviews of the literature, and expositive classes that encourage students' debates [17].

Master in Technology for Social Development. This master program usually takes two years and is offered by NIDES (Interdisciplinary Center for Social Development). There are three research lines available: "Participatory Management," "Solidarity Technology," and "Polytechnical Work and Formation." Its first selective process took place in 2016 with 20 vacancies; from 2018 on, this number increased to 22 vacancies. Until today, all vacancies have been filled [18].

The program, which is co-managed by part of the Soltec's team, which makes four of the total of twelve teachers in NIDES, has an explicit commitment to social justice and sociotechnical change. In order to do so, the program seek: to create new concepts and methods that can support a solidarity technical development; to influence the elaboration of public policies; to produce knowledge that addresses demands from grassroots groups; to strengthen and conjugate research, action, and critical reflection; to gradually influence and change the undergraduate engineering courses offered by the UFRJ towards a more critical and socially committed engineering education [19].

Finally, the program intends to be multidisciplinary concerning the admitted students' backgrounds, disciplines, and the teachers' backgrounds. In addition to the engineering areas, Social Sciences, Psychology, Letters, Health Sciences, and Natural Sciences are encouraged [18]. However, from the number of 22 admitted students per year, usually only about 3 are from engineering areas. Although NIDES' has intended to increase this number, this aim has been provided challenging to achieve.

In the same line, Soltec's service learning activities also seek multidisciplinarity [12], considering that practicing action research and popular education ideally require not only educator engineers, but also educators, social services workers, sociologists, psychologists, and, depending on the project's goals, additional specific areas of knowledge.

Partnerships and funding

There are at least three different types of partnerships cultivated by Soltec: with social movements, with other engaged engineering centers in Brazil and Latin America, and with unions and some public sectors. These three types are fundamental for Soltec for funding and scaling up a grassroots sociotechnical order that Soltec aims to co-construct.

In partnering with broader social movements, such as the Workers Landless Movement and the National Movement of Recyclable Materials' Pickers, Soltec follows a twofold rationale: a broader movement facilitates the dissemination, with the context adjustments, of local sociotechnical solutions to other initiatives; a broader movement is also much stronger than isolated local initiatives to demand and influence political changes in public policies, governmental funding programs, etc. Soltec distrust partnerships with the private sector unless this support does not interfere with Soltec's freedom to act by its own ideals. In Soltec's staff perception, a democratic State should fund initiatives fostering a new sociotechnical order. As a result, Soltec's activities have only been funded by the government, unions, other anti-capitalist groups or institutions, and militants.

Highlights and bottlenecks

Soltec presents some remarkable achievements in both doing grassroots engineering and educating grassroots engineers. They can be summarized as follows:

- A very well-adjusted educative process of the service-learning teams, conjugating theoretical learning, critical thinking, and learning in practice with individual and collective feedback;
- A master program providing a space for researching different subjects associated with solidarity technological developments, grassroots technology methods, etc.;
- A high degree of institutionalization of both service learning practice, creative research, and undergraduate engineering disciplines;
- Solid partnerships with relevant Brazilian social movements as well as universities and civil society's organizations in Latin America;
- Achievements in providing a new approach to rethinking public policies and the interaction between social movements and technology and society, including the development in practice of concepts such as grassroots engineering and solidarity economy and technology.

However, there are some limitations too. As far as we can see, Soltec faces two significant challenges for the students' education: funding and evaluation. In the first case, the problem gets more evident with administrations less sympathetic to left-wing projects, which is the case of Brazil and both the State and city of Rio de Janeiro, currently in the hand of far-right politicians.

This situation is new to Soltec, after thirteen years of the leftist Worker's Party's federal administrations. However, after far-right Jair Bolsonaro came into power (2019), Federal Universities (such as UFRJ), social movements, and social policies experienced not only funding shortage but also a delegitimization process (in a sort of cultural wars far-right governments have been practicing in some countries).

Concerning the evaluative process, Soltec counts with different instruments that can be used to assess students' performance and progression: students' participation at the studying sessions; reports; direct observations from Soltec's staff; conference papers/posters made by students; etc. However, they seem to be not much articulated and are not published. This situation makes it difficult for anyone analyzing Soltec's educative program to construct a more accurate picture of what has (and has not yet) been achieved in the service learning practice. Without such pieces of information, it can be hard, even to Soltec, to help its students evolve and to improve the educative process it provides [15].

There is another evaluative area in which Soltec and other grassroots engineering centers need to do better: assessing the impact on the supported groups of the sociotechnical assistance provided. It is undeniable that the empowerment of the assisted groups and/or adequate sociotechnical solution) can be found in many (most of?) Soltec's activities. Though, it is not clear what is, in fact, achieved compared with what is possible and desired. How can the results be improved? These and other related questions find little data and few systematizations, concepts, and/or measuring methods so to be answered more appropriately. Whereas Soltec mentions such questions occasionally in its many publications, there seems to be no general attempt to consolidate an evaluation strategy [15].

Minor in Humanitarian Engineering - Australian National University (ANU)

Background

In Australasia, one of the first courses of Humanitarian Engineering (HE) in higher education was established in 2015 with the Engineering for a Humanitarian Context (EfaHC) within the bachelors engineering program at the Australian National University (ANU) in Canberra. In 2019 it was established a minor program in HE.

The ANU is a research-intensive university established after the second world war and with a focus on postgraduate studies. The four-year undergraduate engineering degree has a common systems engineering core, with many discipline majors [20]. Implementing a minor pathway at ANU was motivated by "*a perceived gap with students lacking background in humanitarian approaches and aspects of human-centered and participatory design* [in capstone experiences]" along with the experience of utilizing EWB service learning opportunities for some years, and a perceived "*natural alignment between systems and humanitarian engineering*" [20]. Inspired in existing HE programs internationally, ANU's HE pathway was "*specific for Australia's unique humanitarian and development context, which is embedded in the country's location, geopolitical influences, history, and domestic challenges and vulnerabilities*" [1].

The EfaHC course has gathered our attention by its in-depth development process between 2007 and 2015, in which the learning outcomes and the topics covered have undergone an intensive process of external inputs and peer reviews [4]. Developed jointly with Engineers without Borders (EWB), the course recommendations have intended to provide a framework for HE courses for Australasian universities in general.

The program

Minor in Humanitarian Engineering. ANUS' minor in HE offers a semi-structured pathway allowing student activities in all year levels, with the option to integrate extra-curricular opportunities. The bachelor degree has a compulsory systems engineering core through all four years, with students selecting a major program in the third year (changed from second to third year in 2019) and is accredited by Engineers Australia (EA), allowing professional mobility assured by international agreements [5].

The HE minor program is structured with up to seven activities, among courses, opportunities, and projects, in all four engineering undergraduate years, in which HE is integrated [5]. The basic curricular structure may be visualized as following [5]:

- Year 1 - Optional research report with a HE focus. Until 2017, before the minor program was in place, the course 'Discovering Engineering' (compulsory) run an EWB Challenge;
- Year 2 - Systems Design and Systems Analysis including opportunities to undertake "*domestic projects focusing on access, inclusion and disability, and follow-up EWB Challenge projects*";
- Year 3 - Engineering Innovation - Ideas for social enterprises created by the students;
- Any year - Work Experience or internships with community-based organizations or social enterprises;
- Year 3 or 4 - Engineering for a Humanitarian Context course as a dedicated elective subject;
- Year 4 - Systems Engineering Project (1 semester) and Individual Research Project (2 semesters) - both involve service learning and external partners, the former with a group capstone project, the latter, with research to development or humanitarian contexts.

Engineering for a Humanitarian Context (EfaHC). Although the student may participate in HE driven activities in all years, just one elective course is specific to the subject of HE, the key course EfaHC. This elective has been delivered in two modes [20], [21]:

- On-campus based mode. This is an intensive mode, which is given at ANU Canberra over five weeks. This mode is currently run every two years. It includes site visits in the region.
- Off-campus in a short-term immersive community development experience (CDE). This mode is generally run overseas in the EWB Humanitarian Design Summit but also includes immersions with organizations such as WindAid in South America. This modality of the course is run every six months.

In 2015, the EfaHC course was delivered for the first time as a five-week intensive course (four-week delivery and one-week assessment) during the winter term. It incorporates appropriate technology workshops, class discussions, guest speakers, site visits, and online material. In its first pilot, it had thirty-eight students completing the course [1]. Running in parallel to the campus mode in 2015, the first immersive CDE incorporated the two-week EWB Humanitarian Design Summit in Cambodia. Eight students, six of whom were supported by the Australian Government New Colombo Plan (NCP) short-term scholarships, completed the course in this mode [1].

In 2015, a total of 46 students undertook the course, from which eight undergraduates off-campus and 33 undergraduates and three postgraduates (Master of Engineering) on-campus [20]. All students were enrolled in engineering courses, either as a single four-year bachelor degree or as a five-year double degree. The course is available as a special topic, meaning enrolment was by the approval of the course coordinator. The prerequisites were either a bachelor's degree or two years of undergraduate engineering [20].

Finally, ANU's pathway is structured by a wide range of course topics and subtopics, with corresponding learning outcomes, focused around four main topics: Humanitarian Engineering (through EfaHC), Development, Context, and Multi-disciplinary engagement. These topics comprise a total of 17 sub-topics and 70 individual topics, encompassing as far as 'Indigenous Australian background and engineering examples' and 'Communicating with interpreters and sign language.'

Partnerships and funding

In the case of ANU's HE, the key partnership has been with EWB - Australia, which was established as an independent national EWB in 2003. It places approximately 20 volunteers a year with partner organizations in Australia, South and South-East Asia (including Cambodia, India, Nepal, and Timor-Leste) [22]. EWB was working with ANU's faculty and students even before the establishment of the minor program and has cooperated intensively in conceptualizing and designing the program framework. Further, it is the leading partner in providing service learning and community immersion experiences for students at ANU.

More specifically, EWB's involvement in the ANU pathway encompasses [5]:

- The EWB Challenge in the first year. In 2015, the EWB Challenge was used by almost 30 universities in Australia, reaching an impressive number of around 10,000 first-year engineering students [22].
- The two-week immersive study abroad, EWB Humanitarian Design Summit (EWB Summit), in the middle to later years;
- The EWB Undergraduate Research Program in the final year. This program is a project-based service learning initiative to support capstone courses for final year engineering undergraduate or master coursework students [22].

There are other governmental and non-governmental organizations supporting internships and scholarships in the area but of much less weight than EWB.

Site visits and materials for prototypes in workshops are covered by the course budget, remarking that hereto costs are held deliberately low [21]. For many students taking part in the service learning activities, especially overseas, depend on financial support. This is the case of the EWB Humanitarian Design Summit, which is usually located in Southeast Asia. The costs of involvement in EWB Summits are borne by students, with about 80-90% of students supported through by the Australian Government New Colombo Plan (NCP) short-term scholarships, to which eligible students provide 60-70% of the cost [5]. Additionally, the costs of taking part in the EWB Challenge and the EWB Undergraduate Research Program are covered by ANU through a formal partnership. The College of Engineering and Computer Science provides a student experience fund for students not eligible for NCP (good academic standing must be provided). Domestic students also have access to OS-HELP, which is a student loan scheme [21].

The relationship between financial privileges and HE engagement is yet to be better understood. In this regard, J. Smith et al. [5] identified that students engaging in HE are more likely to undertake paid work as the main source of financial support for their studies, including 53% of those involved in HE international experiences.

Highlights and bottlenecks

ANU's HE minor has achieved remarkable results, despite being a relatively new program. In this regard, we highlight a few particular features of the program:

- Consistency in combining learning outcomes with tools and multiple activities in all four years of the undergraduate education;
- A high degree of flexibility in the overall program design, allowing students to have more options on how to combine the desired activities, including on- and off-campus modules, guest speakers, community immersion, project and hands-on challenges, overseas working opportunities, and integration of teaching with service learning and research;
- Flexibility to teachers and students in the elective EfaHC (by concentration in alignments and outcomes), in order to align practicalities and interests;
- A broad scope of topics covered in EfaHC, and positive impact on student formation gathered by research-based evidence;
- Application of self-improvement tools using structured research especially focused on student’s perceptions and course learning achievements.

In general, the program seems to be well institutionalized at ANU, including the opportunities of capstone projects and HE activities integrated into engineering courses other than HE specific ones. It is not clear, however, if the program could be maintained without his current strong leadership. Whereas in the first version of the program, there were still few capstone projects in the pipeline and few graduate students involved, this may change over time with the program getting well-known.

Regarding the student progress, the HE program benefits are made evident - particularly in regard to social responsibility, professional skills, and cross-cultural competency [5] -, but there

are still some challenges here. This is the case, for example, of a more comprehensive way in the students understanding of the connections between social and cultural dimensions in engineering design, seen as a main student threshold [5], and considering that there is no consensus about which social and cultural dimensions shall be worked in the formative process of engineers. Further, although the program has improved the general employability of students according to a survey [5], it seems that opportunities to work in HE are still restricted.

There is plenty of data published about the program impact on students, though barely anything is being reflected on the impact on the supported community development activities. This issue is, however, highly considered by ANU's HE leadership as a critical aspect. In fact, there is a long-term partnership of ANU's minor with five or six community organizations beyond EWB. A few social enterprises have been established by alumni, which are working both domestically and internationally, broadening the students opportunities to undertake internships or research projects, including Abundant Water with programs in Lao and Timor Leste, which helps remote communities stop diseases by providing access to clean water, and Enable Development, which works with empowering people with disabilities [21].

Finally, HE at ANU is not compulsory but restricted to interested students. The evidence provided in the benefits for a professional career and consistent educational formation of HE at ANU raises the question, whether some sort of compulsory course or activities should be extended to all engineering majors.

Engaged Engineering at the Aeronautics Technological Institute (ITA)[23]

Background

The Aeronautics Technological Institute (ITA) was founded in Brazil in 1950, following the example of the Massachusetts Institute of Technology, and is located about 80 km from São Paulo city. The institute is known for its central role in the making of Embraer S.A., the Brazilian aerospace conglomerate. The institute is focused on postgraduation and research and innovation and has today six majors, all in engineering areas. ITA is also known to be an elite school, providing a social network that facilitates careers in business and services, having in its entrance examination approximately one hundred candidates per available place [24].

The Citizenship and Social Technology Lab - LabCTS at ITA aims to promote the concept of ‘engaged engineering’ to picture its vision and values. Engaged engineering in the strict sense arises from the Science and Technology Studies, in the light of the 'engaged program,' which combines public interest activism with research of theoretical relevance and is inspired in the Science for the People movement [25]. So, engaged engineering demands to rethink sociotechnical production in a fundamentally democratic and participatory way [26].

At ITA, the educative process aimed at forming *engaged engineers* was initiated not by engineers, like in many other programs, but by professors of the Department of Humanities. LabCTS is a result of two development phases: an incubation time starting in 2009 and a mature phase from 2018 on. The first step of this process was the creation of a new compulsory discipline for first-year undergraduates named Technology and Society in 2006, which works

issues of the Science and Technology Studies (STS). In 2009, the first electives focused on community engagement projects were created (see below) as a result of ethical-political concerns about the role of universities in society, the desire of students to engage in hands-on activities, and the critical debates about social technology initiatives in the STS.

From 2012 on, a few joint activities with D-Lab/MIT [27] were undertaken, such as the collaboration and participation in three *International Development Design Summit* (IDDS): in São Paulo (2012), in Colombia (2015), and in the Brazilian Amazon (2016). Inspired in the D-lab, the "Citizenship and Innovation Lab" (CI-Lab) was created in 2012 as an instance that should assist the students with their engaged works. Between 2014 and 2017, CI-Lab undertook a few financed community engaged projects involving research and development and the participation of engineering faculty in service learning. These projects included: 1) an evapotranspiration basin by river dwellers (Aug 2014 - July 2015), in collaboration with a Civil Engineering professor and three students with research awards from CNPq - the Brazilian National Council for Scientific and Technological Development [28]; and 2) building internet infrastructure in an Amazon rainforest village, involving faculty and students from Computer Science (2016), and linked to the previous mentioned IDDS Amazon. With the retirement of one of the two faculty leaders in 2015, the CI-lab activities were driven to a difficult time. By the end of 2017, however, a new faculty team was formed, giving strength to the vision of what came to be the current LabCTS.

In 2016, an ITA Enactus team was set up working in close interaction with CI-Lab. Enactus is an international social entrepreneurship organization based in the competition of university teams at the national and international levels. Among others, ITA Enactus developed solar energy projects in communities and schools and got the second-best place in the Enactus national competition in 2017. This student's initiative was quite innovative, managing to build in some of their challenges in curricular disciplines of Sciences and Engineering working with projects with ambitious research and development (new technological alternatives in solar energy), in parallel to undertaking extra-curricular learning activities and working with the sociotechnical capacitation of community partners in building solar heaters and installing solar panels [29].

In 2019, CI-Lab was rebranded LabCTS, that is, Citizenship and Social Technology Lab. It got a formal room and currently counts with five official members (four teachers and one post-doctoral researcher) and one volunteer collaborator (a retired teacher from the Department of Humanities). They have a background in Social Sciences (2), History (1), Psychology (1), Applied Linguistic (1), and Engineering and Philosophy (1). Further, some faculty of Engineering and Sciences collaborate in the mentorship of LabCTS projects. LabCTS pursues transdisciplinary projects between engineering and humanities as well as changing the institutional culture of ITA's faculty, which never worked before with community engagement challenges.

The program

LabCTS core curriculum activities in community engagement are the following:

- The project “Engineering Education and Citizenship” (EEC) runs along with the compulsory discipline 'Technology and Society' (HUM-70) for all first-year undergraduates. Technology and Society is a 16 weeks course (48 hours) along the semester, having now half of the course load dedicated to Science and Technology Studies and the other half to EEC;
- The project-based electives “Topics of Social Technology” (HUM-61) and “Social Technology, Education and Citizenship” (HUM-73), open for students from the second to the fifth year;

Project “Engineering Education and Citizenship”. The project (EEC) is run both in the first and in the second semester for different classes. In each semester, two classes, each with around 30 students, are organized in small groups (usually of four) and trained and engaged in design thinking challenges. After five weeks of preparation, the projects are developed in about eight weeks, along which the students usually visit the local communities two to four times. Around eight working teams are engaged at each partner organization each semester. Students are challenged to come up with an intervention proposal that allows for as much co-design and knowledge dialogue with the assisted community as possible, alongside with being technically robust. In this sense, concepts of design thinking, co-creation, participatory research, epistemologies of the South, and anthropological perspectivism [30], are worked intensively with the students in all project phases.

The EEC is structured as follows [31]: 1) students are briefly taught about engaged engineering and social technologies and about the methodological tools of design thinking and participatory research; 2) partner organizations are invited to speak at ITA, presenting their needs; 3) good practices for field working in marginalized communities are worked out; 4) students visit the communities and identify possible opportunities of intervention; 5) students make two project proposals (ideation), which are then submitted to a critical selection by the partners in collaboration with the teachers; 6) depending on the proposals chosen, engineering mentors are invited to get involved; 7) project implementation begins with establishing a timeline of steps and activities to be undertaken; 8) during the whole project process, a close interaction is kept between students, LabCTS teachers, mentors, and the partner organization’s leaders; 9) final assessment takes place in a public presentation of the students’ works.

Rather than being a model ready from the beginning, the project EEC is self-comprehended as experimental and in progress through a constant course assessment. So, for example:

- In 2018/1st sem., LabCTS decided to make EEC compulsory for all students, due to its perceived relevance and following the national curriculum guidelines for undergraduate engineering education;
- In 2018/2nd sem., LabCTS introduced, alongside the option of technological development projects, which are unlikely to be ready for implementation in the short time of the projects, the option of action projects feasible to undertake in the project timeline. For example, workshops for artisans on how to use social media for income generation, or a financial mathematics workshop designed for people with disabilities, are a few of the accomplished activities done in this line of work. This decision was of great relevance

to provide the desired moving forward by partners, after an experience of having though smart project ideas, but with no delivering in the social realm of the communities;
- In 2019/2nd sem., LabCTS assigned mentors to each student's team, and course time was reserved for meetings and supervision;
- In 2019/2nd sem., LabCTS decided that every student team must present a project preview in the middle of the phases to get feedback and learn from other groups. In this phase, the students are already aware of their project difficulties and opportunities in practice.

Topics of Social Technology (HUM-61) and Social Technology, Education and Citizenship (HUM-73). After doing the EEC in the first year, interested students may opt for one or two electives in engaged engineering projects. These are a standard 16 weeks course (32 hours) along the semester, integrating hands-on service learning, a short internship experience, and in-class theoretical reflection. HUM-61 is dedicated to the phases of project building in close relation to the partners, and HUM-73 is the follow-up course, allowing project testing and implementation. In the first years, the electives were strongly oriented to projects in schools located in low social class areas. Later, the focus has changed to engineering applications with communities and civil society organizations, such as the construction of a biomass shredder for small farmers and the production of math toys from remnants of MDF (medium-density fiberboard). Also, social entrepreneurship projects have taken place, for example, a project on income generation based on the talents of the women in vulnerable conditions of the Association of Mothers and Friends of Pinheirinho - AMAP. Since 2009, there were more than 30 sociotechnical projects developed by more than 120 students.

Partnerships and funding

LabCTS (and previous CI-lab) initiatives have worked with a variety of social partners since its beginning, including schools, communities, social movements, and organizations of civil society. In 2018, EEC worked with two partners: the Coolab, which is a social movement to rethink community-based and self-reliant uses of the internet, including the building of low-cost digital access in rural areas and the use of mesh technologies and alternative routers; and Sorri, an institution for the professional training for people with disabilities.

In 2019, the EEC worked with two new partnerships: Cooperative São Vicente, a recycling self-organized cooperative directed to unemployed people in a vulnerable situation, with a strong commitment to sustainable development, and the Eco-Museum, which works with empowering marginalized communities, by means of the revitalization of the living space (public squares, sport places, rebuilding parks, planting trees, making the living space more welcoming), income generation (with artisans and vegetable gardening) and schools.

In 2020, the EEC is working with a state secondary school and an electronic waste cooperative. EEC changes the social partnerships every year due to the great number of student teams working by each partner along the whole year, accomplishing a great variety of responses to local needs and desires. Many of the ideas put in practice have been, in fact, further developed by the partners themselves.

Concerning funding, the lack of a reliable and continuous financial backup represents one of the main vulnerabilities of LabCTS, regardless of having a low-cost budget as a primary goal. Specific grants for service learning and teaching projects are scarce in Brazil. Between 2014 and 2017, substantial funding was achieved by an endowment of two ITA's alumni initiatives. Since 2018, the EEC project has been funded by the Brazilian Innovation Agency – FINEP. However, uncertainties about funding in the future are looming.

Highlights and bottlenecks

Possibly, the main highlight of ITA's engaged engineering is that, despite all adversities, it was achieved a rich experience of learning by doing and a consistent network of faculty collaboration and of partnerships in the local region, towards changing the institutional culture and integrating teaching, service learning, and technology development.

In spite of all the advances made, LabCTS faces a difficult pathway to move forward. Among the many challenges, we underline here the following:

- Reaching stronger cooperation between engineering faculty and humanities, allowing capstone projects focused on social impact and community development. ITA is a conservative institution in which capstone projects are driven to hardcore engineering and industrial ends.
- Establishing a more articulated educative program around specific student projects, combining disciplines, service learning, and accredited activities. A possible way of doing so is integrating the engaged engineering program as a cluster into the recently established minor in innovation. Part of this "(re)searching and trying effort" is one of the research objectives of a current postdoctoral fellowship been carried out at LabCTS.
- Achieving more robust institutional support to LabCTS' program. Although ITA is strongly identified with high-technology development and its students are disputed by leading financial market institutions, there is increasing recognition of the relevance of social responsibility in engineering.
- At ITA, a main complaint of students is about continuous work overload and minimal time to engage in social projects. A possible way out is to achieve more integration of the social projects along with more disciplines in collaboration with aligned faculty. However, most professors have had no service learning nor anything close to engaged engineering in their academic formation, challenging the building of bridges and a common language between the epistemic cultures of traditional engineering and social sciences.

Findings

In this section, we briefly summarize the findings about the program design and the institutionalization process of the three cases, making clear what are their main differences and similarities, as well as the respective challenges each of them is facing. Table 1 shows the main CE program features linked to curriculum, from which we depict the following features:

1) Whereas the ANUS's pathway delegates to a third party, the EWB, the service learning activities, Soltec and LabCTS are responsible themselves for the organization of service learning, which increases the transaction costs of time spending, but may have the advantage of a more intensive integration between activities in class and in the communities.

2) The opportunity of an experience abroad is a distinctive feature of ANU's pathway, as usual in rich countries. It is especially of value for cross-cultural learning. Notwithstanding, the Brazilian cases have a strong commitment to local communities, increasing awareness for local problems, and may work with different local cultures, such as indigenous peoples and black communities. Further, Soltec and, to a certain extent, also LabCTS value long-lasting partnerships with the supported groups. That is so because such an experience offers better conditions for a co-construction/co-design process committed to empowering the local group; something that demands affective bonds, trust relationships, and an open and confident dialogue of different knowledge, academic and non-academic, theoretical and practical, between the technical team and the grassroots group.

3) Most importantly, all CEP programs allow students to engage themselves along with the curriculum, combining curricular and extracurricular activities, service learning, and research.

	Compulsory disciplines	**Elective disciplines**	**CEP allows engagement of undergrads in all years**	**Experience abroad**	**In-depth and long-lasting technical assistance**	**Transdisciplinarity**	**Participation of Post-graduation**
Soltec	Yes	Yes	Yes	No	Yes	High *involving students, faculty, and courses*	Yes
ANU's pathway	No	Yes	Yes	Yes	No	Medium *no students, but courses and invited speakers*	Yes
LabCTS	Yes	Yes	Yes	No*	+/-	Medium *no students, but faculty, courses, and invited speakers*	No

*Some students participated in IDDS, with limited opportunities.

Table 1 - CEP & Curriculum

Turning to the institutionalization process, Table 2 summarizes the main findings in this regard. 1) Concerning the institutionalization process, all three cases managed to implement CEP programs in curriculum and assure permanent staff, showing a high degree of creativity and adaptation to local constraints and opportunities. All cases have budget limitations, are capable though to move the educational activities and service learning projects forward, assuring low-cost standards.

2) Some initiatives were implemented with a comprehensive planning process, others developed by a high degree of experimentation. In LabCTS' case, contingencies as time-limited partnerships with D-Lab/MIT and an intensive but short-lived two-year long experience of the ITA/Enactus team have opened space for inspiration in teaching tools and networking and also shown that some windows of opportunities may be time-limited.

3) All three cases have strongly profited from partnerships, as well as sought to widen transdisciplinary synergies both in the student teams and in faculty expertise. However, for ITA, which is exclusively an engineering school, transdisciplinary projects are more difficult to establish as it is for Soltec or the ANU, which are both large universities.

	Soltec	**ANU's pathway**	**LabCTS**
Implementation strategy	Planned beforehand and development through experimentation and adaptation	Planned in detail beforehand	Development through experimentation and adaptation
Core team	4 faculty, 2 technical-administrative officers, 6 graduate students, 6 collaborators	1 faculty and a strong team of supporters from EWB and other organizations	4 faculty (Humanities) and one postdoctoral researcher
Financial support	Scholarships, institutional funding, public notices, unions	Course budget, governmental scholarships	Federal agencies and endowment funds (Not assured)
Partnerships	Pool of civil society organizations and some communities	Special partnership with EWB and further with some local communities	Pool of civil society organizations and some communities
Transdisciplinary projects	Master program & grassroots engineering practice	Experts in development and engineers. EWB activities may include experts of different areas	Mentorships from engineering and sciences, alongside humanities
Physical space & access to lab	Yes	Yes	Yes

Table 2 - The institutionalization process

Final comments

This paper sought to provide clues about the institutionalization process of three very different programs of community engagement: Soltec, the ANU's pathway, and LabCTS. Dismissing the idea that there is one unique best program model for all contexts, we think lessons may be learned from each case.

From Soltec, the most valuable insights involve smart methodologies for approaching and supporting communities; tools for students' preparation to grassroots engineering practice; the idea of a "holistic" educative process, deeply rooted in service learning, but also highly committed to teaching and to integrating research and service learning.

From ANU's path, the main contribution may be the overall program concept, which structures the learning process in all formation years, balancing teaching, service learning immersions, and research in a sound way, simultaneously giving flexibility to students to do their individual time planning, according to their own interests and commitments. It is also clear that the strong partnership of the well-structured EWB Australia is of great advantage hereto.

From ITA, in turn, is remarkable how LabCTS has been developing an experimental service learning and project-based initiative for all first-year undergrads, by means of innovative education methods and networking, in an environment of substancial constraints.

There are clear dissimilarities between the depicted cases. For instance, for Brazilian institutions, an overseas immersion is difficult to finance and possibly not a priority. Further, the EWB Brazil is by far not so well-established as in Australia, so that Brazilian engaged faculty cannot delegate community immersion to a specialized organization as ANU's path does but have to organize this by themselves.

Inversely, LabCTS has introduced compulsory engaged engineering activities in a key Brazilian engineering institution, which is not the case of ANU. Additionally, whereas Soltec is located in a large university, known as generally politically active and left-wing, ITA is a small institution, regarded as rather conservative and business-driven. Here we may see attributes of structural coercion in the institutionalization process of CE programs.

At the same time, there are free options made in each case. For instance, whereas ANU's pathway has dedicated remarkable efforts in doing evaluation and research on the impact of HE on students, Soltec is more focused on engaging directly with social movements and community work, and ITA's LabCTS in designing a sound integration of service learning and teaching in a compulsory module for more than 120 engineering students every year.

Regardless of how well-established they are, all the three programs have the continuous challenge of improving their impact on partner communities, as well as on the students' formation. One of the findings of this paper is that programs do recur to creative and experimental solutions in pursuing their goals and in tackling the particular constraints they are confronted with. Although many challenges to CE programs remain, having in place the initiatives here described represents a milestone in integrating education and service learning in engineering schools when compared to previous situations.

For further research, it would be of value to have a better understanding of the perceptions, motivations, and difficulties of the stakeholders around community engaged projects, including partners, faculty, and students, especially regarding the co-creation and co-construction process, in order to facilitate the strengthening of the projects towards the desired outcomes of empowering assisted people and tackling their needs as soundly as possible.

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